Volume 9, 2017

SHODH CHINTAN

Technological Changes and Innovations in Agriculture for Enhancing Farmers' Income

- H.P. Singh
- A.R. Pathak
- R.K. Tyagi
- H.P. Sumangala
- Sherry R. Jacob
- Rajeev K. Singh

Organised by:

Lt. Amit Singh Memorial Foundation
ASM FOUNDATION
New Delhi, India

Junagadh Agricultural University
Junagadh, Gujarat, India

CHAI
Confederation of Horticultural Associations of India

Publishing Partner

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9th Swadesh Prem Jagriti Sangosthi - 2017

National Conference on

Technological Changes and Innovations in Agriculture for Enhancing Farmers' Income

May 28-31, 2017, JAU, Junagadh, Gujarat, India

Organised By:

Lt. Amit Singh Memorial Foundation

ASF

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सत्यमेव जयते

भारत सरकार
कृषि एवं किसान कल्याण मंत्रालय
कृषि, सहकारिता एवं किसान कल्याण विभाग
Government of India
Ministry of Agriculture & Farmers Welfare
Department of Agriculture, Cooperation & Farmers Welfare

Dr. S.K. PATTANAYAK
SECRETARY

FOREWORD

I am happy to learn that Lt. Amit Singh Foundation, New Delhi and Junagadh Agricultural University, Gujarat are jointly organizing a National Conference on **Technological Changes and Innovations in Agriculture for Enhancing Farmers' Income,** from 28th to 31st May, 2017 at Junagadh, Gujarat.

India is an agrarian economy providing livelihood to nearly half of the population. The sector also is a source of raw material to the industry. Therefore, the sustainable growth of the sector is essential not only for ensuring food and nutritional security of the nation but also for contributing to the economy. It is well-known that the country has emerged from an era of food deficits to that of self-sufficiency, and has become an exporter of many agricultural commodities. The development of agriculture sector has witnessed many dynamic changes, including Green Revolution. While our efforts have contributed to the country achieving phenomenal growth in food production, issues like under employment and related factors continue to plague the agriculture sector. There is also the challenge of sustaining the nutritional security in the face of growing population. These dynamics require a shift in our approach from production based approach to farm income based approach so that the advantages of the policies, programmes and technological changes and initiatives which helped us achieve self-sufficiency are not lost.

The Hon'ble Prime Minister has given a clarion call to double farmers' income over the next six years. The annual budget for 2017-18 has also brought focus to double farmers' income through investment on infrastructure, marketing, credit support and risk management. There is a felt need for new approaches that would reduce the cost of production and increase the margin of profit to enable farmers realize enhanced incomes. The Ministry of Agriculture and Farmers Welfare is committed to enhance productivity by efficiently managing water and plant nutrients, encourage value chain management to reduce post-harvest losses, create a national farm market by setting up e-National Agriculture Market and cover risk management by launching the Prime Minister's Fasal Bima Yojana. It is worthwhile to note that the target of doubling farmers' income is possible, but is challenging which need careful and well-designed strategies.

I am sure this Conference would provide opportunities for dialogue and sharing of knowledge and help refining reason specific technologies adoptable at farm level, for doubling income.

I compliment the organizers for choosing the subject of topical importance attuned to current needs. I wish the National Conference all success.

(S.K. Pattanayak)

Date: April 27, 2017

From the Chairman's Desk . . .

Devotion to humanity and beneficence is patriotism, thus endeavor of Lt. Amit Singh Memorial Foundation (ASM Foundation) is charged with the responsibility of spreading patriotism among the youth through education, health care, economic development and inculcation of ethics and values. Accordingly, the focus of ASM Foundation has been on developmental activities which addresses children education, self-reliance of youth, confidence building, health care for people and technology-led development of agriculture/ horticulture for the benefits of the farmers. The ASM Foundation is working for fulfilling its objectives and mandate, and I am happy that the Foundation is altogether implementing the proposed programmes, and is bringing out overall development of the marginalized people, in all aspects, and taking them towards self- sufficiency.

Inspired by the past efforts, the ASM Foundation organized the 8th **Swadesh Prem Jagriti Sangosthi**- 2016 (SPJS-2016), and **Global Conference on Perspective of Future Challenges and Options in Agriculture**, 28th – 31st May, 2016, at JISL, Jalgaon, Maharashtra. The Sangosthi platform was shared by diverse group of stakeholders, such as farmers, extension workers, scientists, entrepreneurs, industrialists and policy planners, which facilitated an effective interaction. The participation of diverse group of people was the uniqueness of the Sangosthi, which benefitted large number of people including youth and farmers. The ASM Foundation is extremely grateful to Shri S.K. Pattanayak, Secretary Agriculture, Ministry of Agriculture and Farmers Welfare; Dr. R.S. Paroda, Former Secretary, DARE and DG, ICAR and Chairman, TAAS; Dr. A.R. Pathak, Vice-Chancellor, Navsari Agricultural University; Dr. P.L. Gautam, Former Chairman, PPV and FR, New Delhi; Dr. A.K. Srivastava, Director and Vice Chancellor, NDRI, Karnal; Dr. A.K. Sikka, DDG, ICAR; Dr. S.K. Malhotra, Agriculture Commissioner, Govt. of India; Dr. N.N. Singh, Former Vice Chancellor, BAU, Ranchi; Dr. S.K. Khurana, Former Vice Chancellor; Dr. R.C. Srivastava, Vice Chancellor, RAU, Pusa, Bihar and Dr. D.R. Mehta, Former Chairman, SEBI and Chairman, Jaipur Foot; Dr. A.K. Singh, Vice Chancellor, Gwalior and to all the Directors, Coordinators, Scientists, Representatives of Industries, Entrepreneurs, and Farmers, for gracing the occasion.

The activities during the year also included, distribution of seeds, school bags to school children, demonstration of new technologies to farmers and confidence building in youth. In the honour of Lt. Amit Singh, "Shahid Diwas" was observed on 3rd September 2013 under chairmanship of Dr R.C. Srivatava. Vice-Chancellor, Rajendra Agricultural University, Pusa, Samastipur and and Dr. H.P. Singh, Former DDG, ICAR and Chairman, CHAI. One day Kisan

Gosthi was arranged wherein vegetable seeds were distributed and knowledge empowerment of farmers was done through sharing the knowledge by the experts. Apart from the above, the ASM Foundation office at Mahamada also executed several activities for the benefit of children by providing them education, vocational support, celebrating the Independence Day and Republic Day. This office is involved in several activities to improve livelihood and socio-economic conditions of the rural people. Notable among them are dissemination of improved agricultural technology and distribution of seeds. The Foundation also organized Kisan Gosthi at many locations which were attended by many farmers. During the year, the Foundation supported two workshops organised at Junagadh and Jodhpur and a conference on Maize, organised at DRPCAU, Pusa. These workshop and conference helped the farmers in adoption of new technology for improving farm productivity and their income. Managing Trustee Mrs Bimala Singh visited fields of farmers along with Dr. H.P. Singh to motivate them for improved practices in diversification for enhancing their income. The Foundation also distributed blanket for the poor people in many villages. We are grateful to Jain Irrigation Systems Ltd, Jalgaon for hosting this important Global Conference on Perspective of Future Challenges and Options in Agriculture.

ASM foundation has also instituted many awards in various categories *viz*., Amit Krishi Rishi Award, Amit Padma Jagriti Award, Amit Prabudh Manishi Award, Amit Swah Award, to conferred on the achievers, who have contributed outstandingly to Indian Agriculture and have dedicated their service to Nation. Udyan Ratan Award, Lt. Amit Singh Memorial Award for best Coordinating Centre of AICRP and National Elocution/Essay Competition for school students have now become a regular phenomenon. I wish to congratulate all the recipients of the awards for the year 2017.

I deem it a proud privilege to share with you that services of ASM Foundation has been recognised for its excellence services towards National building activities. The Lt. Amit Singh Memorial Foundation was conferred **Institutional Excellence Award-2016** in recognition of outstanding contribution in reconstruction of Rural India through involvement of youth in Agricultural transformation, by AIASA, New Delhi. The award carried a citation, Plaque of Honour and certificate, which were bestowed by the Chief Guest, honourable Minister of State for Agriculture, in presence of all the dignitaries on 20th February, 2017.

I take this opportunity to express my sincere gratitude to all the staff, volunteers and well-wishers of the Foundation, who are incessantly working hard for achieving the objectives of the Foundation. I also congratulate all farmers/students/delegates/guests who have contributed significantly during the last SPJS-2017, and owe the entire credit for our successful journey into 2016-2017 and helped in preparation for the preparation of National Conference on Technological Changes and innovations in Agriculture for enhancing Farmers Income. I also express our gratitude to the Vice-Chancellor, Dr. A.R. Pathak, JAU, Jungadh for hosting this conference. I have a great pleasure in presenting to you this "Shodh Chintan-2017" especially published to commemorate the occasion. The Sodh Chintan (ISBN: 978-81-932266-2-9) has the compilation of articles from the best of the experts in their respective field of specialization. I am sure you will find "Shodh Chintan" highly useful document, which can be referred to, again and again.

May God bless you all "Jai Jawan Jai Kisan, Jai Hindustan"

G. Trivedi
Chairman, ASM Foundation

Preface

Lt Amit Singh Memorial Foundation (ASM Foundation) is committed for spreading patriotism among the youth through education, health care, economic development and inculcation of ethics and values. Accordingly, ASM Foundation has taken up activities, which addresses children education, self-reliance of youth, confidence building, care for people and technology-led development of horticulture/ agriculture for the benefits of farmers. The ASM Foundation is working for fulfilling its objectives and mandate, and is happy to share that, Foundation is implementing the proposed programmes to bring overall development of the people in all the aspects to improve their quality of life. Inspired by past efforts, ASM Foundation continues to organise Swadeshi Prem Jagriti Sangosthi, exhibition, farmers quiz, essay competition, and conferences, and recognises the services of people through awards and rewards.

The 9th Swadesh Prem Jagriti Sangosthi-2017 (SPJS), with a focus on'National Conference on **Technological Challenges and Innovations in Agriculture for Enchancing Farmers' Income** is being organized by Lt. Amit Singh Foundation, New Delhi and Junagadh Agricultural University, Junagadh in collaboration with the Trust for Advancement of Agricultural Sciences (TAAS), New Delhi, Confederation of Horticulture Associations of India (CHAI), New Delhi and Jain Irrigation Systems Limited, Jalgaon. The event comprises various activities *viz*., farmers quiz, Mango Eating Competition and Conferment of various awards to the scientists, eminent personalities and farmers, for their outstanding contributions to agriculture/ horticulture. The Sangosthi platform shall be shared by diverse group of stakeholders, such as farmers, scientists, farmers, industrialists and policy planners, for effective interactions. The participation of diverse group of people will be the uniqueness of the Sangosthi, which shall benefit large numbers of people including youth and farmers. It is expected that, more than 250 sceientists, students, experts and farmers will participate.

The activities during the year, besides 8th Swadesh Prem Jagriti Sangosthi and Global Conference on Perspective of fFuture Challenges and Options in Agriculture, included, distribution of seeds and planting material, bags to school children, demonstration of new technologies to farmers and confidence building in youth, for furtherance of the Agriculture. During the year, the Foundation supported these workshops, organised at Jalgaon, Junagadh and Jodhpur and a National conference on New Paradigm in Production and Value Chain Management for Achieving Targeted production and utilization of Maize, organised at DRPAU, Pusa on 4-5 March, 2017. A tribute was paid to Lt. Amit Singh by dignitaries on his birth day, 28th May 2016 and in his honour Sahid Diwas programme was organised on 3rd September, 2016, the day when, he made supreme sacrifice. The programme had special focus on farmers, wherein seeds of high yielding varieties and planting materials were distributed, and experts from various sectors of agriculture discussed about hi-tech cultivation and management of agriculture/horticultural crops.

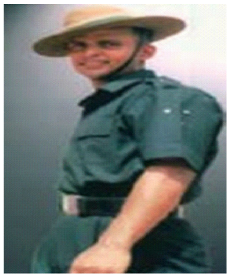
The ASM Foundation Branch office at Mahamada, also executed several activities for the benefit of children by providing them educational and vocational support besides celebrating the Independence Day and Republic Day. This office is involved in several activities to improve livelihood and socio-economic conditions of the rural people. Notable among them are the technology dissemination of improved agricultural practices, at Mahamada and Dholi (Muzaffarpur) for providing training to farmers on latest techniques. The awards instituted by ASM Foundation are **Amit Prabudh Manishi Award, Amit Krishi Rishi Award, Amit Padam Jagriti Award,** and **Lt. Amit Singh Memorial Award for Best Coordinating Centre in Vegetable.** Awardee for the year 2017 have been selected and will be conferred the award during the conference. Various publications, *viz*., Sodh Chintan Vol. 9, Proceedings of Global Conference and a Book-Award and Awardee have been published. It is hoped that the forthcoming conference will be successful in terms of participation, content and outcome.

The ASM Foundation, is happy to share its slection for the conferment of Instituttion of Excellence Award-2016 for their contribution, from AIASA, New Delhi, in recognition of our outstanding contribution in reconstruction of rural India by involving youth in Agriculture. The award was conferred on 20th February, 2016, by Honourable Minister of State for Agriculture, in presence of all the dignitaries.

I take this opportunity to express my gratitude to all the staff, volunteers and well-wishers of the Foundation, who are working hard and incessantly for achieving the objectives of the Foundation. I also thank all the stakeholders i.e., farmers/ students/ delegates/scientists/ guests who have contributed significantly in SPJS- 2017, and owe the entire credit to them for our successful journey in 2016-17. I also express my gratefulness to Mr A.R. Pathak, Vice-Chancellor, JAU, Junagadh, Gujarat, for hosting this National Conference on Technological Challenges and innovations in Agriculture for enchancing farmers' income. I have great pleasure in presenting the Sodhchintan (ISBN13: 978-81-932266-2-9) which contains the articles from best of experts in the field of agriculture. I am sure you will find Shodh Chintan an useful document.

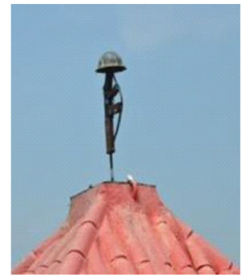
May God bless us all!

Bimala Singh
Managing Trustee



About ASM Foundation

(ISO 9001-8002 certified organization)



Lt. Amit Singh Memorial (ASM Foundation), since its inception, in 2001, has tremendously grown in its outreach and the spectrum of activities carried out to fulfill its commitments, within the ambit of its stated aims and objectives to develop a patriotic society through education, secured health, economic development and inculcation of ethics and values among the masses in general and youth in particular. To begin with, the foundation started its activities with the distribution of books and school bags amongst the poor and needy children to support their education; organizing health camps to improve the health status of poor and needy; scientific exhibitions and workshop to disseminate the knowledge of newly developed technologies particularly in the field of agriculture and horticulture to empower the farmers with up-to-date knowledge,and inspirational discourse by spiritual leaders to inculcate social ethics and values especially among youth.

In its strive to achieve the aims and objectives, the Foundation organized the first Swadesh Prem Jagriti Sangosthi (SPJS-2009), a national level mega event in 2009 to commemorate the birthday of the Martyr Lt. Amit Singh, at his birth place, Mahamada, Pusa, Bihar. This Sangosthiwhich included activities like inauguration of Smriti Bhawan, essay/elocution competition and talent search for students of schools and higher secondary schools from different states; health camps; national conference on horticulture; national exhibition; farmers quiz; distribution of quality seeds and planting materials of the agricultural and horticultural crops; diversity shows; litchi eating competition and spiritual discourse to inculcate ethics and values.This Sangosthi was a big success as it was a well attended event.The overwhelming response and encouraging feedback of participants of the first Sangosthi made it annual feature of the activities of the foundation. Besides farmers,students and scientists, some prominent political personalities also attended the event.Since then,2nd Swadesh Prem Jagriti Sangosthi (SPJS) was organised at Bangalore in 2010 and 3rdSPJS in 2011 at Dehradun. Both these events were a great success. 4thSwadesh Prem Jagriti Sangosthi was organised from 27-31May, 2012 at OUAT, Bhubaneswar, and 5thSPJS was organised on May 28-31, 2013, at JISL Jalgaon, Maharashtra. 6th SPJS was organized at NAU, Navsari, 7th SPJS was organised at Chitrakoot, Satna, Madhya Pradesh. Now 8th SPJS is being organized at JISL Jalgaon, Maharashtra. To inculcate the spirit of healthy and fair competitiveness and catalysing the minds of the people, to serve the society better,ASM Foundation has instituted many rewards and awards.

The rewards include the cash prizes to the winners of national debates/elocution National Talent search in Horticulture. Different awards instituted by the Foundation to recognise the outstanding contributions made by different peoples in their respective fields for the welfare of the society, at large include, **Amit Krishi Rishi Award, Amit Padma JagritiAward,Amit Prabudh ManishiAward, Amit Swah Award, Udyan Ratna Award, Amit Agrani Award, National Talent Award in Horticulture, Best All Rounder Awards** (for school students), **Lt. Amit Singh Memorial Best Performing Centre of AICRP on Vegetables**. The recipients of these awards are leading and distinguished educationists, corporate sectors, scientists, entrepreneurs, farmers,students and leading research institutes, which act as a great driving and inspirational force for the participants and stakeholders to work harder with full zeal in theirrespective fields to be among the recipient of such awards. The activities of the Foundation carried so far have been very successful as is evident from the impact on impressionable tender minds of youth to instill patriotism and building nationalistic character in them; economic empowerment of the poor farmers through innovative technologies and current knowledge disseminated through conferences and exhibitions on agriculture and horticulture.

The Foundation has expanded its activities over these years with its major focus on improving the health of children and empowerment of women. The emphasis is also given on improving the income of farmers through distribution of quality seeds and planting material, dissemination of modern technologies and techniques, knowledge and imparting training and awareness.

ASM Foundation Team

Dr. H. P. Singh
Former DDG, Horti,
ICAR, New Delhi

Dr. G. Trivedi
Chairman
Former VC, RAU, Pusa, Bihar

Trustees of Foundation

Ms. Bimala Singh
Managing Trustee

Ms. Neeta Singh
Trustee

Prof. (Dr.) Babita Singh
Trustee

About JAU

1. Name of the University: JUNAGADH AGRICULTURAL UNIVERSITY, JUNAGADH

2. Year of Establishment: 2004

3. Vision

Junagadh Agricultural University intends to be one of the nation's leading universities in terms of its academic quality, advancement in technological research and enhancement of farmers' knowledge for sustainable agriculture as well as ensuring food and nutritional security to the people.

4. Mission

Play pivotal role in teaching, research and extension education related to agriculture and allied sciences.

5. Jurisdiction / Area of Operation

Junagadh Agricultural University is among the four different Agricultural Universities in the Gujarat State carved out of Gujarat Agricultural University under GAU Act-2004 and came in to existence from 1st May, 2004. University's jurisdiction is spread over the districts of Junagadh, Jamnagar, Rajkot, Porbandar, Surendranagar, Bhavnagar, Amreli, Devbhoomi Dwarka, Gir Somnath and Morbi of the Gujarat state.

University through its eight constituent colleges offers higher education (UG & PG up to Ph.D.) in the faculties of Agriculture, Agricultural Engineering & Technology, Fisheries Science, Veterinary Science & Animal Husbandry, Horticulture and MBA in Agri-Business Management. University also offers Polytechnic/Diploma/Certificate Courses in the field of Agriculture, Horticulture, Agro Processing, Agricultural Engineering, Animal Husbandry, Home Science, Bakery and Mali.

6. List of Academic Programmes

SN	Name of the Constituent College/Faculty	Bachelor's Programme	Master's Programme	Ph. D. Programme
1.	College of Agriculture (COA),Junagadh	Bachelor of Science (Hons) inAgriculture	M.Sc. in Agriculture in Agricultural Extension, Agricultural Economics, agricultural Statistics, Agronomy, Soil Science, Agricultural Meteorology, Agricultural Entomology, Plant Pathology, Genetics & Plant Breeding, Seed Science & Technology, Plant Physiology, Biochemistry, Plant Molecular Biology & Biotechnology, M.Sc. (Horti.) in Fruit Science, Floriculture and Landscape Architecture	Ph.D. in Agriculture in Agricultural Extension, AgriculturalEconomics, Agricultural Statistics, Agronomy, Soil Science,Agricultural Meteorology, Agricultural Entomology, Plant Pathology,Genetics & Plant Breeding, Plant Physiology, Biochemistry, PlantMolecular Biology & Biotechnology, Ph.D. (Horti.) in Fruit Science,Floriculture and Landscape Architecture
2.	College of Veterinary Science & Animal Husbandry (COVSAH), Junagadh	BVSc & AH	MVSC in Animal Genetics & Breeding, Livestock Production and Management, Animal Nutrition,Veterinary Surgery and Radiology, VeterinaryMicrobiology, Veterinary Pharmacology and Toxicology, Veterinary and Animal Husbandry Extension	Ph.D. in Veterinary Science in Animal Genetics and Breeding,Livestock Production and Management, Animal Nutrition
3.	College of Agricultural Engineering & Technology (CAET),Junagadh	B. Tech. (Agril.Engg)	M.Tech. (Agril. Engg) in Soil & Water Engg,Farm Machinery & Power Engineering, Processing & Food Engg, Renewable Energy Engg	Ph.D. (Agril. Engg) in Soil & Water Engineering, Farm Machinery & Power Engineering, Processing & Food Engineering
4.	Post Graduate Institute of Agri Business Management (PGIABM), Junagadh	-	MBA in Agri Business Management	-
5.	College of Fisheries Science(COF), Veraval	B.F.Sc.	M.F.Sc. in Fisheries Resource Management, Fish Processing Technology, Aquaculture	Ph.D. in Fisheries Resource Management
6.	College of Agriculture, Amreli	B.Sc. (Hons) inAgriculture	-	-
7.	College of Horticulture, Junagadh	B.Sc. (Hons) inAgriculture	-	-
8.	College of Agriculture, Khapat	B.Sc. (Hons) in Agriculture	-	-

7. Major area of Research

Junagadh Agricultural University has 31 research stations including multidisciplinary main research stations, sub centres on various crops and testing centres spread over in whole North Saurashtra & South Saurashtra Agro-climatic Zones and part of North-west and Bhal & Coastal Area Agro-climatic Zones of Gujarat. The research carried out on various issues related to different crops and disciplines including Wheat, Millet, Pulses, Oilseeds, Cotton, Sugarcane, Fruit Crops, Vegetables, Dry Farming, Grassland, Agricultural Engineering, Cattle Breeding and Fisheries.

To strengthen the location specific research 20 AICRPs are functioning in the University. Since inception of the university, as an outcome of the research by release of about 50 varieties Out of these nearly 15 varieties got recognition at national level. University has developed 427 technologies / package of practices for the benefits of the farmers.

8. Highlights of Extension Education Activities

The University is having seven Krishi Vigyan Kendras (KVKs), Sardar Smruti Kendra (SSK), evenCentre of Comunication (CoC), Agricultural Technology Information Centre (ATIC) etc. for extension activities impart training to extension functionaries of the line departments, to transfer the agricultural technologies to the farmers and end users. Agro based ITI are also running in the university. Community FM Radio Station releasing extension progarmme on “Janvani 91.2” started by the university.

FLDs are being conducted on various crops and technologies at Farmers’ fields through KVKs and Research Stations. A mega event Krushi Mahotsav is organized every year since 2005 for dissemination of latest technology at farmer’s door step.

9. Strength of the University

- Well qualified faculty for latest quality education and research
- Well-developed infrastructure including laboratories, libraries, internet connectivity, smart class rooms, boys & girls hostels, indoor & outdoor sports, auditorium, etc.
- Good governance + original initiatives
- Good placement through campus interview
- Healthy environment and medical facilities
- NSS and extra-curricular activities like capacity building lecture, summer training, cultural, sports, tracking, internship, RAWE programme, etc.
- The technologies of crop production through research and development activities of the University.
- The substantial support from agricultural department in the State with technical human power and the much needed infrastructure, to keep agricultural development going.
- The departments have plan and other agency schemes with abundant funds for research and development.
- Proximity to the largest fish landing centre in the western coast of the country.

10. Important Achievements

- 51 new varieties were developed for major crops of the Saurashtra out of which 18 varieties were released at National level.
- Cow urine elemental composition and metabolites detection. Above, 380 metabolites detected in cow urine samples, some of them has great medicinal values.

- For the first time in the scientific realum the gold content is detected in more than 300 samples of Gir Cow urine.
- Whole genome sequences of antagonist microbes (*Bacillus. Rhizobacter, Pseudomonas*) and plant pathogenic fungi (*Sclerotia, Macrophomina, Puccinia*) and their functional annotation
- DNA Barcoding of developed crop varieties and fish for identification and conservation purpose.
- A foldable container for storage and transportation of agricultural produce.
- Noticeable increase in the seed production and distribution of various crop seeds, viz., Groundnut, Wheat, Chickpea, Pearl Millet, Castor, Sesame and other crops of Saurashtra region. Plantlet, grafts, saplings of the horticultural crops and other ornamental plants are also being sold out at reasonable price.
- Different bio-agent and bio-fertilizers, viz., *Trichoderma, Rhizobium, Azotobacter*, PSB, *Beaveria* etc. are supplied to the farmers at reasonable prices.
- The NABL accredited Food Testing Laboratory is functioning under the Department of Biotechnology.
- The demand for D x T Coconut hybrid seedling is increasing. Hence, Elite farm developed in 20 ha area at Mahuva center to meet the requirement of farmers.
- Control measures of Pink bollworm in cotton crop were developed and suggested for farmers.
- Sea weed is used for preparing the liquid fertilizer at Fisheries Research Station, Okha and it will be useful for Zinc and Iron deficient soil.
- Larvae of pearl oyster were released in the sea at Fisheries Research Station, Sikka for further harvesting of matured pearl oyster by fish farmers.
- Popular Kesar mango of Saurashtra has received the GI certificate.

11. Niche Area of Excellence (Area in which University is strong)

Research in Soil & water management, groundnut, cotton, mango, spices, animal breeding, fisheries, etc.

12. Status of Autonomy: Autonomous body as SAU governed with own act and regulation.

13. Funding Support Received (From state and other agencies)

Total fund received during 2015-16 was Rs. 191.5 crore out of which Rs. 171.5 crore was funded by state government under plan and non-plan. Rs. 16.6 crore received from ICAR under AICRP, KVK, Education and Rs. 3.4 crore from other central funding.

14. Faculty position particularly the vacant position or percentage: Total sanctioned posts are 588 out of which 444 are filled up and 144 (24.5 %) posts remained vacant.

15. Contact Details

Name of Vice Chancellor	:	**Dr. A. R. Pathak**
Telephone (Office)	:	(0285) 2671784
Telephone (Residence)	:	(0285) 2671709
Fax	:	(0285) 2672004
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About the Organizers

ASM Foundation, an ISO 9001:2008 certified organisation is committed to economic development and knowledge empowerment of people through various activities. It has head quarter at New Delhi, India. The ASM Foundation has successfully organised Global and National Conference in part and is known nationally and internationally. The Foundation, besides organizing the conference, exhibitions, and farmer's friendly activities is committed to education health care and economic development. The Foundation also confers awards in various categories to recognise the contribution of individuals/ organization. www.ltamitsingh.org.

Junagadh Agricultural University, Junagadh, established in 2004, was started as college of Agriculture in the year, 1960 affiliated to Gujarat University and Saurashtra University and then in 1972 to Gujarat Agricultural University. The University offers education in agriculture and allied sciences – agriculture, agricultural engineering, veterinary and animal sciences and fisheries and farm business. The university has seven multidisciplinary main research station, five main research station for various crops, and eleven sub-research station / testing centres for the development of new varieties / hybrids of crops, vegetable, fruits. The University is known to have developed first hybrid of bajra and castor and many varieties and technologies. 6 KVKs are attached to the University. www.jau.in

About the Collaborators

The Trust for Advancement of Agricultural Sciences (TAAS) was established on 17 October 2002 for harnessing the agricultural sciences for the welfare of the people through scientific interactions and partnerships. The TAAS acts as think tank on key policy issues relating to agricultural research for development (ARD). The main activities include organizing foundation day lectures, special lectures, brain storming sessions/symposia/seminars/workshops on important themes, developing strategy papers on key policy matters, promoting farmers' innovations and conferring Dr. M.S. Swaminathan Award for Leadership in Agriculture. www.taas.in

Jain Irrigation Systems Ltd. known as JISL, India, is a multinational organization with global presence in 120 countries, provides solution for efficient management of water, protected cultivation, quality planting material, farmers access to market and processing, solar energy, waste utilization, and education. The company is one of the largest agro-based company in the world and have many innovations to its credit. The company in its recognition has been conferred with highest national award and many International recognition. www.jains.com

Indian Council of Food and Agriculture (ICFA), an the apex think tank, is serving as global platform for partnerships though proactive policy and trade agenda The Council through its current 25 Working Groups and 14 National Councils and country specific Joint Business Councils represents the interests of all the stakeholders at the national level on one hand and positions India's food and agriculture sector globally on the other hand. ICFA is also promoting investments and technologies in farm sector by forging global partnerships with right institutions and by taking up projects, training and entrepreneurship development to accelerate growth in productivity, agribusinesses and exports. www.icfa.org.in

Confederation of Horticulture Association of INDIA (CHAI), an ISO 9001:2008 certified, non-profiting organization, is a forum of stakeholders in horticulture/agriculture to work together in mission mode with set goals and objectives. The aims of CHAI are the furtherance of horticulture/ agriculture research and development, through; Conduct and support in organizing of National/International conference, workshops, Publication of journal- International Journal of Innovative Horticulture. To bring the competitiveness the CHAI has instituted various awards to motivate the innovators for the excellence in research, education, extension, teaching and farming. www.confedhorti.org

Contents

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Technological Changes, Innovations and Policy Reforms for Enhancing Farmers' Income

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Indian Agriculture is vital for socio-economic development of the country, as it provides livelihood to half of the population supplies raw material to industries and ensure food and nutritional security to the nation. Agriculture production and agri-business together are larger in size, than any other sector. Past three decades have witnessed un-parallel development of agriculture in India, compared to any other part of the world. The country has emerged from an era of food deficits to that of self-sufficiency and has become an exporter of many agricultural commodities. The dynamics of development have been through various revolutions including Green Revolution. All these changes have helped to become food secured nation and achieve better farm income and also opportunities for both direct and indirect employment. But the challenges ahead are much greater than before.

Emerging Scenarios in Indian Agriculture

1. While India has crossed the hump relating to food security over the years, but under employment and disguised unemployment besides the challenge of nutritional security and farmers' distress continue. Currently, the sector is confronted with pressures of increasing population, dietary changes, depleting and degrading natural resources (soil and water), climate change, and shortage of skilled human resources and continued fragmentation of land leading to agrarian distress. Impacts of the past approaches, focused on technology-led development and investment have been impressive in terms of production and productivity, which has achieved much higher levels. Earlier, policies, programmes, technological changes and initiatives were designed and implemented for achieving higher production through improving productivity parameters, as it was important to achieve self- sufficiency in food, a primary concern than looking to the challenges of producing and helping the farmers in achieving improved farm income. In this context, there is need to transit from production based approach to farm income based approach. The Honourable Prime Minister, himself, has emphasized on the farmers' income and has set a goal for the country to double the income of its farmers by the year 2022. Annual budget for 2017-18 has also brought focus for doubling farmers' income through investment on infrastructure, marketing, credit support and risk management. As we can think, approaches needed are to reduce the cost of production and increase the margin of profit, needed for enhancing farm income. This will require efficient system of technology management, marketing, inputs, infrastructure, risk management and above all policy reforms. Various discussions to develop strategies have emphasized on enhancing the productivity of water and nutrient, value chain management to reduce losses, creation of national farm market, removing distortions and e-platform across districts and risk management.

Approaches for Doubling the Farmers' Income

Dynamics of these approaches for doubling farmers' income would revolve around reducing cost of production through technological changes, innovations and well planned market strategies to

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improve margin of profit, insulating against risks by insurance and landless allied activities to compliment the farmers' income. Diversification, ancillary activities and approach to aggregation of land for better operation are also discussed as means to increase farm income. Invariably, it is noted that doubling of farmers' income in 5 years' time is possible but is challenging, which need careful and well-designed strategies in regionally differentiated manner, with careful examination of strength, weaknesses, threats and opportunities, based on the climate, soil and farmers' capabilities. The drivers to double the farmers' income would be technological changes, innovations, improved delivering systems, infrastructure and governance with farmer centric approaches, and above all strategic diversification. This calls for a dialogue to discuss all the issues to develop a road map for agricultural reforms for transformation, which can help in achieving the doubling of farmers in next five years and add to food and nutritional security.With this background this national conference has been organized to discuss on agricultural reform for transformation to Enhance Farmers' Income. The conference shall understand and devise a means for needed policy changes from production to income and develop strategies for technological changes, enhancing efficiency of inputs *i.e.,* water, nutrients, energy, delivery; risk management and marketing. The issues would be discussed in thematic area to develop recommendation, a way forward for transformation of agriculture and doubling farm income.

Diversification to Horticulture - An Option

The agriculture development in the past has been means of food and raw material, which has to be seen now as means of employment- led economic goals, alleviation of poverty and self–reliance through its linkages and a multiplier effect. Globalization of agriculture has opened up new opportunities and also the challenge of stiffer competition. The challenge thus demands for adjustment of the structure of the economy to resonate with internal stipulation. To address the challenges in agriculture, diversification has emerged as the best option, to address nutritional adequacy, employment opportunities, farm income enhancement and use of natural resources. Among various options for diversification, horticulture has proved, beyond doubt, its potentiality for gainful diversification. The emerging trend worldwide and also in the country is indicative of a paradigm shift in dietary needs of the people, with rise in the income that demand more horticultural produce. In the scenario, where more than 300 million people are malnourished, while millions of people are below poverty line, there is need for improving quality of life through food and nutritional security. The trend of development in the past especially during the last decade has been satisfying that adoption of horticultural crops in systematic manner has improved quality of life of people in the many of the regions of the country.

Horticulture, generally referred as gardening, has expanded in its scope and activities, moving from rural confine to commercialization, and is providing best option for land use, nutritional security, employment opportunity, health care and above all environmental services. Indian, horticulture development has five phases of growth, characterized by pleasantry, a hobby in pre- indigence India, which moved further to adopt innovations in fifth phase of growth heralding Golden Revolution. Expanding horticulture is demanding knowledge, skills, and technologies for growing plants intensively to achieve efficient, profitable and competitive horticultural industry. The sector includes a wide variety of crops under different groups such as fruits, vegetables, root and tuber crops, mushroom, floriculture, medicinal and aromatic plants, nuts, plantation crops including coconut and oil palm. Government of India has accorded high priority for the development of this sector, particularly, since the VIII Plan-and beyond, which has impacted production, reaching to 283.8 million tons from 96 million in 1990-91, contributing 34.45 to the AGDP only from 11% cropped area. This trend of development in horticulture has been termed as Golden Revolution. However, challenges to feed growing population suiting to their dietary behavior and nutrition requirements, is demanding science and technology led development, backed by enabling environments, resource utilization strategies. Change in dynamics of horticulture is now for health care through the use of horticultural produce for the treatment of many diseases, therapy, environment services and above all to the improved quality of life of people living in rural as well as in urban area. The paradigm necessitates for knowledge empowered human resources, who can provide leadership in technology development and policy formulation to attract investment, and keep the pace of development.

Horticulture Development in India

In India, horticulture profession is as old as humans civilization but its development has passedthrough different phases of growth. The practicing horticulturists, in the past, were differentiated based on their trade, which they had adopted, like gardening and vegetable cultivation. Kings and *Jamindar* (landlords) promoted horticulture in the form of gardens and orchards for their pleasantry and hobby that helped in conservation of plants and species. Describing the current horticulture scenario in India, we have to divide it into pre-independence and post-independence era Pre- independence horticulture is referred to as first phase of development, characterized by home gardens as hobby for aesthetic and social values. In the second phase of growth of horticulture (1948-1980), commercial production system started for few commodities and institutional support system was initiated to support the development; yet most emphasis was on crop production.

In third phase of growth (1980-1992) institutional support system was consolidated and focus to horticulture gained momentum considering its role in nutritional security. The fourth phase of development (1993-2000) was characterized by movement of horticulture from rural confine to commercial production, with enhancement in plan allocation and strong institutional support for research and development. The fifth phase of growth (2001-till now), horticulture of 21st century is characterized by innovations, large scale adoption of technology like micro-irrigation, protected cultivation and precision farming for strategic planned smart horticulture which is a integration of skills and knowledge for achieving higher output on time scale by reducing the vulnerability of horticulture to biotic and abiotic stress. Resultantly, production has reached to the level of 283.8 million tones

Indian horticulture is the core sector, representing a broad spectrum of crops and production of a wide range of horticultural commodities. The horticulture includes fruits, vegetables, nuts, ornamental, plantation, tuber, spices, medicinal and aromatic crops and mushrooms. Collectively, these horticultural crops make a significant contribution to the Indian economy, in terms of rural employment generation and farmers' income. Increase in demand for horticultural produce due to greater health awareness, rising income, export demands and increasing population poses the challenge for further increasing the production and productivity of horticultural crops. Production trend and likely demand of horticultural produce is presented in Table 1, which is self-explanatory.

The issue of climate change and climate variability has thrown up greater uncertainties and risks, further imposing constraints on production systems. The challenges ahead are to have sustainability and competitiveness, to achieve the targeted production to meet the growing demands in the environment of declining land, water and threat of climate change, which needs innovations and its adoption for improving production in challenged environment.

Research and Development in Horticultural Commodities

Horticultural crops or commodities are known to be cultivated from time immemorial, as its mention is seen in ancient literatures. Many of these horticultural crops have their regular uses as

Table 1: Trend of production and estimated demand of horticultural produce

Commodity	Production (million tonnes)						
	1991-92	2007-08	2010-11	2015-16	2016-17(Target)	2020 (expected)	2050(Estimated)
Fruits	28.63	63.50	74.87	91.44	98.00	105.50	198.60
Vegetables	58.53	125.89	146.55	166.66	220.20	230.60	430.80
Spices	1.90	4. 10	5.35	6.35	5.50	6.30	13.70
Flowers	-	0.87	1.08	2.23	1.50	2.05	3.80
Plantation Crops	7.49	11.30	12.38	15.47	15.60	16.00	41.80
Others							9.00
Total	96.95	207.01	244.50	283.36	333.80	358.40	696.80

nutritional food forming a part of the daily diet, besides, aesthetic and medicinal values Fruits: Growing and utilization of fruits has been inherent in the Indian culture, as a way of life, from ancient times. *Charak Samnita* and *Sushrut Samhita* have long list of fruits which have medicinal values. In Kautilya's *Artha Shashtra*, Written in 4th century BC, has a mention of mango, banana, bael, aonla and coconut associated with cultural rituals. Fruit research in India was first started in six agricultural colleges established in 1905 at Pune, Coimbatore, Lyallpur (now in Paksitan), Nagpur, Sabour, and Kanpur. At that time responsibility of fruit research was with State Government. Most of the work in fifties emanated from Bihar, Bombay (Mumbai), Madras (Tamil Nadu), Uttar Pradesh and Punjab. In 1933 four Regional Research Stations were established by Imperial Council of Agriculture Research at Sabour (Bihar), Kodur(AP), Krishnanagar (Bengal) and Chaubatia (then UP, now Uttarakhand). During 1956-61 eight research stations coordinated by ICAR were established at Mashobra (HP) Abohar (Punjab), Kahikuchi (Assam), Pune (Maharastra), Kodur (AP), Chethalli (Mysore), Saharanpur (UP) and Sabour (Bihar). ICAR continued to support fruit research in states and a significant step in research was through establishment of central institutes. In seventies and eighties many central institutes, National Research Centres and All India Coordinated Research Projects were established. These institutional support system have given a technological backup for the development of fruit industries benefiting large number of farmers.

Vegetable and tuber crops: Although many of vegetables have been grown traditionally, vegetable research and development finds its mention in second phase of development, i.e. after 1947 except potato. Research in vegetable started in 1947-48 with introduction of cultivars. In 1949 a vegetable breeding station was established in Katrain (Kullu valley). Subsequently in 1956-57 a separate Division of Horticulture was created at IARI, New Delhi and Indian Institute of Horticultural Research (IIHR), Bangalore, was established in 1968 took intensive research in vegetables. Creation of vegetable division in IARI and other SAUs gave a boost to vegetable research, which was further strengthened by the establishment of Indian Institute of Vegetables Research at Varanasi and Nation Research Centre on Onion and Garlic in eighties and nineties. Among the vegetables, potato is the most important crop, which supplements the food needs. Potato is believed to have been introduced in early seventeenth century. Commercial crop of potato was grown in hills of North and South India. First evidence of potato research in India is from Pune, in 1824. In 1930, potato farms were established. In 1912 system of growing two successive crops was developed in south India. To establish the potato work was done in Bengal, Punjab, Madras and Celong. In 1948, Himachal Pradesh took up potato seed production. Thus pre-independence work on potato gave a confidence for growing potato. Potato Research got fillip with the establishment of Central Potato Research Institute (CPRI), with headquarter at Patna (Bihar), which was subsequently shifted to Shimla. In 1971 coordinated research on potato was stated. The efforts have resulted in significant improvement in cultivar and technology resulting in production and productivity enhancement. Tuber crops (cassava, sweet potato, yam aroids) have history in India. Although research of cassava was started in 1942 in erstwhile Travancore-Cochin State, systematic research through Ad-hoc project started in 1951, which got fillip with the establishment of Central Tuber Crops Research Institute at Trivandrum (Thiruvanathapuram) in 1964. All India Coordinated Project on tuber crops was started in 1969. These research supports have helped in the development of cultivars and technology, which have enhanced the productivity of crops resulting in improved farm income.

Medicinal and aromatic plants: *Medicinal and aromatic plants have long history in India, as herbs have been used* for curing many diseases from time immemorial. India is also a centre of origin of many medicinal and aromatic plants and has a treasure of bio-diversity. The drugs, pharmaceuticals, perfumery, cosmetics and flavor industries use a large number of medicinal and aromatic plants and new items are continuously added to the list. ICAR, DST, CSIR, ICFRE, FRI and Medicinal Plant Board are engaged on research in these plants. Research efforts have helped in identification and domestication of many medicinal and aromatic plants and dissemination of knowledge. Many farmers in different parts of the country have been benefited by growing medicinal and aromatic plants.

Plantation crops: Major plantation crops grown in India are coconut, areca-nut, oilplam, cocoa and cashew. Cocoa and oil palm are of recent origin, which were introduced in India during sixties and eighties, respectively. Coconut research and development work was initiated in India during 1916 with the establishment of Coconut Research Station at Kasaragod by then Government of Madras of erstwhile Madras Presidency. In 1943, the Government of India constituted the Indian Central Coconut Committee, which took over the Kasaragod station and formed the Central Coconut Research Station. Coconut Development Board was established in 1981 to oversee the development of coconut industry. In 1957 Central Areca-nut Research Station was established at Vittal. History of cashew is only five century old, which came to India in 1498. From Goa it spread to Konkan and then to Kerala, Karnataka, Tamil Nadu, Andhra Pradesh and Orrissa. In 1800, Kerala raw nuts were roosted in pots. In 1941, India achieved a monopoly over global cashew market. However, systematic development took place only in 1969, with the establishment of Cashew Development Corporation. Research supports provided through All India coordinated Project on Cashew nuts and National Research centers on cashew nut have made a significant change in cultivars and production technology resulting in improved productivity and profitability.

Spices*:* Major spices grown in India are black pepper, small cardamom, large cardamom, cinnamon, clove, coriander, cumin, fennel and fenugreek. Although spices have historical importance in India its systematic development is of late origin. Spices research till fifties was limited to standardization of inputs requirement. Establishments of Indian Institute of Spices Research (IISR), Kozikod and National Research Centre on Seed Spices, Ajmer have given a boost to spices research. Besides, Spices Board is also engaged in cardamom research and development of spices.

Ornamental horticulture Floriculture in India comprises of florist trade, nursery plants and plotted plants seeds and bulb production, micro-propagation and extraction of essential oil from flowers. Art and Science of growing ornamental plants is not new to India, and, dates back to 3000 BC. The art and science of arboriculture and silviculture was highly developed in ancient *vedic* times (3000-2000 BC). Garden and flowers have been adored by kings and garden lovers. Planting of avenue trees was taken up by Ashoka the Great. The concept of developing garden in enclosed space was introduced by Mughals in India during 16^{th} and 17^{th} centuries. However, growing of cut flowers for trade is the development during the nineties. Floriculture trade has grown at the rate of 20 per cent during the nineties which has been because of technological changes in growing of flowers and its trade. Regular research was started at IARI, New Delhi and IIHR, Bangalore and subsequently through AICRP floriculture. Now a Directorate of floriculture research has been established for intensive research in ornamental horticulture.

Scenario of Horticulture in India

The role of horticulture in enhancing productivity of land, generating employment, value addition, improving economic conditions of the farmers and entrepreneurs, increasing exports and above all providing nutritional balance to the people has been well acknowledged. The sector includes a wide variety of crops under different groups such as fruits, vegetables, root and tuber crops, mushroom, floriculture, medicinal and aromatic plants, nuts, plantation crops including coconut and oil palm. The horticulture sector has emerged as a promising area for diversification in agriculture on account of high-income generation per unit of area, water and other farm inputs and environmental friendly production systems. Government of India accorded high priority for the development of this sector, particularly since the VIII Plan and beyond. The impact has been visible in terms of increase in production and productivity of horticultural crops, which increased from 96.6 million MT to 283.8 million MT. India has emerged as world leader in the production of a variety of fruits like mango and banana and is the second largest producer of fruits and vegetables. Besides, India has maintained its dominance in the production of coconut, cashew-nut and a number of spices (. Development trend of horticulture during the decade has proved, beyond doubt, that, horticulture is the best option for diversification of agriculture to address the issues of employment profitability and environmental concerns. Considering the need for 660 MT produce, by 2050there is much scope for agribusiness. Agribusiness opportunity could be for input like seeds, poultry material, equipment, green house designs and construction, irrigation, equipment and above all marketing information and marketing for produce and high value addition. This changed scenario is expected to improve the economy and profitability to become competitive. The economic importance of horticultural produce has been increasing over the years due to increasing domestic and international demand. Area, production, productivity, availability and export have increased manifolds. This has provided ample opportunities for utilization of waste lands, employment generation and effective land use planning. Diversification, recognized as one of the options for improving land use planning has dramatic impact. If data from the production of various crops are compared with the base period of 1990-91 horticultural crops have grown much faster.

11. Horticulture is now identified for inclusive growth of agriculture sector in the country. Past trends in research and development have been satisfying in terms of technological generation, adoptions, production, availability and export of horticultural produce, and this trend has been marked as "Golden Revolution". The period after 1998, has been a period of development for horticulture, leading to sustainable development. Planned investment in horticulture became highly productive and the sector emerged as economically rewarding and intellectually satisfying. The period witnessed the movement of horticulture from a rural confine to commercial production resulting in adoption of improved seeds, and technologies like micro-irrigation, protected cultivation, precision farming, integrated management of the insect pest and diseases. The success of development in 8th and 9th plan enthused for mission approach of development; addressing all the links in the chain of production and consumption. The farmers who adopted horticulture benefited immensely but fluctuating prices in few commodities alarmed to create infrastructure for storage and transport. Economic condition of many farmers improved and horticulture became a means for improving livelihood for many unprivileged classes. But regional disparity continued to be wide. Notably, the period succeeded in creating awareness to capitalize on the strength and convert weaknesses into opportunity. This is the time when Golden Revolution took place across the country through technological changes. The emphasis of technology has been for obtaining higher output of horticultural produce. The package included use of quality seeds and plants, efficient management of nutrients and water, and management of pest and diseases with focus on integrated management. Horticulture with a focus on farmers and landless labor became focus of development. The policy interventions supported all the activities of development and pressured farmers for active participants. Amazingly decadal growth in horticulture became impressive both for production and improving conditions of the farmers. The technologies which have been the driver of growth are:

- Utilization of genetic resources and development of cultivars for high yield, quality and resistance / tolerance to biotic and abiotic stresses.
- Macro- and Micro- propagation techniques for mass multiplication of vegetatively propagated plants.
- Use of root stock to mitigate problems related with soil - biotic and abiotic stresses.
- Plant architecture engineering and its management.
- Reduction of production losses through efficient management of pests and diseases.
- Post harvest management to reduce post harvest losses.
- On farm processing, value addition and waste utilization.

Policy Changes for the Development of Horticulture

National Agriculture Policy 2000 has categorically emphasized on integrated development of horticulture, which should be knowledge based, technology driven and farmers'centric. The policy also emphasized on rural institutions, reforms and development of infrastructure. There is no policy document for horticulture, but focus has been given on post harvest management in the policy paper of food processing industries. Most notably policy change is related to storage, processing and marketing of horticultural produce. Backward and forward linked marketing with reform in agriculture produce marketing act, encouragement for contract farming are some of important policy changes which are likely to impart production, quality and competitiveness of horticultural produce. Other area of reform needed is in aggregating of land law, which can help in better investment as well as adoption of technology. To enhance the delivery their is a need for innovations in PPP mode for its better adoption in agriculture.

Emerging Challenges to Horticulture Research and Development

In the present global scenario, world is concerned to meet food needs of growing population. The FAO predicts that the agricultural productivity in the world will sustain the growing population in 2030, but millions of people in developing countries will starve out of food and remain hungry due to food shortage. By 2025, 83% of the expected global population of 8.5 billion people will be in the developing world. The question before us is: Can we meet food needs and provide nutrition, health care, fuel and fibers to growing population? The answer is: It is difficult, but not impossible. Past experiences build the confidence that country has achieved. It was difficult to feed 320 million populations and now we are able to feed 1300 million people and have surplus too. Crops which were not grown at particular location are made to grow. Indian Agriculture, even with high pressure on land (17% population from 2.3% land and 4.5% water) has fed the Indian population. In the post-independence period, India made a steady progress in agriculture. Agriculture was simple, extra land and water was available, few genes did wonder that ushered in '*Green Revolution*'. But the challenges, now, are much greater than before. In the prevailing circumstances of shrinking farm land, depleting water resources and changing climate, the situation has become complex. Optimistically, through the inputs of science and technology, challenges ahead could be converted into opportunities for sustainable production. Horticulture has proved to provide the best mean of diversification and high land productivity has been achieved with context to gross return per hectare. But there is need to make the sustainable development in production of fruits, vegetables, tubers, plantations and tuber crops for meeting the growing demand of rising population for nutritionally rich horticulture produce.

Achieving the high production levels keeping in view the present and future needs are some of the issues, which needs to be addressed in a systematic manner. The issues are dynamic but they move around the sustainability of production and competitiveness. Challenges to feed growing population suiting to their dietary behavior and nutritional requirements has to be addressed though the drive of science and technology, backed by enabling environments, resource utilization strategies and reducing the losses. A large number of varieties developed have been adopted by the farmers and there is phenomenal development in horticulture with respect to production and growth, which has provided the benefits to small and marginal farmers and also consumers. But, gap between the demand and availability continue to widen. How to harness the potentiality and face the challenges are the issues, which need to be addressed. In this context, it is pertinent to analyze the critical gaps which can be addressed in systematic manner. Critical gap needing attention are low productivity and poor quality of the product, inadequacy of infra-structural facilities for post-harvest management and marketing, inadequate efforts for product diversification and consumption, inadequacy of quality seed and planting material, inadequacy of human resource in horticulture, lack of appropriate database for effective planning, inadequacy of trained manpower and infrastructure in the states, poor delivery system, credit support/and price support and slow pace in adoption of improved technology. Horticultural development has to be seen as integrated approach, addressing important gaps, in harnessing the potential for horticultural development to meet the demand as stipulated (Fig.1).

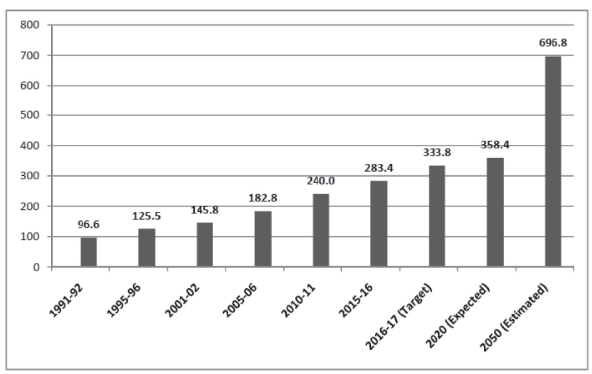

Fig. 1: Trend of horticulture production and future projections (Million tons)

Diagnostic of study into the aspect of projected growth rate in XII Plan, by the working group in horticulture for XII plan brought out the fact that opportunities in horticulture has not been harnessed to its potential, and has suggested approaches to address the gaps with emphasis on value chain management and addressing the problem of urban area through urban and peri- Urban Horticulture. Fact of under exploitation of horticulture potential was also highlighted in the studies of World Bank 2007. A case study of Indian Horticulture highlighting that with the production of 11 per cent vegetables and 15 per cent fruits of the world, its penetration is global market is only 17 per cent and 0.5 per cent, respectively. Although we may have satisfaction of achieving above 6 per cent growth rate and reaching to production level of 283.8 million tones, but to harness the potential and achieve leadership, we may have to travel a long distance, which cannot be achieved without knowledge empowered human recourses. Considering the needs for value chain management, mission programmes in horticulture have been implemented which aims to –

- Enhance horticulture production by providing holistic growth of the horticulture sector through an area based regionally differentiated strategies.
- Establish convergence and synergy among multiple on–going and planned programmes for horticulture development.
- Promote, develop and disseminate technologies through a seamless blend of traditional wisdom and modern scientific knowledge opportunities for employment generation for skilled and unskilled persons, especially unemployment youth.

Dynamics of Research and Development in New Paradigm

Demand for high value produce is growing both in domestic and overseas market, at the same time, competition is also increasing. New changes in retailing participation of corporate sector means that retailing will depend upon strategic alliance and supply chain management. Strengthened research on impact assessment to climate change on horticultural crops using controlled environmental facilities and simulation models, analysis of past weather data and integration with productivity changes (including extreme events) will be a guiding principle of new paradigm for orientation of education too. Production, demand and supply of commodities, economics and trade, sensitive stages and process during crop development, diversity and dynamics of major insects, microbes and pathogens, intensification of studies on pest, disease and weather relationships would be essentiality. Sustainability will depend upon improving competitiveness, reducing impact on environment, quality assurance and food safety and capability of communities engaged in this sector to manage changes. The new initiatives to strengthen the research activities, includes, are the development of varieties with durable resistance to multiple diseases and pests; heat, drought and salt tolerant varieties, and varieties with efficient nutrient and water use efficiency. Biotechnological tools in conjunction with conventional breeding to tag genes of interest and in marker assisted selection is needed. Some other focal points are:

- Generation of eco-region specific technologies based on maximum productivity of available natural resources like climatic condition, soil fertility and water.
- Developing system for productive use of water to get enhanced water productivity by increasing the water and nutrient use efficiency, technology packages for various fruit crops as an integral component of multifunctional agriculture of specific zone, IT based enabling mechanism for technology transfer such as decision support system are needed.
- Holistic approach for water, nutrient, pest and disease management with adoption of recent ago-techniques, use of locally available inputs and promotion of organic farming,
- Identification of new and effective bio-molecules for management of biotic stresses for eco friendly and sustainable management of diseases and pests, new innovative diagnostic techniques for rapid, accurate and cost effective detection of high impact pests and diseases. Integrated management system for emerging diseases and pests would minimize the health risks.
- Post-harvest technologies to improve product quality and minimize environmental impacts, increasing the value of production by reducing variability in yield, quality, reducing crop losses and increasing marketability would be crucial to minimize the losses.
- Production systems that minimize wastes and maximize recycling will enhance resource efficiency. Plenty of wind and solar energy is

available in the various ago-climatic zones, which can be utilized in mechanization, such as running of small equipments and dehydration of fruit and fruit based products. There is tremendous potential of processing of horticultural produce. Therefore, establishment of processing units, standardization of recipes for various products, certification and marketing network etc. should be given priority.

Integrated Water Resource Management for Enhancing Farmers' Income

Water is a critical resource in sustainable development, which is getting scarcer, and meeting the multifaceted uses is a great challenge of the future. Long lasting solutions to water problems would be a new water governance and management paradigm. Such a new paradigm is encapsulated in the Integrated Water Resources Management, which promotes the coordinated development and management of water, land and related resources in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems. This management system has focus on efficiency, equity and environmental sustainability. Increasing scarcity and vulnerable nature of water as a resource, and the increasing demands upon it, water must be used with maximum possible efficiency. Adequate quantity and quality of water is required for the sustenance of human well-being without compromising ecological sustainability. Undisputedly, water is a key driver of economic and social development while it also has a basic function in maintaining the integrity of the natural environment. Therefore, water is one vital natural resources which cannot be considered in isolation.There are great differences in water availability from region to region - from the extremes of deserts to humid tropics. There is a variability in supply through time, as a result, both of seasonal and inter-annual variation exist. All too often the magnitude of variability and the timing and duration of high and low supply are not predictable which equates to unreliability of the resource posing great challenges to water managers in particular and to societies as a whole. There are supply-side infrastructure to assure reliable supply and reduce the risks but only supply-side solutions alone are not adequate to address the ever increasing demands from demographic, economic and climatic pressures, waste-water treatment and water recycling necessitating demand management to counter the challenges of inadequate supply.

Water, a life sustaining resource, closely linked to the quality of life, a renewable resource, is getting deteriorated in terms of quality as well as quantity. Adequate, timely and assured availability of water is critical to agriculture, to ensure food and nutritional security and livelihood of growing population. In general, water management assumes paramount importance to reduce the wastage of water to increase the water use efficiency and ensure equitable distribution. In India, the surface water potential is about 180 million ha m and the ground water resource is about 44 million ha m. With annual precipitation of about 400 million ha m, the average annual natural flow is about 188 million ha m. The annual requirement of fresh water is estimated at 105 million ha m by the year 2025 AD which is nearly equal to the ultimate water resources level of the country. Although India has the largest irrigation system in the world, its water use efficiency has not been more than 40 %. If it continues, water crisis would lead to reduced production and productivity, which would affect the quality of life of the people. This calls for productive use of water, more crop per drop. This would need efficiency at all the levels, storage, distribution and application. Agriculture sector uses 82 per cent of water, which covers only 38% of cultivated area and with increasing demand from industrial and domestic sectors, water availability for agriculture is going to be less. Currently, efforts are being made to cover additional area to ensure food and nutritional security and enhanced income to farmer. Approaches, have largely been for creation of water resources, through major and minor dams, water harvesting structures and water conservation measures, with less emphasis on enhancement of irrigation efficiency. However, with current level of efficiency and losses of water in distribution, more than 50 % area may remain rain fed. With increasing population, economic prosperity and industrialization, it is expected that by 2025, the water available for agriculture will decrease to less than 70 per cent. Recognizing the challenges of water, Government of India has launched a flagship program- PMKSY with the objective, to achieve convergence of investments in irrigation at the field level, expand cultivable area under assured irrigation, improve on-farm water use efficiency to reduce wastage of water, enhance the adoption of precision-irrigation and other water saving technologies (More crop per drop), enhance recharge of aquifers and introduce sustainable water conservation practices by exploring the feasibility of reusing treated municipal waste water for peri-urban agriculture and attract greater private investment in precision irrigation system. This is a well conceived program to address the Integrated water resource management to provide water to all the agricultural land (Har Khet mei Pani). Since three ministries are involved in implementation of this program integration of efforts will be a key to success, in achieving more crop per drop. This will need effective balance of water for people, for food, for nature and for industrial and productive uses, and at the same time achieve social equity, economic efficiency and environmental sustainability.

Sustainable management of water in agriculture is critical to increase agricultural production, ensure that water can be shared with other users and maintain the environmental and social benefits of water systems. In this context there is a need to improve the economic efficiency and environmental effectiveness of policies that seek to improve water resource use efficiency and reduce water pollution. Therefore, there is a need to establish a long-term plan for the sustainable management of water resources in agriculture taking into account climate change and climate variability impacts, including the increased need for protection from flood and drought risks and alteration in the seasonality and timing of precipitation. To enhance Irrigation use efficiency micro Irrigation is a best option. Micro-irrigation could be seen as the congruence of sustainability, productivity, profitability and equity. Since micro-irrigation greatly enhances water, fertiliser and energy use efficiency and promotes precision horticulture/ agriculture, the sustainability could be achieved without the burden of environmental degradation. Agriculture including horticulture have to gain much for meeting the challenge of more production with declining land and water by adoption of efficient techniques towards high water productivity. The advanced methods of irrigation which are otherwise known as drip and sprinkler could be introduced for all types of crops depending upon the soil, slope, water source, farmers' capacity etc. It is a known fact that the yields of the crops are better in addition to the saving of water with the above methods. Micro-irrigation was developed all over the world towards the later part of the last century. In India, micro-irrigation, which provides the water in root zone was introduced at farmers level in late eighties. In last two decades, the system has created awareness among the farmers. The area under micro-irrigation system is around 8.2 million ha now. To promote the concept efforts were made, and research support was provided by Indian Council of Agricultural Research. Since, micro-irrigation also enables the use of fertilizer, pesticides and other soluble chemicals along with the irrigation water more economically; it has become the means of precision farming In order to get vertical expansion of efficient water management could prove boon to achieve higher productivity much needed to meet our future demands. Obviously, in achieving this goal, appropriate enabling environment and policy support for the development of seed sector is a critical need. Our country with its vast pool of trained manpower, a well established network of scientific institutions and strength in information technology can become hub of research and development in water management and play a major role globally. Indian Agriculture has made impressive achievements in terms of technology development, adoption and overall growth, but, th gap in potential yield and realised yield is much away from reality. Therefore, institutional support system linked with public and private enterprise would be essential. A concerted efforts with identified destination evolving all the stakeholders keeping the technology at driving seat and farmers as centre of attention would definitely help in achieving faster and inclusive growth. This will need policy crop per drop, to achieve highest productivity of water.

Use of Improved Technologies

Agricultural Biotechnology

Indian agriculture has made a rapid stride in last 5 decades, converting the country from food shortages to self-sufficiency, achieving the production level of 261.5 million tones and 283.8 million tones of horticultural crops. Recognizing the essentiality of nutrition and improved farm income, and to meet the growing demand, in last few decades, diversification of agriculture has gained focus. Globally, food and nutritional security of growing population, which would be more than 10 billion at the end of 2050, with declining land and water in the scenario of climate change is a great challenge.

Gene technology coupled with production system management, in the past, have helped in improving production and productivity. But, these technological changes have to be strengthened to harness the potentiality. In this context, biotechnology, which is the use of living system and organisms to develop and make useful products, or any technological application that uses biological systems, living organism or derivatives thereof to make or modify product or processes for specific use, stands out as the frontier area of research, with many success stories and concerns. Advancement in regeneration system has helped in commercial production of disease free plants for improved production and the system has also been used for embryo rescue. Molecular genetics, recombinant DNA technology and ability to move genes across sexual barriers have opened new opportunities. Understanding of gene through genetic analysis has improved, and bioinformatical tools are used for the management of gene function. Consequently, biotechnology has opened up uncommon opportunities for enhancing the productivity, profitability, sustainability and stability in many cropping systems. The science of biotechnology has created scope for developing crop varieties tolerant/resistant to biotic and abiotic stresses through a appropriate blend of GM, Mendelian and molecular breeding technologies, Marker Assisted selection has now become an integral part of breeding programme. Many noble and powerful markers are available to the breeder for precise and rapid transfer of desired traits. Biotechnological application in diagnostics has enhanced reliability and rapidity of test for early diagnosis. While the benefits are clear, there are concerns about the short and long term impact of GMOs on the environment, biodiversity, human and animal health. There are also equity and ownership issues in relation to biotechnological processes and products. Thus, there is need for transparent and truthful risk-benefit analysis in relation to GMOs, on a case-by-case basis. Biotechnology offers opportunities for converting the biological wealth into economic wealth and new employment opportunities on an environmentally and socially sustainable basis.

Nanotechnology for Enhancing Inputs Use Efficiency

Beginning of the 21st century saw the advent of biotechnology that has already made a mark across the globe, including India. Nanotechnology provides opportunities for the development of processes and products that are precise and impossible to achieve through conventional systems has potential to address the challenges and concerns of agriculture to produce more for growing population, in the scenario of declining land, water and climate change impact. Nanotechnology on its own and/or complementing biotechnology can provide further strength to Indian agriculture by way of development of nano-agri inputs like, nano a fertilizers, nano herbicides and nano-pesticides which have much higher input use efficiency than the conventional agri products. Pests and diseases are a real menace to crop production leading to 20-30% average crop losses. Their early detection, before the threshold value, is a key to their management. Nanotechnology can be exploited to develop biosensors and other efficient early diagnostic tools for this purpose. Nutrient deficiency and food contaminants can also be detected using nanosensors. Nano technology may help in developing a "Smart Delivery System" that would have capability to detect and treat diseases, nutrient deficiencies or any other malady before appearance of visual symptoms. Seed is subjected to various abiotic and biotic stresses that limit its potential. Nanotechnology can help in developing nano-molecules and polymers that can invigorate the seeds thereby resulting in enhanced seed germination and better vigour and can also provide protection from various seed and soil borne diseases. Smart Delivery Systems can possess timely controlled, spatially targeted, self-regulated, remotely regulated, pre-programmed or multi-functional characteristics to avoid biological barriers to successful targeting. This technology has very wide application in food packaging – nano-biodegradable packaging, anti-microbial nano-packaging, intelligent packaging concepts based on nano sensors and nano encapsulation of functional foods. Environmental safety can also be addressed by nanotechnology through waste water treatment, and air purification based on nano-chemistry. The scope of nanotechnology in agriculture is unlimited and therefore, it can be exploited to bring about a new dimension to Indian agriculture. Nanotechnology also has its role in biotechnology for increasing its efficiency. Marriage of the two technologies may (i) provide higher resolution materials and devices for separation of enzymes and other bio-molecules that act as key catalysts, (ii) helps in developing novel laboratory-on-a-chip proteomics technology for assessment of metabolic pathways in important bio control agents, (iii) development of novel nucleic acid engineering based films with more sophisticated and controllable nano structures for agricultural and food systems and many more such applications.

The primary area of focus includes productivity and management of crops and livestocks–crop and livestock improvement, precision agriculture, soil and water management, pest diagnosis/surveillance, food processing, food safety and packaging. The secondary area of focus of nanotechnology may include, vaccines, pesticides, fertilizers, water, gene, drug, inputs for remediation of natural resources and other input delivery formulations in plants and animals, nano-array based gene technologies for gene expressions and utilization of waste. Area of Nanotechnology applications may include, gene delivery, expressions, sequencing therapy, regulation, DNA targeting, extraction, hybridization, finger printing, cell probes, cell sorting and bio imaging, single cell based assay, tissue engineering, proteomics, and nano bio genomics. In order to harness the potential application of nanotechnology in agriculture and also to address the critical gaps in the field of agriculture,Application of nanotechnological development in the field of Agriculture is of recent happening. GB Pant University of Agriculture & Technology, Pantnagar, has taken a lead in the field of disease diagnostics. They have developed a nano-gold based lateral flow immuno-dipstick assay using anti teliospore antibodies for detection of Karnal bunt. The dipstick assay is very sensitive to detect the antigens of even five teliospores. Central Potato Research Institute has also developed dipstick assay based on nanogold particles for detection of potato viruses at field level. The assay is even superior to ELISA. Tamil Nadu Agriculture University, Coimbatore, has initiated nanotechnology research in various fields of Agriculture. Formulation of nano fertilizers is one of them. Nano-fertilizers has been developed using naturally occurring clay minerals and zeolites by reducing them to the size of nano dimensions. Nano-zeolites retain nutrients due to extensive surface area and release slowly for an extended period of release of NO_3- N more than 40 days while nutrient release cease to exist beyond 12 days Even the release pattern of slowly diffusing PO_4 ion is altered by the surface modified nano-zeolites. Nano-zeolites have also been found useful in slow release of K (Zhou and Huang, 20

Nano-herbicides have a potential to overcome the traditional problems of lack of moisture in soil by encapsulation of herbicide molecules with polymers that breaks open only when the soil moisture is present. Remediation of herbicide residues, which is potential source of ground water pollution has also been successfully achieved using nano particles of FeO. Nano-biodegradable packaging and antimicrobial nano-packaging have been developed which can be used to reduce food spoilage and environmental pollution. Besides, concept of intelligent packaging based on nanosensors has been introduced to detect leaks in the packaging. The challenges that Indian agriculture is likely to face in coming years are enormous. Various strategic approaches including the use of biotechnological tools have been employed to overcome yield stagnation yet, the problem continues to be there. Therefore, we have to look for other cutting edge technologies which can address these problems and can help in sustaining the food production commensurate to our future requirement. In this context, nanotechnology is one such cutting edge technology which can provide sustenance to our food production by many ways including early detection and management of pests, diseases and nutrient deficiencies, enhancing input use efficiency and, avoiding/reducing spoilage of food items including fruit and vegetables through smart packaging.

Aeroponics - A Viable Option for Increasing Profitability

In changing scenario of declining land and water, the is need for new technology to produce more with less land and water. Vertical system of cultivation added with artificial light in controlled condition has provided an option. In this context, aeroponics, which is a system wherein roots are continuously or discontinuously kept in an environment saturated with fine drops (a mist or aerosol) of nutrient solution paper to be potential. Since, this method requires no substrate and entails growing plants with their roots suspended in a deep air or growth chamber with the roots periodically wetted with a fine mist of atomised nutrients. Excellent aeration is the main advantage of aeroponics. This technique has proven to be commercially successful for propagation, seed germination, seed potato production, tomato production, leaf crops, and micro-greens and has appeared tobe an alternative to water intensive hydroponic systems.Distinct advantage of aeroponics over hydroponics is that any species of plants can be grown in a true aeroponic system because the micro environment of an aeroponic can be finely controlled. In this system, suspended aeroponic plants receive 100% of the available oxygen and carbon dioxide to the roots zone, stems, and leaves, thus accelerating biomass growth and reducing rooting times.. Aeroponics is also widely used in laboratory studies of plant physiology and plant pathology. Aeroponic techniques have been given special attention now when we think of growing crops under controlled conditions since a mist is easier to handle than a liquid. The system of aeropincs has been successfully demonstrated for disease free seed production of potato at CPRI, Modipuram, and now has been extended to many crops. At Jain Irrigation, Jalgaon aeroponics is being tested for large number of crops. Considering that, nutrient requirement varies with the cultivar, there is a need to customize the nutrient balance for different different cultivars and crop. This technology has to provide higher income per unit of land and water and can help farmers in achieving better income.

Precision Farming for Improved Inputs Use-efficiency

There is an ever increasing concern for meeting the food and nutritional security of growing population, necessitating concerted efforts to meet the needs of food, nutrition, environmental services and health care from declining land and water resources, besides, the threat of climate change. The scenario, calls for strategic approaches to the technology-led development for producing **more from the less** land, limited water and sustaining the effect of climate change. Precision horticulture, which focuses on observe, measure and respond to use inputs precisely to get maximum output in given time frame. This also referred as region specific and site specific management having choice of crops as per the climate and soil and technology adopted are base on measurement of variables affecting the production. in this approaches of production there is a focus on 4S, save, sustain, skills and scale up. Whole system of precision farming is based on revolution in science and emergence of new technologies like biotechnology, information technology, nanotechnology and bioinformatics, fertigation, Greenhouse technology, smart nutrient and water management. The precision farming becomes more effective if decision support system is strong. These technologies applied in congruence with socio-economical conditions of the community becomes more productive and is referred to smart agriculture**.** Therefore**,** agriculture is an integration of science and technology, complimented with information technology, in consonance with socio economics, which can mitigate and adapt to changes for maximised output of horticultural crops. Dynamics of smart agriculture is a measurement of changes in technologies needed to address the challenges.

Linking Farmers to Market

Considering that linking farmers with market is critical to enhancing income of the farmers, attempts for improving market access through reforms have been attempted from time to time. Ministry of Agriculture has brought reforms by Model Agriculture Produce Market Committees (APMC) Act-2016,to encourage healthy competition, so that both private and public sector markets can provide access to farmers as well as consumers directly, as far possible and avoid intermediaries An expert panel has been set up to look at statutory changes that may be required to remove inter-state restrictions on sale of produce by farmers and create an environment for free-trade. The E-NAM (Electronic-National Agriculture Market), launched by Prime Minister last year, is aimed at taking agriculture marketing towards unification and creating marketing efficiency through an online platform. Minimum support price (MSP) for farmers is an important tool, the government is moving towards greater procurement intervention which will include other crops also like pulses and oilseeds. The marketing reforms also include de-listing of perishables like fruits and vegetables from APMC to enable farmers to realize a better price. However storage infrastructure of cold storage and ware house facilities are needed . The market access further depends on: (a) understanding the markets, (b) organizing of the firm or operations, (c) the existence of communication and transport links, and,

(d) an appropriate policy environment. Understanding the markets in a modern context involves understanding the value chains and networks and their dynamics from a small producer perspective. Interventions like Farmer Common Service Centers could be an appropriate forum for such a market access.Producers organizations (PO) could be the best alternative for enabling farmers / producers to get better remuneration for their produce because it enables aggregation of the produce and in turn gives the necessary bargaining power to get better price. To strengthen the Producer Organizations and to make them play an effective role in alternate marketing the need attention for Credit availability, Capacity Building, Alternatives to Equity, Venture Capital Fund, State Support to Producer Companies (PCs), and Convergence.

Functioning of traditional markets (APMCs) needs to be improved to enhance their cost efficiency so that producers and consumers can realise better prices. The amended APMC Act allows for the setting up of private markets. It is also necessary to enforce an open auction system, improve buyer competition in markets, provide better facilities such as cold storage, and improve farmers' access to market information. These markets are important to small farmers and even a significant proportion of medium and large farmers, who still depend on them; they also serve as main competitors to contract farming and can improve the terms offered to contract growers.There is a need to combine value chain promotion with livelihood perspective to enable the resource poor to enter in to and stay in to globalized commercial markets. Innovation in smallholder market linkage are needed in terms of partnership, use of information and communication technologies, leveraging networks, value chain financing, smallholder policy, and, even in contracts that can promote both efficiency and inclusiveness of the linkage. Choosing the right market and a market development strategy is essential to scale up the operations that can come only by innovation of products and business models. It is not market access but effective market participation that is at the heart of success of any market linkage for primary producers.

Partnership with the private sector can come in handy as they can provide technology, and upgrade business (quality) and social standards. For this, POs and their staff and farmers should be more market-oriented and have the capacity to work with and negotiate fair contracts with private agencies.. Farmers also need to be made aware of the need to respect contracts and specific terms and conditions including prices, rejections and penalties for default. Private sector agencies also need to invest in linkage building. Contracting agencies may provide inputs on credit to their contract growers in India as cost of production and transaction for high value crops is generally higher and difficult for growers to provide for from their own resources and networks. Convergence with various ongoing programmes for backward linkages provided to a private player taking care of forward linkages could be the desired model for PPP. Non-farm income (generated from works like dairy and poultry which are other than crop production) of farmers is also important.

Land Reforms for Enhancing Farm Income

There is an imposed restriction or legal ban on agricultural land leasing in most of the states, which has forced tenancy to be informal, insecure and inefficient as they do not have legal access to institutional credit, insurance and other support services. This has also reduced the occupational mobility of many landowners who have interest and ability to take up employment outside agriculture and yet are forced to stay in agriculture due to the fear of losing land if they lease out and migrate. Thus there is need for amendment of the prevailing act as legalization and liberalization of land leasing is required for much needed agricultural efficiency, equity, occupational diversification and rapid rural growth and transformation. Even the socialist countries like Peoples Republic of China and Vietnam have liberalized agricultural land leasing with significant positive impact on economic growth as well as equity. Legal restrictions on land leasing have affected agricultural efficiency in several ways-

(a) The ban led to concealed tenancy in almost all parts of the country. Informal tenants are most insecure, as they either have short duration leases or move from one plot to another, so that they cannot prove continuous possession of any particular piece of land for particular period which could give them occupancy right, according to law of state. This provides a dis-incentive to tenant farmers to make any in-vestment in land improvement for productiv-ity enhancement. Legislation of land leasing would ensure security of land ownership right for the land owners, which in turn would provide security of tenure to the tenants.

(b) Informal tenants do not have access to institutional credit, insurance and other support services, which affect productivity of land cultivated by them. Legalization/ formalization of land leasing would help to improve tenant farmers' access to credit, insurance and input use and consequently productivity of leased in land. Study suggests that productivity of leased land can be as good as that of owner operated land.

(c) Due to legal restrictions, many land owners prefer to keep their lands fallow due to the fear of losing land right if they lease out. Keeping the land fallow results in underutilization of land and loss of agricultural output. The lifting of ban or restrictions on leasing in such cases will result in better utilization of available land and labour and increased farm output. Restrictive tenancy laws have prevented optimum allocation of land resources and denied the poor access to land.

(d) Lease market transfer land to those who have less land available for use, more ability to use land, and a higher adult force . The considerations of subsistence and family labour use are important reasons for leasing in land (mani and Pandey, 2004). Leasing of land is used as an adjustment device by many in response to change in family labour availability, cash resources, debt situation etc.

Thus, formalization of land leasing would help improve agricultural efficiency and thereby adding to the income of farmers. The landless and marginal farmers would improve their economic viability and social status. The rural poor would maximize their family income by way of farming on lease, alongwith access to other farm, off-farm and non-farm employment opportunities. Improved access to land on lease by the poor would help reduce their poverty and enhance economic and social status.

The share of agriculture in India's GDP is only about 14 per cent, but agriculture employ 49 per cent of the total workforce and 64 per cent of the rural workforce. The high dependence of the population on agriculture is one of the main reasons for low size of land holding and for low per-capita income as well as high incidence of poverty among agricultural workers. There is a limit beyond which agriculture cannot productively absorb any additional workforce. It is therefore, absolutely necessary that there is transfer of population from agriculture to non-agriculture. Legislation of land leasing could be an important contributing factor in this respect. It would encourage large land owners to lease out land without fear of losing their land ownership rights and investment in non-farm enterprises with appropriate capital and technology support, which is vital for occupational diversification and rapid rural development and transformation. This will reduce the pressure of population on agriculture and enable small farmers to augment their size of operational holdings by leasing in land. NITI Aayog is already working on this policy and have come up with Model Agricultural land Leasing Act which proposes:

(a) Legalize land leasing to promote agricultural efficiency, equity and poverty reduction. This will also help in much needed productivity improvement in agriculture as well as occupational mobility of the people and rapid rural change

(b) Legalize land leasing in all areas to ensure complete security of land ownership right for landowners and security of tenure for tenants for the agreed lease period

(c) Remove the clause of adverse possession of land in the land laws of various states as it interferes with free functioning of land lease market

(d) Allow automatic resumption of land after the agreed lease period without requiring any minimum area of land to be left with the tenant even after termination of tenancy, as laws of some states require

(e) Allow the terms and conditions of lease to be determined mutually by the land owner and the tenant without any fear on the part of the landowner of losing land right or undue expectation on the part of the tenant of acquiring occupancy right for continuous possession of leased land for any fixed period

(f) Facilitate all tenants including share croppers to access insurance bank credit and bank credit against pledging of expected output.

(g) Incentivize tenants to make investment in land improvement and also entitle them to get back the unused value of investment at the time of termination of tenancy.

Summary

Indian Agriculture is vital for socio-economic development of the country, as it provides livelihood to half of the population supplies raw material to industries and ensure food and nutritional security to the nation. Agriculture production and agri-business together are larger in size, than any other sector. Past three decades have witnessed un-parallel development of agriculture in India, compared to any other part of the world. The country has emerged from an era of food deficits to that of self-sufficiency and has become an exporter of many agricultural commodities. The dynamics of development have been through various revolutions including Green Revolution. All these changes have helped to become food secured nation and achieve better farm income and also opportunities for both direct and indirect employment. But the challenges ahead are much greater than before. Earlier, policies, programmes, technological changes and initiatives were designed and implemented for achieving higher production through improving productivity parameters, as it was important to achieve self- sufficiency in food, a primary concern than looking to the challenges of producing and helping the farmers in achieving improved farm income. In this context, there is need to transit from production based approach to farm income based approach. Dynamics of these approaches for doubling farmers' income would revolve around reducing cost of production through technological changes, innovations and well planned market strategies to improve margin of profit, insulating against risks by insurance and landless allied activities to compliment the farmers income. Diversification, ancillary activities and approach to aggregation of land for better operation are also discussed as means to increase farm income. Invariably, it is noted that doubling of farmers' income in 6 years time is possible but is challenging, which need careful and well designed strategies in regionally differentiated manner, with careful examination of strength, weaknesses, threats and opportunities, based on the climate, soil and farmers' capabilities. The drivers to double the farmers' income would be technological changes, innovations, improved delivering systems, infrastructure and governance with farmer centric approaches, and above all strategic diversification

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Human Resources and Skill Development for Enhancing Farmers' Income

NARENDRA SINGH RATHORE

Agriculture sector has given the status of priority to the Indian economy because directly or indirectly more than 50% of the total work force is employed in this sector. Agriculture contributes about 14% in national GDP and responsible for about 12% export. Agricultural field is a diverse discipline which introduces improved farming techniques to increase and sustain agricultural production quality and quantity wise and to reduce drudgery**.** Education is an act or process of imparting or acquiring knowledge, developing the powers of reasoning and judgment. Agricultural education provides couple of educational activities with the primary aim of achieving human resource development throughout the rural economies of almost all nations. It covers the learning needs of all associated aspects of agricultural and allied sciences. India has acquired status of first green revolution by increasing about 5 times grain production, 9 times horticultural production, about 9.5 times milk production and 12 times fish production. Perhaps it is because of deep rooted agriculture education in this country. However, in present context, Agriculture Education need new challenges of broadening scope of its operation, bridging gap between demand and supply, having proper cooperation & collaboration among different stakeholders and proper documentation and dissemination of technologies across different stakeholders. Further, there is need to energies the sector by enabling new education technologies.

Today we need skills, not just degrees, with the ability to assimilate, adapt, apply and develop new technologies. Today we need high quality agricultural graduates equipped with problem solving and creative skills and ability to think and improve productivity of agricultural sector. Apart from the technical and generic skills, our graduates need leadership and entrepreneurial skills to build leading teams, and put innovations into practice and respond to competitive environments. There is need to articulate four T's *i.e.* Tradition, Technology, Talent and Trade to make agriculture as alternative field for livelihood and sustainable development. Traditional means what is our status as far as agriculture is concerned in our country, technology means what is present state of art of devices, system, process and package of practices available indigenously and internationally. The concept of talent is how to use innovation and creativity among all stakeholders of agriculture to make this profession remunerative and finally there is need to introduce concept of trading in agriculture field i.e. how to federate farmers into business group.

It is observed that education must include knowledge (basics, fundamental, theory, practices,) to know what to do, skill to know how to do, ability to make work simple & convenient, experience for increasing efficiency and finally attitude & resources for doing work in actual. Thus we need updated Syllabus with proper articulation of quality and reform. Quality assurance in higher agricultural education in the country has been achieved through policy support, accreditation, framing of minimum standards for higher agricultural education, academic regulation, personnel policies, review of course curricula and delivery systems, development support for creating/strengthening infrastructure and facilities, improvement of faculty competence and admission of students through All India competitions.

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As first and most important step for quality improvement of education, the Indian Council of Agricultural Research has been periodically appointing Deans Committees for revision of course curriculum. In the series, recommendation of Fifth Deans Committee had been made considering contemporary challenges for employability of passing out graduates and to adopt a holistic approach for quality assurance in agricultural education and declaring agriculture as professional degree. The committee has recommended that in first year of each sub sector of agriculture courses related to traditional, in second year courses related to technology, in third year courses related to increase in talent of students and in final year courses related to trade or federating students into business group should be planned. Further, the Committee has also recommended to introduce ICAR funded 'Student READY programme (Rural Entrepreneurship Awareness Development Yojana) in each UG courses for one complete year period to promote skill development in the graduating students for specialized jobs in view of market needs and demands.

Student READY programme was conceptualized to reorient graduates of Agriculture and allied subjects for ensuring and assuring employability and develop entrepreneurs for emerging knowledge intensive agriculture. The proposal envisages the introduction of the programme in all the Agricultural Universities as an essential prerequisite for the award of degree to ensure hands on experience and practical training by adopting the following components depending on the requirements of respective discipline and local demands. Since Agriculture & its allied disciplines have been declared as Professional degree, therefore there is need to put more practical orientation and efforts should be made to make our students job provider rather than job seekers. Component of this programme meant for entrepreneurship development is having following component.

- Experiential learning with business mode
- Rural agriculture work experience
- In plant training/ industrial attachment
- Hands-on training (HOT) / skill development training
- Students projects

All the above mentioned components are interactive and are conceptualized for building skills in project development and execution, decision-making, individual and team coordination, approach to problem solving, accounting, quality control, marketing and resolving conflicts, etc. with end to end approach.

Experiential Learning (EL) helps the student to develop competence, capability, capacity building, acquiring skills, expertise, and confidence to start their own enterprise and turn job creators instead of job seekers. This is a step forward for "Earn while Learn" concept. Experiential Learning is an important module for high quality professional competence and practical work experience in real life situation to Graduates. The module with entrepreneurial orientation of production and production to consumption pattern is expected to facilitate entrepreneurship skill among the students. The Experiential Learning provides the students an excellent opportunity to develop analytical and entrepreneurial skills, and knowledge through meaningful hands on experience, confidence in their ability to design and execute project work. ICAR has established more than 426 such units throughout India in different AU's on various components. The main objectives of EL are to promote professional skills and knowledge through meaningful hands on experience, build confidence and to work in project mode and finally to acquire enterprise management capabilities.

Hands-on training (HOT) / Skill development training aim to make conditions as realistic as possible. The biggest benefit of hands-on training is the opportunity for repeated practice. Training programs are more beneficial when they provide many opportunities for practicing a skill. The students will be provided such opportunities to become skilled in the identified practices/methods and gain confidence. The ultimate aim is to make student ready to pursue the learned skills as their career. By participating in hands-on-training programs, the students will be able to strengthen their existing skills while learning new techniques. These accomplishments are not possible to get acquired in the classroom alone as they are the direct result of the one-on-one training between trainer and students. In university where experiential learning unit cannot run on business mode may impart skill development through available experiential learning unit facilities in repair, maintenance & operations, etc.

The Rural Agricultural Work Experience (RAWE) helps the students primarily to understand the rural situations, status of Agricultural technologies adopted by farmers, prioritize the farmer's problems and to develop skills & attitude of working with farm families for overall development in rural area. This may be Rural Horticulture work. Experience for Horticulture students, Rural Fisheries Work experience for Fisheries students and so on for different stream of Agriculture. Sciences. The timings for RAWE can be flexible for specific regions to coincide with the main cropping season. The main objectives of this component are:

- To provide an opportunity to the students to understand the rural setting in relation to agriculture and allied activities.
- To make the students familiar with socio-economic conditions of the farmers and their problems.
- To impart diagnostic and remedial knowledge to the students relevant to real field situations through practical training.
- To develop communication skills in students using extension teaching methods in transfer of technology.
- To develop confidence and competence to solve agricultural problems.
- To acquaint students with on-going extension and rural development programmes.

In Plant Training (IPT)/ Industrial Attachment training, students will have to study a problem in industrial perspective and submit the reports to the university. Such in-plant trainings will provide an industrial exposure to the students as well as to develop their career in the high tech industrial requirements. In-Plant training is meant to correlate theory and actual practices in the industries with the main objectives to expose the students to Industrial environment, which cannot be simulated in the university, to familiarize with various Materials, Machines, Processes, Products and their applications along with relevant aspects of shop management, to understand the psychology of the workers, and approach to problems along with the practices followed at factory, to understand the scope, functions and job responsibility-ties in various departments of an organization and finally exposure to various aspects of entrepreneurship during the programme period

Students Projects: work provides opportunities to students to learn several aspects that cannot be taught in a class room or laboratory. It may be adopted based on the interest of student and expertise and facilities available with the College. It is observed that many students after graduation are interested for higher education, for them it is must to get first hand information related to identification of problems, experimental set up, observations and documentation. The student's projects may bring sense of report writing and research aptitude among graduating students. The Students Project is proposed with the main objectives to impart analytical skills and capability to work independently, to conceptualize, design and implement the proposed work plan, learn to work as a team- sharing work amongst a group, and learn leadership qualities, to solve a problem through all its stages by understanding and applying project management skills, to do various implementations, fabrication, testing and trouble shooting and communication report writing skills.

As far as enhancing farmer's Income is concerned, it may be attempted by enhancing agriculture input use efficiency, new agriculture technologies for increasing production and profitability, new directions of processing and value addition and finally by articulating ICT and Agriculture market concept for getting right remuneration for agriculture products. Presently Agriculture is in crossroad which need a formula of PQRST *i.e.* Production (Productivity and profitability), Quality enhancement, Remunerative, Sustainable development including get rid of climate change and finally trading into business group. For this perhaps agriculture education need right attention. In order to solve problem of PQRST there are ample solutions and can be tackle by articulating concept of Integrated Farming System (IFS) for enhancing production and profitability, Food Safety (FS) for ensuring quality, Good Agriculture Practices (GAP) for ultimate solution of Remuneration, Agriculture Processing (AP) and value addition for sustainable development and Agriculture Market (AM) for trading.

Skill Modules of Agriculture requires a systematic arrangement for providing a thorough foundation in the basic physical sciences, applied agricultural sciences and fundamentals. At the same time there is need to teach the students the basic scientific principles in solving problems of agriculture and food production by providing them instructions in analysis, development, design and practical work and to expose the students to laboratory and field exercises that will enable them to tackle challenges in the field. This arrangement will train the students to acquire the capability for meaningful output in Agriculture and livelihood generation. There are number of sub sectors for skill development in agriculture field, where there is potential for enhancing farmer income. They are summarized as follows.

Agriculture mechanisation: Hand, animal drawn and power operated implements and tools, training for establishment of custom hiring centers, farm machines and equipments: repair and maintenance, mechanization for on farm applications, mechanization for horticulture crops, farm tractor system and its overhauling, pesticides application equipment and tools, land development and grading machines and draught animal power and tools in agriculture.

Animal husbandry and veterinary: Feed and fodder management, densification techniques for fodder: pellet, briquettes and cubs, breed improvement, animal health practices, poultry farm raising, infrastructural development for thermal comfort for animal raising, commercial broiler production, good dairy farming practices, male weaner goat rearing, veterinary clinical practices, non – clinical vascular infusion technology, veterinary dentistry, clinical immunology of the dog and cat and AI practice.

Cooperatives/ cooperation: Construction of godowns for procurement, storage and distribution, fertilizer distribution practices and farm inputs dealer training.

Crop development: Paddy breeding and production, wheat production, coarse cereals production, oilseed and pulses production, sugarcane production, cotton production, integrated farming systems.

*Dairy development:*Advanced dairy farming, promotion and management of milk collection centers, organic dairy units to farmers and processing and value addition in milk.

Food processing: Food packaging, functional foods and nutraceuticals, food additives and ingredients, meat and meat processing, cereal and pulses processing, fruits and vegetables processing, chocolate and confectionary, domestic product processing, fruits & vegetable processing, drying of agriculture and horticulture products, fisheries & sea product processing, development of consumer products, grain processing, plantation (tea, coffee, cashew processing), eggs, poultry & meat processing and fresh- cut fruits and vegetable processing.

Fertilisers and INM: Soil testing labs, fertilizer labs, micro-nutrients labs, soil health cards and soil testing.

Fisheries: Farmers fish ponds, infrastructure / ponds of fisheries, fisheries marketing and fish post harvest technology.

Horticulture: Nurseries & green houses, development of horticulture farms, land scaping and area expansion, floriculture production, vegetables production, fruits production, coconut production, tissue culture management, commercial horticulture, protected cultivation of high value horticulture crops, precision farming of floriculture and exotic vegetables and development of quality planting material.

Information technology: Development of ICT facilities, ICT enabled agriculture, e-sensors and micro processed based tools, AI and robotics and ICT for weather forecasting.

Integrated pest management: IPM labs, pest surveillance and management, promotion of IPM and farmers field schools.

Marketing & Post harvest management: Godowns & warehouses management, setting up/ strengthening of marketing infrastructure, private sector/ ppp projects and cold storages & cold chains development.

Micro/minor irrigation: Shallow wells/dug wells irrigation, tube wells operation and maintenances, percolation tanks, diggis for water storage, minor irrigation works, farm ponds; construction and management, sprinkler & drip irrigation, techniques for canopy under canopy, rain water harvesting structures, best management practices for drip irrigated crops, water and fertigation management in micro irrigation, closed circuit trickle irrigation system and sustainable practices in surface and subsurface micro irrigation.

Natural resource management: Water conservation structures &watershed development, soil treatment techniques (acidic, alkali, waterlogged) and land reclamation techniques.

*Non farm activities:*Agri business centers and post harvest processing facilities.

Organic farming / biofertiliser: Production of bio fertilizer/ bio agents and bio pesticides, composting and vermi composting, nadep and prom, promotion techniques for organic and natural farming, waste recycling and resource recovery system, marketing of organic products, zero budget farming, cow based farming.

Seed & planting material: Seed testing labs, seed processing centers & seed storage, seed farms, seed distribution, seed production and technology, seed certification, tissue culture and seed conditioning

*Sericulture:*Cocoon production.

Innovative programmes: Conservation agriculture, secondary agriculture, precision agriculture, hi-tech agriculture, specialty agriculture, poly house/ net house/ glass house management, greenhouse design and control, aeroponics, hydroponics for growing plants, mushroom production, honey bee keeping, waste water treatment, traditional agro industries-clean and green advancements, integrated land use planning, agribusiness supply chain management, small dams: planning, construction and maintenance, banana breeding, sugarcane breeding, and integrated watershed management.

Renewable energy sources: Solar cooking, solar water heater, solar distillation, solar drying solar tunnel dryer, solar space heating, solar refrigeration and air-conditioning , solar pond: for electricity generation & thermal uses,solar furnaces for industrial process heat, solar greenhouse technology, solar thermal power generation; centralized tower system, distributed farm concept type system, solar photovoltaic technology: water pumping (shallow well and deep well), solar photovoltaic technology; power generation: small stand alone (few to 1000 watts), large stand alone (1000 w to 3000 w) and central generation system (multi mw production), biomass production, densification and pyrolysis, biomass gasification and application, improved cook stoves and furnaces and energy audit in agro industries.

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Strategic Approaches in Livestock Management for Doubling the Income of Farmers

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Livestock plays an important role in socio-economic life of India. It is a rich source of high quality foods such as milk, meat and eggs. Today livestock is playing an important role in strengthening India's economy. Animal husbandry enterprises provide significant livelihood opportunities to rural families especially smallholders and landless who constitute over 75 % of India's livestock resources. Livestock is the life line of Indian agro-based economy. About 70 million rural households are engaged in the milk production, with high proportion being landless, marginal and small farmers. Among various species of livestock, cattle and buffaloes are the major contributors from this sector to the National GDP. Dairying provides a stable year round income to farmers. It directly enhance the household income by providing high value output from low value input besides acting as wealth for future investment. Farmers, despite being at the heart of agricultural and livestock production, receive only a paltry portion of the price paid by consumers. On an average, the income of a farmer in India is less than $2 per day. According to an NSSO survey in 2014, the income of an average farm household is about Rs 6,000 ($90) per month, only 50 per cent of which comes from farming. In today's perview, most burning issue is development of strategies which could double the farmers' income significantly. In order to double the income of farmers, we need to improve the individual animal's milk productivity, which would need interventions at genetic, nutritional and management levels. In this review, few major areas are emphasized where critical managemental intervention is required for doubling the income of farmers in India.

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Strategies for Breed Improvement of Dairy Animals

Dairy production in India is characterized by small-scale, unorganized and widely scattered dairy farmers with large animal number but low productivity. The strategies for increasing livestock production should focus on increasing individual animal productivity rather than animal population. To increase average productivity of dairy animals, animal production system based breed improvement programme with clear breeding goals, targets and with adequate infrastructure facilities need to be planned. For successful implementation of such programme, full administrative and financial support from government and other stakeholders and active participation of the breeders and farmers are needed. Agro-climatic region and animal production system based breeding policies and active participation of farmers /breeders should be undertaken and implemented. Based upon the collected information of agro-climatic region and given animal production system, following region specific and animal production system based breeding strategies could be planned for genetic improvement of cattle and buffaloes.

1. Improvement of non-descript cattle by cross-breeding

The most effective approach to genetically improve the large population of non-descript zebu cattle is through cross breeding with exotic dairy cattle breeds particularly in milk shed areas around peri-urban and industrial towns where good marketing facilities for milk and milk products and round the year availability of adequate amount of green fodder and quality feed resources is available. The optimum level of exotic inheritance in crossbred cattle should range between 50 and 75 per cent. Under semi-intensive animal production system, it is advisable to restrict exotic inheritance between 50 and 62.5 per cent in crossbred cattle. Under intensive production system; higher levels of exotic inheritance between 62.5 and 75 per cent can be sustained.

2. Improvement of non-descript cattle by grading up

The local non-descript cattle are usually low producers. They are reared mainly under low-input production system across the different agro-climatic zones where quality feed and fodder resources are not available in sufficient quality. The non-descript cattle could be genetically improved by grading up using high genetic merit pedigreed and preferably progeny tested proven bulls of well-known indigenous cattle breeds like Sahiwal, Tharparker, Rathi, Red Sindhi, Gir, Deoni, Hariana, Ongole, Kankrej etc. For successful implementation of grading up programme of non-descript cattle with improved indigenous breeds need to be out-sourced for production of quality frozen semen and AI Infrastructure networking be strengthened. The bulls to be used for this purpose initially should be produced from superior dams identified from organized farms and farmer herds which have more than 2000 kg as lactation yield for milch breed of Sahiwal, Tharparker and Gir cattle and more than 1500 kg for dual type cattle breeds of Hariana, Ongole, and Kankrej.

3. Improvement of well-defined indigenous cattle breeds by selective breeding

It is necessary to undertake large-scale genetic improvement programmes in well defined zebu cattle breeds in their respective breeding tracts through selective breeding. The areas of country where the indigenous cattle breeds need to be improved by selective breeding are: Gujarat state for Gir and Kankrej; Rajasthan State for Rathi and Tharparker; Haryana, parts of Punjab, Western U.P. and Rajasthan for Hariana, parts of Karnataka and Maharashtra for Hallikar, Amritmahal and Deoni, Tamil Nadu for Kangayam and Andhra Pradesh for Ongole.

4. Improvement of non-descript buffaloes by grading up

The low producing, local non-descript buffaloes are generally reared under low to medium input production system in areas where feed and fodder resources and milk and animal marketing facilities moderately exist. The production potential of low producing non-descript buffaloes can be increased rapidly through upgrading with superior sires of improved breeds like Murrah, Surti and Mehsana.Surti is recommended for Karnataka, Kerala, parts of Gujarat & Rajasthan, Nili Ravi for few pockets of Punjab, Murrah for Haryana, parts of western UP & Punjab. In other parts of country where sufficient feed and fodder resources are available, Murrah is recommended for grading up of medium body sized non-descript buffaloes. This programme is expected to increase the milk production of village non-descript buffaloes by 2-3 times in early generations of grading up. Thus through grading up with superior breeds in 5-6 generations, the low producing non-descript buffaloes can be replaced with relatively high producing buffaloes conforming to the characteristics of well-defined breeds.

5. Improvement of well-defined buffalo breeds by selective breeding

The relative high yielding buffaloes of well-defined buffalo breeds are maintained under intensive production system at organized farms. Genetic improvement of buffalo herds in country could be brought by selective breeding. For effective implementation of such programmes particularly on large scale, existing organized farms of Murrah, Mehsana, Nili Ravi, Nagpuri, Bhadawari and Jaffarabadi buffalo breeds should be strengthened for production of breeding bulls.Genetic improvement in indigenous buffalo breeds for higher milk production, reduction in age at maturity, reduction in service period and calving interval will lead to higher economic return to farmers.

Strategies for Feed Management

Feed management is the most critical aspect to achieve the target of doubling the farmers' income.

Following strategies for feed management should be adopted.

Increase in forage yields: Presently, improved practices are not followed for cultivating forage crops. Hence, efforts are needed to breed superior fodder varieties, produce and supply good quality seeds, promote use of biofertilizers and forage harvesting equipment.

Efficient management of crop residues: New food crop varieties having higher grain yield and superior fodder quality should be promoted. Plant breeders should promote dual-purpose varieties of sorghum, maize, bajra, and a wide range of legumes.

Provision of area specific mineral mixture: Good quality area specific mineral mixture should be available to all dairy animals. *Introduction of by-pass protein feed:* Techniques have been developed to avoid wastage of nutrients by feeding by-pass protein and fat. Support should be provided to establish by-pass protein/fat production units particularly in milk sheds where high quality milch animals are maintained.

Enhancement of nutritional values: Major quantity of dry matter is contributed by paddy straws, wheat straw, maize stalk, sugarcane bagasse and trash, which are of poor nutritional value, due to high fibre content. With new techniques, the quality of such fodder should be improved. This will also help in counteracting the fodder shortage.

Reduction of herd size: It is necessary to create awareness among farmers to reduce herd size and ensure optimum feeding instead of maintaining a large number of underfed animals.

Complete feed rations: To overcome nutritional imbalance in the field and to facilitate small farmers and landless to maintain their livestock under balanced feeding, decentralised complete feed production units can be established.

Fodder banks: Establishment of fodder banks in fodder scarcity regions through dairy federations and People's Organisations can help small farmers to feed their livestock during scarcity. Fodder banks can play a critical role in timely supply of feed to livestock owners during the years of drought. The fodder banks could also take up the production of complete feed for local distribution.

Support for small farmers: For calf rearing, feed subsidy, insurance coverage, venture capital, etc. may be given to ensure their active role in dairy development and in rearing of small ruminants.

Strategies for Reproduction Management of Dairy Animals

The profitability of milk production from cattle and buffaloes depends to a large extent on their reproductive efficiency. Reproductive efficiency is influenced by several factors including genetic, nutritional, hormonal, physiopathological and managemental practices.

The most important strategy related to reproduction management is to obtain "One calf per year" from cow. To achieve this, a cow should concieve within stipulated time of 85 days post partum. She should commence her cyclicity as early as 45 days and should be bred by 60 days.

Following reproductive indices of dairy animals has to be optimized in order to maximize reproductive efficiency and double the income of farmers.

Calving interval of cow should be optimized to 12-13 month interval. If calving interval will be shorter, there will be more lactation and calves per lifetime of each breeding cow. It will provide better economic return to farmer. If it is > 14-15 month, it indicate serious problem.

Average days to first observed estrus should be optimized to about 45 days. If it is > 60 days, it indicates problems. Proportion of cows observed in estrus <60 days after calving should be about 90%. If it is <90%, it indicate problem. Average days open to first breeding should be optimized to 45-60 days. If it is >60 days, it indicate serious problem.Service per conception should be maintained between 1.3-1.6.If it is >2.5, it indicate serious problem. First service conception rate of heifers should be maintained between 65-70%. If it is <60%, it indicate serious problem. First service conception rate of lactating cattle should bemaintained between 50-60%. If it is <40%, it indicate serious problem. Average days open should be maintained between 85-110 days. If it is >140 days, it indicate serious problem. Average age at first calving should be about 30 months. If it is >30 months, it indicate serious problem.

Abortion rate should be<5%. If it is >10%, it indicate serious problem.

In order to double the farmers' income, three broad areas of reproduction management should be targeted. They are:

1) Development of effective protocols for advancing the age at maturity in heifers.
2) Improvement of estrus detection and conception rate in dairy animals.
3) Management of reproductive disorders of dairy animals.

1. Protocols for advancement of age of puberty/sexual maturity in heifers

One of the most important managemental strategies which will help in doubling the income of farmer is development of protocols which could hastens the age at puberty in dairy heifers. If age of puberty will be advanced, there will be a direct increase in income of farmers. The onset of puberty/ sexual maturity is an important determinant for reproductive efficiency in farm animals**.**

Puberty is the stage at which animal becomes cyclic and secondary sex characteristics become conspicuous. The term sexual maturity means that the animal is capable of reproduction. In others words, puberty is the age at which the first estrus occurs in the heifer and maturity is the age at which she attains desire and ability to mate, the capacity to conceive and to nourish the embryo, complete gestation period and finally power to expel a normal fetus. Zebu heifers attain puberty earlier-around two years of age at about 250 kg body weight. Puberty occurs much earlier in crossbred cows at around 15–18 months of age. In organized farms of defined breeds of buffaloes, first signs of estrus occur at 24–36 months of age and nearly 280 kg body weight. In non-descript buffaloes, the first estrus appears at a comparatively higher age. It should be noted that age of puberty/ sexual maturity within the breed is more a function of growth than that of age. Hence breeding, feeding and management should be directed towards attaining faster growth. Recently many nutritional and hormonal interventions have been approached to advance sexual maturity in farm animals.

a) Nutritional intervention to advance sexual maturity

Most of workers agreed that age at first estrus in dairy heifers was decreased through improved feeding management during pre pubertal period. Bortone *et al*., (1994) reported that heifers fed energy 115% of NRC had lower age at puberty than of those fed ME 100% of NRC. Reduction in age at puberty was also reported though rich energy concentrates supplements. In a study in Nili-Ravi buffalo heifers, Chaudhary *et al*., (1988) fed green fodder only and fodder plusconcentrate at rate of 1% of body weight in two groupsof buffalo heifers. They found that age at puberty wasreduced by 8 months in heifers fed fodder plusconcentrate than those fed fodder only. Theconcentrate ration had 15.4% CP and 65% TDN. In a study, Saleem and Rehman (1989) reported that concentrate supplementation to ad lib green fodder reduced age at puberty in Sahiwal heifers. In this experiment, all animals were fed green fodder ad lib and different proportions of concentrate having CP 14.5% and TDN 68%. They compared the effect of feeding concentrate levels fulfilling nutrient requirements 0, 25% and 50% of total requirements as per recommended by NRC, respectively. Results indicated that concentrate supplementation fulfilling nutrients requirements 25% of NRC recommendations decreased age at puberty by 69 to 84 days. Ionophores are antibiotics produced by a variety of actinomycetes. Feeding ionphores typically increases the efficiency of feed utilization in ruminants. Meinert *et al*., (1992) reported that feeding monensin significantly decreased the age at breeding by 15 and 24 day and age at calving by 36 and 61 days for heavy and light Holstein heifers, respectively. In an earlier study, Mosley *et al*., (1977) reported that 92% of the heifers fed monensin reached puberty compared with only 58% of heifers in control group, with no effect on weight gain. Developing feeding strategies for faster body growth is essential for the onset of puberty at an early age.

b. Hormonal intervention to advance sexual maturity

Age at puberty/sexual maturity can be hastened by using hormones. Recently several hormones have been tried in order to reduce the age at maturity, *viz*., GnRH, bGRF, bST etc. Madgwick *et al*., (2005) administered 120 ng GnRH to heifers between 4-8 weeks of age and observed an early rise in LH secretion and reduction in age at puberty by 6 weeks. He suggested that early rise in LH concentration results in younger age at puberty. Narwaria, (2013) conducted an experiment to determine the effect of supplementary concentrate feeding (20%) and GnRH hormone on age of puberty in 24 Sahiwal Heifers. He administered 4 μg GnRH at monthly interval and reported that age of puberty was advanced by about 2 months in supplemented group as compared to control. Haldar and Prakash (2006) investigated the possible effect of long term administration of growth hormone releasing factor on age at puberty of buffaloes. Exogenous bovine growth hormone releasing factor (bGRF) was administered to buffalo heifer @ 10μg/100 kg BW at an interval of 15 days for 9 months and there was advancement in age of puberty by 2 months. bGRF bring its effect by increasing the rate of body weight gain, plasma concentration of Progesterone and GH. Somatotropin is a hormone produced by the anterior pituitary and is transported by the blood to various body organs where it has its biological effects. It has been extensively used in ruminants for promoting growth and production. Radcliff *et al*., (1997) reported that injection of bST (25 ìg/kg of body weight) in Holstein heifers increased daily body weight gain and weight at puberty by 10%, and 25 kg, respectively and reduced the age at puberty by up to 24 days.

c. Other managemental strategies for optimum heifer management to attain maturity at optimum age

Heifers should be fed good quality green fodders or straws supplemented with concentrates and mineral supplements. Growth and body condition of the heifers must be monitored closely. A growth rate of 500-600 g per day must be ensured. Heifers must be vaccinated regularly. All the heifers should be dewormed against internal parasites at 4-6 month interval. Heifers must be well protected from inclement weather conditions and free access to clean drinking water must be ensured. The floor must be clean, dry and non-slippery. A close eye must be kept on the age of maturity. Optimum breeding weight for smaller (Indian) breeds of cattle can be 225-250 kg and that for larger breeds should be 275-325 kg. The optimum breedable weight in heavy breeds should be reached by 15-18 months and in smaller breeds it should not take more than 22-25 months. An optimum combination of age and body weight should be considered for breeding the heifers. Breeding very young heifers is also not recommended. 15-20% of the average milking herd should be replaced every year.

2. Improvement of estrus detection in dairy animals

Estrus detection is one of the most important factors among many components of reproduction management, as it contributes towards the ultimate pregnancy rate and survival of the embryo (Layek *et al*., 2011). The major critical issue is the time gap between the actual time of onset of estrus and observation of estrus by farmers because there exists a lot of difference between the "animal found in estrus" and "onset of estrus". It is evident that animals are wrongly detected in estrus and inseminated. The wrong time of AI leads to a heavy loss in term of wasteful expenditure of quality male germplasm, production loss and increased risk of introducing genital infection in the female.

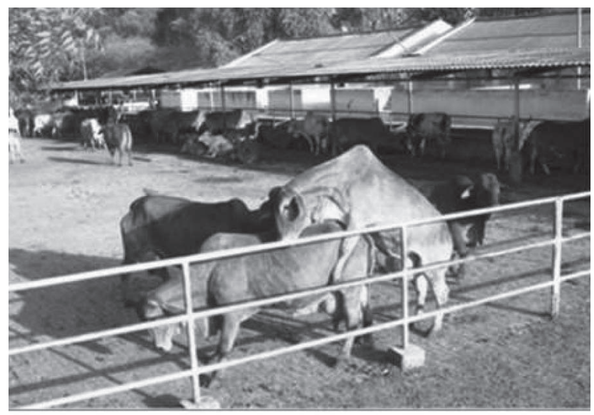
If a farmer missed one estrus, it represents the loss of a complete estrous cycle as well as 21 days production loss i.e. about Rs. 5901 to 7728 per zebu and crossbred dairy cattle, respectively. Accurate and efficient detection of estrus could be helpful for improving both the individual animal as well as overall herd fertility and calving interval.Therefore it is essential for a fermer to understand the primary and secondary signs of estrus to achieve accurate and efficient heat detection. Different methods of estrus detection have been developed starting from the visual appraisal of estrus symptoms to fully automated estrus detection aids.

Visual observations for estrus detection

One of the most common, simple and economical methods of estrus detection for the dairy farmers is visual observation. This method involves visual observation for primary and secondary signs of estrus for 30 to 45 minutes, a minimum of two times (early morning and evening) regularly (Bujarbaruah and Kumaresan, 2013). To achieve better estrus detection efficiency, buffaloes should be watched during early morning and late evening and also night time (Prakash and Mohanty, 2013). Farmer should carefully observe common cardinal signs of estrus exhibited by dairy animals. These are given below

Before estrus

- There will be alteration in vocalization pattern of animals.
- Cows will starts smelling and sniffing other cows.
- Cows will start mounting other fellow cows.
- Vulva will become moist, red and slightly swollen.



During standing heat

- Animal will show stand to be mounted behaviour i.e. if fellow animal mount on estrus animal, she will not move from its place and accepts mounting.
- Animals will bellow frequently
- Animal will become nervous and excitable.
- Mounting behaviour will be displayed.
- Animal will become off-fed and there will be decrease in milk production.
- Vulva will be moist and red.
- There will be discharge of clear transparent mucus.
- Eye pupil will be dilated.

After heat

- Animal will not stand when mounted by fellow animals.
- Met-estrus bleeding may appear in cow.

The animals should be observed for estrus two to three times daily for 30 minute period. Detection should be preferably done during quite times of the day. In winter, most estrus should be checked during warmer part of the day while in summer, most estrus checking should be performed during cooler part of the day. Provision of shaded areas in summer months and protection from winds in winter months can improve the efficiency of estrus detection. Good flooring could improve the estrus detection efficiency. Kachcha floor has been proved better than concrete floor.

Record

History of the animals should be made available for making visual detection of estrus more effective. Records will help observer to pay more attention to the animals expected in estrus.

Practices to achieve high conception rate

For best fertility rate with AI, cattle should be inseminated during mid to last half of standing estrus. The A.M. - P.M. rule has been developed as a guide. As per this rule, Cows that have come into estrus in the morning (A.M.) should be inseminated in afternoon (P.M.) and those who have come into estrus in the evening should be bred next morning. In village conditions, generally, the animals are brought to the Veterinary Hospital or AI Centre from a distance. Inseminating these animals immediately after arrival, or taking back the animals immediately after insemination is not desirable. The adrenaline and cortisol levels would increase in these animals, leading to altered LH surge and thereby ultimately decreasing the chances of conception. Thus all animals brought for AI should be given rest for 10-15 minutes before performing AI. Handling of semen right from the storage containers to loading of the gun should be done by qualified veterinarian / trained persons. While doing AI at doorstep of farmer, it is advisable to carry the semen in liquid nitrogen container and thawing should be done at doorstep of farmer and insemination should be carried out within two minutes after thawing. Cattle should be fed with a well balanced diet with energy, protein, minerals and vitamin supplements. This helps in increased conception rate, healthy pregnancy, safe parturition, low incidence of infections and a healthy calf.

3. Management of reproductive disorders

One of the major causes for reduced life time milk production by an individual dairy animal is transient loss of fertility or infertility. Major factors responsible for infertility condition in dairy animals include nutritional deficiency, diseases, hormonal imbalance, environmental changes, herediatary and congenital factors etc. Post partum infections accounts for around 30 per cent of infertility conditions. Anestrous and repeat breeding in bovines are 2 of the most serious reproductive problems affecting 30-40% of the total cattle and buffalo population followed by uterine infection. On a conservative estimate, the country is losing 20-30 million tones of milk annually on account of anestrus and repeat breeding in cattle and buffaloes which translates to a loss of nearly Rs. 40-50000 crores annually. Effective prevention of these 2 conditions could prevent major economic loss and aid in doubling the income of farmers.

Post-partum Anestrus

Post partum anestrus is most common disorder in dairy herds in which estrus is not observed in cow by 60 days post partum. It leads to increase in days open, services per conception and calving interval and hence decrease in fertility resulting in major economic loss to farmers. Major factors responsible for post partum anestrus are nutritional deficiency, lactation stress, periparturient diseases etc. Management play a very important role for prevention of post partum anestrus in dairy cows. Nutritional intervention during prepartum and postpartum period is one of the major inputs to prevent post partum anestrus. Balance ration should be provided to animal's througout pregnancy especially during last trimerster of pregnancy. Prepartum and postpartum dry matter intake should be optimum. Energy intake should be maintained to minimize negative energy balance. Proper mineral mixture supplement should be provided. All animals should be provided 50—60 gm mineral mixture daily. Green fodder should be provided to animals through out the year.

Repeat breeding

Repeat breeding is one of the most frustrating reproductive problems at field conditions. Two main causes of repeat breeding are failure of fertilization and early embryonic death. It is a multifactorial disease. Identification of cause of repeat breeder animal and appropriate treatment is best strategy for management of repeat breeding. One of the major causes of repeat breeding is ovulation abnormalities. Abnormalities in ovulation include delayed ovulation and anovulation. They can be treated by administration of hCG or GnRH on day of estrus. Another major cause of repeat breeding is sub clinical uterine infection in which there may not be any visible abnormalities in discharge except occassional whitish flakes. It could be managed by administering antibiotics, antiseptic, hormones etc. Luteal insufficiency also results in repeat breeding to a large extent. It could be managed by administration of GnRH or hCG at 2-3 days after insemination.

Strategies for Health Management of Dairy Animal

*Establishment of disease resistant herd:*Effective vaccination is most critical aspect of health management. It is the most promising way to control several diseases. All dairy animals should be vaccinated at regular schedule with good quality vaccines. Cold chain should be effectively maintained. There should be development of new generation vaccines. There should be selection of those breed and animals which are well suited for local environment and farming system. Herd size and stocking rate should be determined based on management skills, local conditions and availability of land, infrastructure, feeds and other inputs.

Prevention of entry of disease:Animals of known health status should only be purchased. Strict quarantine measures should be followed.There should be a limited access of people and wild life to farm. Clean milk production practices should be promoted.

*Effective herd health management programme :*There should be an identification system developed that allows all animals to be identified individually from birth to death. There should be a regular checking of animals for signs of diseases. There should be proper diagnostic facilities available at field level. Sick animals should be attended quickly and appropriately. All sick animals should be isolated from healthy herd. There should be a proper maintenance of all the records of treated animals. Zoonotic diseases should be managed effectively. There should be launching of systematic disease control and eradication programmes for OIE listed diseases along with effective disease surveillance.

Apart from these strategies, major emphasis should be put on control of mastitis.

Mastitis management: Mastitis has been recognized as one of the most complex andeconomically important disease of cow particularly high yielding cross bred cows (De and Mukherjee, 2009). The estimated loss due to mastitis in India is about Rupees 16000 million per annum which is mainly due to lowered milk production, poor quality of milk, culling of infected cows, drugs and veterinary cost. Sub clinical mastitis is more important as it is 15—40 times more prevalent than the clinical form. Under health management strategies, control of mastitis is most important. If incidence of mastitis could be reduced, income of farmers will be increased to a large extent.

Following goals should be targeted under mastitits management programme: There should not be more than 10% of cows and 5% of quarters infected at any particular time., There should not be more than 0.5% of herd milk discarded due to clinical mastitis., There should not be culling of more than 3% of animals due to mastitis per year in a herd.,Bulk tank milk somatic cell count should be less than 200,000 cells/ml., Bulk tank milk standard plate count (SPC) should be less than 10,000/ml.

Mastitis control strategies

Effective and economic mastitis control programme will rely more on prevention rather than treatment. Basic prevention is good control of herd environment and hygienic milking. Following control strategies should be implemented for effective prevention of mastitis in dairy animals., Properly designed and bedded free stalls should be provided to all animals., Adaptation of dry cow therapy should be done., All cows should be supplemented with Se and Vitamin E during dry period., Adequete energy intake after calving should be facilitated., Udder health status of cows and heifers before introducing into herd should be assessed., Animals suffering from clinical mastitis should be handled separately., Culling strategies should be adopted and mastitis resistant animals should be bred., There should be proper cleaning of udder and teats before milking. Paper towels or reusable cloth towels should be used for cleaning and drying of teat., There should be application of post milking teat disinfectants. Teats should be dipped in antiseptic solution for 30 seconds after every milking. Animal should be kept standing for about half an hour post milking so as to prevent the passage of microbes from the surrounding through open teat canal.

Transfer of Technology to End Users

In spite of lot of advancement in research and development of several technologies, lacunas exist in our system like absence of channels to disseminate technology to the farmers. Presently transfer of improved technologies is not occuring by and large, neither at farmer's door nor at organized farms. Following strategies should be implemented in order to transfer the technology to rural farmers. This could be perhaps most important strategy for doubling the farmers income.There should be proper provision of education and training to farmers in the fields of animal health management, feeding, breeding, economics of dairy farming and dairy processing. There should be demonstration of new technologies on farmers' fields and they should be assessed through field trials. More number of farmers meets should be organized in the country for effective transfer of informations and technologies. They should be financed by state/SAUs/ ICAR/Central govt. ICT-based livestock/dairy extension should be promoted which could bring incredible opportunities and has the potential of enabling the empowerment of farming communities. Information technology can support disease monitoring and prevention. Skill oriented training should be regularly arranged for paravets. There should be provision of timely supply of inputs such as liquid nitrogen, frozen semen, vaccines, first aid kit, feed concentrates, mineral mixture and forage seeds to the paravets for onward supply to dairy farmers, through local Dairy Federation or NGO engaged in livestock husbandry. Regular monitoring of the services of paravets is required, to maintain high technical standards. There should be proper. Consultation with farmers before framing of policies should be done. There should be more emphasis on technology assessment and refinement through farmer- participatory mode to internalise the adoption process at micro-farming system level. More attention and funds should be provided by government to ground level institutes like KVK which could play critical role in transfer of technology from lab to land.

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Dynamics of Management of Rice for Doubling Farmers' Income

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Rice (*Oryza sativa* L.) is one of the most widely cultivated (118 countries) crop in the world. Rice rank second to wheat in terms of area harvested but in terms of importance as a food crop rice provides more calories per hectare than any other cereal crop (De Dutta 1981). It is a staple food for about 50% of the world's population. World paddy production is 741 million tonnes from 162.7 million hectares area and its productivity is 4.55 t/ha (Anon. 2017). Asia is considered as 'Rice bowl' of the world, occupying 90% of world's rice area (143.5 mha) contributing 90% of the global production (667 mt) with a productivity of 4.6 t/ha. In India, rice occupies one-quarter of the total cropped area, contributes about 40 to 43 per cent of total food grain production and continues to play a vital role in the national food and livelihood security system. In India rice is grown in an area of 43.8 million hectares with a production of 157.2 million tonnes with productivity of 3.58 t/ha (Anon., 2017). Country's rice productivity is less in comparision to Asia and World. The main reason for low productivity of rice is that it is grown under various production ecologies mainly grouped as irrigated (58%) and rainfed (42%) systems. While former is considered most favourable, rainfed system has again a wide range of subsystems like shallow, mid and deep water rainfed lowlands and rainfed uplands. But it has to face several hindrances like, moisture stress due to erratic and inadequate rainfall, continuous use of traditional varieties due to the non-availability of seeds and farmers lack of awareness about high yielding varieties (upland, rainfed lowland and deep water areas), low and imbalanced use of fertilizers, heavy infestation of weeds and insects/pests, poor crop plant population in case of broadcast sowing method resulting in uneven germination (upland and direct seeded lowlands). Delay in monsoon often results in delayed and prolong transplanting and sub-optimum plant population and poor adoption of improved crop production technology. Moreover rice production will come under additional pressure from intense competition for land, labour and water, a more difficult growing environment because of climate change, higher price for energy and fertilizers. The challenges include quality considerations and problems related to soil health. To increase rice famer's income above mentioned problems needs to be resolved. This can be discussed in relation to technological issues, managemental issues and policies related issues.

Technological Approaches to Increase Farmers' Income

Raising the Yield Ceiling:The yield level set by high yielding semi dwarf varieties of green revolution era needs to increase particularly under high productive environment. These could be feasible by using the concepts of hybrid rice, New Plant Type, multiple resistant varieties, region specific variety and transgenic rice.

a. *Hybrid Rice*: Hybrid rice is a practically feasible and readily adaptable genetic option to increase the rice production. By exploiting the phenomenon of hybrid vigor (Cantrell and Hettel 2004), hybrid rice varieties yield about 1-1.5 tons per hectare higher (15-20%) than the best semi dwarf inbred varieties. This technology has already demonstrated great poten-

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tial to increase rice production in China, where 15 million hectares (50% of the total rice area) are planted to hybrid rice varieties (Virmani *et al* 2003). More than 75 rice hybrids have been released in India and hybrid rice cultivation is about 2 million hectare during 2015. This technology clearly helps rice farmers to increase their yields, productivity, and profitability by using less land and water and enables them to opt for crop diversification to increase their income. An associated seed production technology has helped to develop a seed industry, which in turn has contributed to increased rural employment opportunities.

b. *New Plant Type rice (NPT)*: NPTs will have a major part to play in breaking the yield barrier. The NPTs have many properties mechanical strength to support higher yields and high leaf nitrogen content for building higher grain yield. NPT lines have higher total biomass and the harvest index, with 20% more yield over the current modern varieties. NPT based hybrid will further improve rice yield. This kind of technologies helps to improve rice productivity and profitability of rice farmers in general and farmers of high productivity environments in particular.

c. *Region specific varieties*: Recommendation of crop cultivars with wide adaptability is essential for countries with diverse environments or agroecological regions and seasons. Superior yielding varieties are available (Chaudhary, 1996), which can take farmers' yield to 8.0 t/ha if grown properly. Therefore needs to identify and release stable yielding varieties even on a specific area basis, including rainfed ecologies.

d. *Multiple resistant varieties using molecular breeding*: Marker assisted selection is successfully implemented in resistance breeding in rice. Many rice varieties *viz.,* PR 106, Improved Pusa basmati 1, Improved Sambha masuri, Pusa 1592, Panjab Basmati 3 etc. resistant to bacterial blight developed through MAS in India. Efforts are on to improve complex traits like drought and yield using molecular breeding. Drought and yield Qtls are transferred from wild to cultivated species using MAS. Molecular breeding helps in pyramiding genes for resistance in cultivated lines. Efforts are on to pyramid genes for gall midge, BPH, blast, BLB resistance in rice. It is easier to develop multiple resistant varieties through MAS. Varieties provide multiple resistance resulted in assurance of production helps farmers to invest more.

e. *Transgenic rice*: Golden rice was developed to alleviate malnutrition and vitamin A deficiency by enriching rice with beta-carotene, which when consumed is converted to Vitamin-A. Golden rice will provide nutritional security also provide better price for produce. Like this biofortified varieties rich in Fe, Zn developed recently e.g. GNR4 will get more price. Similarly efforts are on to develop C4 rice, drought tolerant rice, insect pest resistance. Success in these efforts will raise production potential.

Agronomic Manipulation

Other than using genetic means of raising yield ceiling, avenues of agronomic manipulation need to be explored. Bangladesh is becoming a self sufficient country, with stable yield, by using Boro rice, instead of deepwater rice. In our country 42% of rice area is still rainfed. Increase in rice area under irrigation and/or increase in summer/boro rice cultivation would improve rice production and productivity. Other agronomical manipulation discussed under following sub-heads.

a. *Cropping system approach rather than single crop* developments: Rice based cropping system is a major cropping system in India. Rotation of crops involving rice, pulses, oil seeds, sugarcane, vegetables etc. Depending on local needs. Various rice based cropping systems *viz.,* rice-wheat, rice-rice, rice-pulses, rice-oilseeds, rice-vegetables, rice-fibre crops etc. be adopted. Rice-vegetable is a profitable sequential cropping system followed under protective irrigation. Based on local market demand vegetables like okra, cluster beans, chillies, brinjal, amaranthus, raddish, sweet potato, etc needs to cultivate for higher return. Early maturing rice hybrids/varieties followed by Okra in *Rabi* (off) season in Vyara and Dolvan talukas of Tapi district in Gujarat state provide very high price (more than three times) for okra produce. This type of cropping sequence significantly improve livelihood of recourse poor tribal farmers in this region.

b. *Land Leveling*: Laser aided precision leveling~ herbicide based minimum tillage~ dry shallow tillage prior to puddling~ shallow tillage soon after harvest to incorporate crop residues and improve soil N supply and better water management resulted in good crop growth and yield, with decrease in water requirement.

c. *Crop Establishment*: Rice cultivation in India classified in four broad ecosystems, *viz*., irrigated, rainfed lowland, upland and flood prone. Depending upon the ecosystem, the crop undergoes different methods of establishment within each ecosystem. The irrigated ecosystem, the predominant ecosystem, cultivated in about 25 M ha is patronized with many methods of stand establishments. Conventional transplanting, planting using rice transplanter planting and System of Rice Intensification (SRI) for precision farming, are different crop establishment methods used in our country. Similarly Savant's Integrated Rice Agrotechnology (SIRA) for rainfed ecology showed promising results. Direct seeding and seed cum fertilizer drill are method used in upland ecology. Cost saving technologies *viz*., aerobic rice and drum seeder are technologies to conserve resources, timely operation and reduce women drudgery involved in rice planting.

d. *Integrated nutrient management*: In addition to chemical fertilizer, needs to use organic manure, biological nitrogen fixation, to reduce cost of nutrients supply and improve soil health. Soil test based fertilizer application, field specific fertilizer recommendation. Nitrogen being the major nutrient and in demand, it is applied in every crop season. Thus, efforts in improving the N use efficiency will save quantity and cost, and reduce the cost of rice production. Rice suffers from a mismatch of its N demand and N supplied as fertilizer, resulting in a 50 to 70 per cent loss of applied N fertilizer. N is lost due to denitrification, ammonia volatilization, leaching and runoff. Real time N management with chlorophyll meter and leaf color chart~ deep placement of urea briquette~ coated controlled release urea reduce cost of fertilizer and thereby reduce cost of cultivation.Use of biofertilizer such as Blue-greed algae, Azolla, Azosprillum and Azotobacter for supply of nitrogen to crop and Phosphorous solubilizing bacteria for solublizing non-available Phosphorous to available form easy uptake by crop plants are cost reduction and biological means of nutrient application.

e. *Irrigation*: Total irrigated area in the country, including that in *Rabi*/boro season is about 25 million ha (58%) contributed 78% of production (Viraktamath *et al.,* 2011) .whereas 42% of rainfed area contributed only 24%. So adequate water supply is one of the most important factors in rice production. For improving production and productivity more area should beunder assured irrigation. Development of on farm water reservoirs for water harvesting, selection of drought tolerant varieties, land leveling, subsoil compaction, and need based irrigation scheduling may play a major role in increasing water use efficiency and improve production and productivity. Alternate wetting & irrigation as well as SRI reduces water requirements about 25 - 50%.

f. *Integrated Weed Management (IWM)* : Weeds were reported to reduce rice yields by 12 to 98%, depending on method of rice establishment. Rice yield losses due to uncontrolled weed growth and weed competition were least (12%) in transplanted rice (Singh *et al*., 2011) and highest in aerobic direct seeded rice on a furrow-irrigated raised-bed systems (Singh *et al*., 2008) and in dry-seeded rice sown without tillage (Singh *et al*., 2011). The concept of IWM is not new. For example, the traditional practice of puddling soil to kill existing weeds and aid water retention, transplanting rice seedlings into standing water to achieve an optimum stand density, and maintaining standing water to suppress weeds, followed by one or several periods of manual weeding, is a well established example of integrated weed management (IWM) (Rao *et al*., 2007). Effective IWM combines preventive, cultural, mechanical and biological weed control methods in an effective, economical and ecological manner.

g. *Integrated Pest Management (IPM)*: Promoting the integrated pest management approach for control of pest and diseases by emphasizing need based application of pesticides; replacement of old pest susceptible/ low yielding old varieties with improved high yielding pest tolerant varieties/hybrids; no early spraying against leaf folders and thrips~ Pheromone traps for yellow stem borer~ active barrier system for rat control~ silica application for blast control~ timely and judicious use of bio and/or chemical pesticides, not only reduces cost but increase yield too.

Management Aspects

For doubling the rice farmers' income require efficient management of resources. Rice cultivation in main field with high value tree plantation like teak wood on bunds or pulse crop like pigeon pea provides additional income. Animal husbandry in addition to rice cultivation consumes by products like paddy straw and provides income in the form of milk or selling of animals. Also provides by products in the form of manure. Manure not only supply nutrient to improve fertility of soil in turn better rice growth and yield. Fish rearing in rice field also provide additional income. Other management aspects are discussed as follows

Minimize Post Harvest Losses: About 20 to 25 per cent of the harvested rice is lost before it reaches the consumers' table. The postharvest losses in both quantity and quality lead to substantial profit gaps among farmers. Improved processing, storage, and direct marketing will help farmers to increase their profits. Effective farmer organizations such as cooperatives can assist farmers in postharvest processing and marketing. For better grain quality and higher head rice yield, production and postproduction practices have to be improved. Harvesting, threshing, cleaning, drying, and parboiling/drying are labour intensive. These operations must be carried out at the right time to minimize losses and to ensure good grain quality resulted in higher price to farmers for their produce and consumer gets products at lower rate.

Utilization of Byproducts: Rice byproducts *viz.*, rice straw, rice hull, and rice bran provide additional income to farmers and/or traders. Utilization of rice hull in rice hull stove, rice hull briquette~ rice hull ash and cement for hollow blocks~ rice hull mulch for cut flower gardens and mushroom culture. Rice straw for animal fodder with urea treatment. It can also be used for various industrial uses in packaging, mixing in soil for soil health. Rice bran for oil extraction is more rewarding.

Value added quality products: Value addition also enhances the profitability of rice production. Value-added products from organic rice and therapeutic value medicinal rice, basmati varieties have good niche in domestic and export markets. A wide range of product development like processed and canned, ready-to-eat products, vitamin, iron or calcium enriched flaked or puffed rice, flavoured rice, starch extraction from broken rice are nowadays getting popular.

Policy Support to Increase Production

Government policies provide the environment to benefit from research investment, improve productivity, alleviate poverty, ensure systems' sustainability, protect the environment, and provide food security. It is therefore imperative that through appropriate policies, socioeconomic adjustments should be effected in terms of input output pricing, institutional support, and to readress the needs of rice farmers in order to complement the technological gains.

Irrigation Facilities: More area should be brought under assured irrigation as 42% rice cultivation is still rainfed. More dams and canals needs to construct to improve irrigation facilities. River linkage also helps in this aspect. Watershed development programme must be rejuvenated and it should be strengthened. Watershed development programme should be under one department. Define the role of agriculturist in irrigation canal water distribution network and by strengthening it the efficiency of water distribution can be increased. Community based farm pond should be encouraged. The desilting of farm ponds/dams should be covered in the schemes like MNREGA.

Crop Loans: Crop Loans are also called short term loans for "Seasonal Agricultural Operations." The Seasonal Agricultural Operations includes, ploughing and preparing land for sowing, weeding, transplantation, acquiring and applying inputs such as seeds, fertilizers, insecticides etc. and labour for all operations in the field for raising and harvesting the crops. Crop loans are generally disbursed by the banks through the mode of Kisan Credit Card (KCC). The Kisan Credit Card Scheme is in operation throughout the country and is implemented by Commercial Banks, Cooperative Banks and RRBs. All farmers including small farmers, marginal farmers, share croppers, oral lessees and tenant farmers are eligible for KCC. In addition to crop loan, subsidy needs to provide to small and marginal farmers of rainfed ecology growing their crop under unpredictable environment.

Soil Health Profile: Soil profile needs to prepare for group of villages or Tehshil bases and government policy should be framed in consideration with soil profile. Similarly soil health card must be prepared for each and every farm land so that site specific nutrient management is possible. Similarly government support/policy should be prepared for reclamation of saline and alkaline soil.

Input Availability: Fertilizers, especially nitrogen, play an important role in rice production and productivity. Farmers need adequate amounts of fertilizer at the right time for obtaining high yields in rice cultivation. The supply of fertilizers needs to be decentralized to village markets and the quality of fertilizers should be assured. Small farmers are usually unable to buy sufficient quantity on time for application. Hence, the provision of village credit could greatly help them. Cooperative society in Gujarat is good example in this. Member farmer gets inputs like seeds, fertilizer and pesticides etc. on credit from cooperative society run at village level by farmers. Farmers sell their produce to cooperative and get good price for their produce (much more than minimum support price).

Quality Seed: Use of quality seed is the first and foremost way of realizing the yield potential of the recommended technology. High quality pure seed ensures proper germination, crop stands, freedom from weeds and seed borne pests and diseases. It is recognized in general, that quality seed ensures 10 to 15 per cent higher yields under the same set of crop management practices. In the case of superior quality rice, it even ensures higher price and profit. Unfortunately, sufficient quantities of certified seed are not available from all the seed sources put together. As a result large area is cultivated using farmers' own seed. While the private seed producers need to be encouraged to produce more seed of the released varieties and hybrids, governments have to come up with proper legislation where the seed industry can prosper.

Bridging Knowledge Gaps between Researchers, Extension Staff and Farmers

The support of research and extension can ensure the effective bridging of yield gap of rice. Farmers' adoption of improved technologies depends on the capability of national agricultural research centres and extension services, which need more government resource allocation and training. The research scientists should understand well the farmers' constraints to high rice productivity and provide them with appropriate technological packages for specific locations. In this Government of Gujarat policies provide good example as discussed below.

a. *Krushi Mahotsav*: Krushi Mahotsav is introduced in the Gujarat state by the State Government since 2005 as an innovative approach in agriculture. Krishi Mohatsav is a unique way to promote scientific and sustainable method of crop production and development of agriculture and allied sector among farmers, it leads to state's agricultural prosperity as well as better socio economic condition of the farmers. Guidance is provided to farmers of all villages of the state through different activities during Krushi mahotsav. The animal vaccination camp and artificial insemination activities are carried out during the Krushi mahotsav. Agriculture scientists and officers have provided guidance to farmers about scientific farming, organic farming, farm mechanization; micro irrigation, crop value addition and agriculture related information as well as provided knowledge of Government schemes (Anon., 2015). In additions to this, free kits are distributed to small farmer during Krushi Mahotsav. This kind of innovative approach needs to be carried out at national level to solve farmers problems and speedy extension of new technologies.

b. *Strengthen Extension activities*: Multiple agencies in the field of extension education services at Tehshil level should be synchronized. ATMA scheme should be restructured like earlier T and V system where permanent manpower deployed with infrastructure facility at Tehshil and District level and their sitting arrangement should be made available at Tehshil place. One extension worker should be made available per 500 farmer families. Sufficient technical manpower should be provided for all agricultural units. Crop specific extension services should be encouraged. District level / State level / National level / international level training should be arranged for knowledge updating of manpower. The services of agriculture graduate and veterinary doctor should be made available for a cluster of Ten (10) villages.

Technology must be used to Implement Government Schemes: Technology helps in speedy, fair implementation of government schemes. In this,online I-Khedut portal developed for farmers, was started by Agricultural Department, Government of Gujarat. It has the following salient features.

- It will be used for transfer of technology through ‘apps’ FAQs etc. on rice for android mobiles
- Online Application to get benefits of various agriculture related schemes.
- Detailed list of dealers providing equipments related to agriculture.
- Information of Banks/Organizations providing agricultural credit.
- Latest technical information related to agriculture.
- Various APMC market price of agricultural commodities.
- Solutions related to problems in agriculture.
- Details of agricultural land.
- More than 15, 33,022 farmers are registered on this and take benefit of various government schemes (Anon., 2015).

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New Paradigms in Pulses Production for Enhancing Farmers' Income

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Food legumes play an important and diverse role in the farming systems and in the diets of poor people around the world. They are ideal crops for simultaneously achieving three developmental goals in targeted population—reducing poverty, improving human health and nutrition, and enhancing ecosystem resilience. Indian agriculture, is in a way, a victim of its own past success especially the green revolution. It has become cereal-centric and as a result, regionally-biased and input-intensive (land, water, and fertilizer). Rapid industrialization and climate change are raising the scarcity value of land and water, respectively. Evolving dietary patterns are favoring greater protein consumption. To adapt to these changes, agriculture requires a new paradigm shifts for increasing pulses production. Approximately 80 per cent of the atmosphere is nitrogen gas (N_2). Unfortunately, N_2 is unusable by most living organisms. Plants, animals and microorganisms can die of nitrogen deficiency, surrounded by N_2 they cannot use. All organisms use the ammonia (NH_3) form of nitrogen to manufacture amino acids, proteins, nucleic acids and other nitrogen-containing components necessary for life. Biological nitrogen fixation is the process that changes inert N_2 to biologically useful NH_3. This process is mediated in nature only by bacteria. Other plants benefit from nitrogen-fixing bacteria when the bacteria die and release nitrogen to the environment or when the bacteria live in close association with the plant. In pulses and a few other plants, the bacteria live in small growths on the roots called nodules. Within these nodules, nitrogen fixation is done by the bacteria, and the NH_3 produced is absorbed by the plant. Nitrogen fixation by legumes is a partnership between a bacterium and a plant.

Pulses are important food crops due to their high protein and essential amino acid content. The seeds of pulse crops are typically made up of 20-25% protein compared to 6-10% protein content in major cereal crops. Pulses are also rich in dietary fiber and usually have only small amounts of oil. The protein of pulse seeds is high in the amino acids lysine and methionine, making pulses nutritionally complementary to cereals, which are deficient in these two essential amino acids. Pulses are the main source of protein in the diet of vegetarians, and feature prominently in the traditional cuisine of virtually every region of the globe. Moreover, in recent years there has been a change in the consumption of pulses in several developed countries where they are increasingly considered as health foods. India happens to be the major producer and consumer of pulses, which is one of the major sources of protein for the population. India has low yields comparable to most countries. Some states do much better than the all-India average, but even the key pulse producing state of Madhya Pradesh has yields (938 kg/ha) barely three-fifths that of China's (1550 kg/ha). These comparisons are based on the basket of pulses grown in each country. If we compare yields of just tur (or pigeon peas) across countries, the qualitative picture is no different. Given that India is the major producer and consumer of pulses, imports cannot be the main source for meeting domestic demand. Therefore, policy must incentivize movement of resources towards production of pulses.

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Pulses are the second most important group of crops after cereals. The global pulses production was 61.5 million tons from an area of 70.6 million ha with an average yield of 871 kg/ha. Dry beans contributed about 32% to global pulses production followed by dry peas (17%), chickpea (15.9%), broad beans (7.5%), lentils (5.7%), cowpeas (6%) and pigeon pea (4.0%). Developing countries contribute about 74% to the global pulses production and the remaining comes from developed countries. India, China, Brazil, Canada, Myanmar and Australia are the major pulse producing countries with relative share of 25%, 10%, 5%, 5% and 4%, respectively. Countries recording annual production growth of more than 4% are Myanmar (11.48%), Canada (10.80%), Germany (8.27%), Sudan (8.08%), Spain (7.37%), Ethiopia (4.92%), China (4.67%) and Syria (4.12%) (FAOSTAT, 2011)

With dramatic changes in global agricultural scenario on account of implementation of WTO and IPR, the country has to produce not only enough pulses but also remain competitive as the global pulses trade has been registering a 5% annual growth. In order to ensure self sufficiency, the pulse requirement in the country is projected at 32 million tonnes by the year 2030 which necessitates an annual growth rate of 4.2%. This requires a paradigm shift in research, technology generation and dissemination, and commercialization along with capacity building in frontier areas of research.Higher production combined with larger imports has resulted in a marginal increase in pulse consumption estimated at around 50 grams per day in 2012-13 compared to less than 40 grams prior to 2012-13. This level of consumption is estimated to have been maintained in 2013-14. Larger imports of dry peas in recent years due its lower international prices have resulted in its increased share in the domestic pulse consumption.

Enhancement of Potential High Yielding Variety

Early ripening variety: Not only pulse crop but in any crop shorten reproductive period is most desirable character for getting higher yield and lower the risk of biotic and abiotic adversities. Many of our varieties have solved the bottleneck problems like YMV in mung bean but at the same time indeterminate nature or long grain filling period make it exposed to biotic stress like pod sucking bug or extreme high temperature cause poor sinking and ultimately yield losses will be observed.

Situation specific variety/hybrids

- Cultivation of physiologically efficient plant types
- Cultivation of high yielding short duration varieties having multiple and multiracial resistance to diseases
- Cultivation of variety which should be farmers friendly i.e., easy for various operations in standing field.
- A determinate pigeonpea variety would facilitate the operations like spraying, assessment of pest complex due to larger area visibility at a time and further picking of green pods

Resilient pulse crops to climatic adversities

- Cultivation of resilient pulse crop varieties to mitigate the impacts of climate change
- Cultivation of photoperiod insensitive genotypes
- Cultivation of extra early maturing varieties/hybrids
- Cultivation of heat/chilling tolerant varieties.
- Growing such varieties which having wider range of climatic adaptability like suitability for *Kharif* and *Rabi* both season.

Variety suitable for mechanization

Machine harvesting of pulses will reduce production cost and reduce the chances of damage to the crop due to rains, winds, etc. that may occur during the additional period required in manual harvesting. This will become more attractive and remunerating to farmers. Thus, machine harvestable pulses varieties may contribute to enhancing pulses area and production in the country, which is very much needed for reaching country's goal of self-sufficiency in pulse production.

Production and Supply of Quality Seed

The value of good seed has been mentioned in the Vedas "Good Seed on Good Land Yields Abundant Produce"-Manu smrithi.

Seed replacement/ multiplication strategy: Opportunities for increase in crop productivity exist in the form of new varieties of seeds developed for recording higher yields (Singh *et al*., 2012b). Main issue relating to promotion of quality seeds is the availability of seed of promising varieties to the farmers in adequate quantities and in time. Use of good quality/certified seed in pulses has generally been low. Seed replacement Rate (SRR) estimated for the year 2006-07 was only 10.41% and now raising SRR of pulses to 22.5% by the year 2010-11(Anonymous, 2013)., so increase in SSR will benefited to farmers. Seed multiplication rates in pulses are low and unstable. Seasonal and regional variations both in quality and productivity of seed are not uncommon. There is a considerable scope for raising SMR on a sustainable basis. Identification of regions climatically suitable for seed production of various pulses crops is necessary not only for improving yield but also off-season production of seed.

Seed bank/hubs: To make India self-sufficient in pulses production, availability of quality seed is one of the most crucial factors which ensures enhanced per unit yield of pulses in farmers' fields. For augmenting the availability of quality seeds of pulses, the Department of Agriculture, Cooperation and Farmers' Welfare, Government of India, has created seed hubs in various zones for increasing indigenous production of pulses in India"

Genetic purity of Seed: Human resource development programmes for maintenance of genetic purity, seed production procedures, safe storage and seed testing with minimum parameters of quality seed must be launched to ensure quality seed supply of pulses locally.

Seed conditioning/Seed enhancement: Seed quality or seed enhancement refers to various technologies used to increase the consistency in performance of the seed with respect to its vigour, leading to improved crop yield and quality of produce. In recent times with the availability of scientific information of various physiological aspects of the seeds and seed enhancement technologies in ensuring better protection against diseases and insect pests at seed or seeding stage, improve seed vigour and modify seed emergence capabilities, it has become easier to enhance seed quality before its sowing to ensure higher yield with better quality produce. We all are aware of the pulses seed treatment with recommended fungicides and insecticides besides inoculation with rhizobium or PSB culture. Some of the other technologies becoming popular are listed below.

Seed coating: The application of materials on the seed surface to minimize diseases and insect pest incidence is mainly related to seed coating. The chemicals or bio-agents such as fungicides, insecticides, *Trichoderma* etc. are normally used for seeds coating of seeds of pulse crops. In developed countries film coating, in which the active ingredient is applied in a quick-drying polymer film around the seed, has gained popularity. A major advantage of film coating of the seed is that it ensures reduced loss of active material from the seed during seed transport and handling. This can be of value for rajmash and soybean seed in India, where losses in germination has been observed during transportation.

Seed pelleting: The technology is used to alter the seed surface properties to enable more precise seed singulation during sowing through seed drills and placement in the soil through other means. This helps in ensuring proper plant populations and avoids clustering of seedlings. Seed pelleting can also be used to deliver a range of beneficial additives like micro-organisms, micronutrients and plant protection agents e.g. *Trichoderma* for pulses seeds. This technology can be of immense value for the crops like mungbean, urdbean, mothbean, clusterbean, cowpea, lentil, etc.

Seed priming: Seed priming is being used to enhance germination at fast rate and overcome seed dormancy. In seed priming, seeds are hydrated in a controlled manner to provide enough water to initiate the physiological processes of germination (imbibitions), but not enough to allow germination. After soaking of the seeds in desired or recommended solution these are allowed to dry and sowing is done in usual way. These primed seed ensure rapid and uniform germination from the soil compared to non-primed seed of the same seed lot. These differences are greatest under receding soil moisture or poor moisture retentive soils. Seed priming can be of utmost importance in lentil or chickpea when sowing is to be done as utera/paira or under late sown conditions as zero tillage. Even under late sown condition, primed seeds of chickpea and lentil help in good growth and development of biomass.

Pulses Based Cropping System in New Niches

As per Agricultural Statistics at a Glance 2009, the total geographical area of India is 3287.3 lakh ha. Out of this, 1403 lakh ha is net sown area (42.67 %). The net irrigated area is 608.6 lakh ha, which is 43.37% of the net sown area. States with alluvial, sandy, sandy loam and black soils and irrigation facilities, cultivate 2-3 crops in a year, which is deteriorating the soil health and therefore, incorporation of pulse crops in crop rotations is required for restoration of soil health. Pulse crops are grown as sole crop, intercrop, mixed crop, catch crop, relay crop and utera crop, depending upon the agro climatic conditions of the place where they are cultivated.

Utilization of potential area of rice fallow lands: The area left un-cropped after *Kharif* rice is estimated to be around 11.65 million ha. The area is primarily rainfed and exists in the states of Bihar, Madhya Pradesh, Chhattisgarh, Orissa, Eastern Uttar Pradesh, West Bengal and Jharkhand. About 25% of this area has potential for supporting a *Rabi* pulses after rice depending on soil type and depth. Thus, the 3 to 4 million ha additional area can be brought under *Rabi* pulses. Assuming an average productivity of 600 kg/ha, the area can produce 1.8 to 2.4 million tons of pulses. Farmers need to be encouraged through various incentives and region specific extension strategy for cultivation of pulses in the identified districts. Necessary technological back up in terms of suitable short-duration varieties, nutrient application rates and other agronomic practices should come from local research stations.

Replacement of low productivity crops with pulses: About 5 lakh ha area of upland rice, 4.5 lakh ha area of millets and 3 lakh ha area under barley, mustard and wheat can be brought under *Kharif/Rabi* pulses. *Kharif* pulses such as pigeonpea, mungbean and urdbean should replace rice and planted on ridges where as *Rabi* pulses such as lentil and chickpea should replace mustard, barley and wheat. If possible, harvested rain-water should be used for *Rabi* crop establishment.

Cultivation of summer mungbean:About 16.5 lakh ha area vacated by wheat, peas, potato, sugarcane and lentil can be used for raising short-duration (60-65 day) *Summer* mungbean crop in the States of Uttar Pradesh, Punjab, Haryana, Bihar, Gujarat and West Bengal where adequate irrigation facilities exist. These states need to identify such areas, set a modest targets for area coverage, and draw up a plan for producing seed and providing other inputs (fertilizer, plant protection, chemicals, gypsum, and power) and disseminate package of practices to farmers through mass media, state extension network and KVKs. Arrangement for procurement of the produce should also be put in place and widely publicized.

Promotion of intercropping for cultivation of pulses: There are a good number of promising intercropping systems for pulses developed by Zonal Agricultural Research Stations. Farmers in rainfed states (Gujarat, Madhya Pradesh, Chhattisgarh, Maharashtra, Karnataka, and Andhra Pradesh) are familiar with some of them as they have been practicing them in traditional ways which ultimately reduce crop risk.

Cultivation of pigeonpea on rice-bunds by transplanting of pigeonpea seedlings: An area of 20-30 thousand ha can be brought under pigeonpea in Chhattisgarh, Madhya Pradesh, Orissa, West Bengal, Gujarat and Jharkhand by utilizing rice-bunds. Farmers of Chhattisgarh traditionally use rice bunds for pigeonpea cultivation.

Promotion of relay cultivation of lentil and Indian bean in rice fields: Relay cultivation is a practice commonly and traditionally followed in tribal regions of Madhya Pradesh, Chhattisgarh, Bihar and Jharkhand can contribute to pulse production ensuring additional income to tribal rice growers. Relay cropping give an additional chance to grow

Intercrop of Chickpea with Sugarcane

Intercrop of Mungbean with Sugarcane

Intercrop of Indianbean *var.*GNIB-21 with Sugarcane

Indian bean on residual moisture in deep black soil without irrigation.

Sustainable Soil Productivity

In situ brown manuring: Incorporating legumes into the cropping system has been shown to significantly improve the nitrogen nutrition of cereal crops. However, little is known about the effect of these legumes on the chemical and physical properties of soil but it assumed to have positive effect on both ways. The pulses are always having property of shedding their leaves in soil which ultimately incorporate organic matter (low C:N ratio). Legume/pulse acts as a catalyst to augment availability of native and fixed P therefore, increased availability of P under pulse inclusive systems. With higher annual input of N and P inorganic recommended fertilization significantly enriched available N and P in the soil, while higher K input through organics maintained higher soil available K. Apparent nutrient balance and correlation (base crop) the apparent nutrient balance is an important parameter which determines sustainability of any system.

Soil cracking and biological inoculums maintenance: All legumes generally enhanced the chemical and physical properties of the cracking clay, long duration pulses such as pigeonpea would have a greater beneficial effect in the longer term. Fallen leaves when dropped into the deep crack, whole profile of soil was improved by biological of physical properties as against cereals.

Land Configuration

Raised bed: Change over from growing crops in flat to ridge-furrow system of planting crops on raised bed alters the crop geometry and land configuration, offers more effective control over irrigation and drainage as well as their impacts on transport and transformations of nutrients, and rainwater management during the monsoon season. In furrow irrigated raised bed (FIRB) system, water moves horizontally from the furrows into the beds (subbing) and is pulled upwards in the bed towards the soil surface by capillarity, evaporation and transpiration, and downwards largely by gravity. In determining the dimensions of the beds, factors such as spacing between tractor tyres, soil types, rainfall and groundwater conditions, salinity and irrigation water quality and requirements of crops grown in rotation are of prime importance. For developing a permanent system of bed planting, factors like irrigation and fertilizer management, crop residue management, inter-tillage and weed management must be considered together. For major soil types (sandy loam to loam soils) and crops (inter-row crop spacing requirement) grown in the IGP, ridge-furrow system, of 67cm width (top width of bed-37cm; and of furrow-30cm) is often considered appropriate.

- Management of irrigation water is improved is simpler, and more efficient. On an average it uses, 30% less water than flat bed methods and improves crop yields by more than 20%. FIRB planting saves 30% to 50% seed compared to flat bed planting.
- Better upland crop production is possible in the wet monsoon because of better drainage. Fertilizer efficiency can be increased because of better placement including top dress applications.
- Weeds between the beds can be controlled mechanically, early in the crop cycle.
- Yield potential is enhanced through improved nutrient-water lodging.
- Compaction of soil is limited only to the furrows used as tramlines (tractor tracks).

Mechanization in Pulses Production

Mechanization in cultivation & sowing: Pulses are grown in different agro climatic regimes and soil conditions can vary. In many soils mechanization is essential to raise productivity. Adoption of deep ploughing, ridge planting, line sowing, inter-culture operations etc besides, mechanization contributes to timeliness of operations, reduces cost of production and improves resource (water, energy and inputs) use efficiency (Singh *et al*., 2014a and Patel *et al*., 2014). The farm implements used for primary tillage are Tractor drawn plough, Blade harrow, Rotavator and sowing is done by seed drill, fertilizer-cum-seed drill and zero till seed drill. Different methods of sowing: Most of the pulse crops like Arhar, Mungbean, Urdbean, Mothbean, Kulthi, Gram, Lentil, Fieldpea, Lathyrus, Rajmash and Cowpeas are sown by line sowing method and some farmers also undertake sowing by broadcasting method.

Considering small holding of the farmers, custom hiring of the machines is the only viable option for increasing the reach of Farm mechanization.

Mechanization in harvesting: *Machine sutiated to present variety*:A number of farm implements are used for attending the work of primary and secondary tillage including post harvest operations .The field is ploughed by cultivators, disc harrow and sowing is done by seed drill, fertilizer-cum-seed drill and zero till seed drill. No machine/equipment has been designed or made for low cost equipment / machine suitable for harvesting of pulses.

Varieties amenable to harvesting by equipment/ machines:Imagine 2.25 tons of chickpea harvested in just 75 minutes! The process (including cutting and threshing) would normally take three days. This is made possible due to the breeding of a taller chickpea variety that can be harvested by standard machinery.

It adds that machine harvesting is better for the health of the laborers, especially women, as handling the crop causes painful dermatitis due to its high acid content.

Low cost Gravity separator:Seed of same size and general shape can often be separated because they differ in specific gravity. This difference is very useful in removing light immature seed or heavy sand and rocks to improve the purity and germination of crop seed.

Timely Availability of Critical Inputs

Moisture regimes

Rainfed areas developed as watersheds: Multiple ministries/departments and agencies have been involved in the growth and development of watersheds with an array of watershed schemes. States can be asked to include pulses as a major crop component for watershed areas. While *Kharif* pulses can be purely rainfed, *Rabi* pulses can be provided supplementary irrigation for sustaining remunerative productivity levels. It should be possible to cover 30-40% of cultivated watershed area under pulses.

Expansion of irrigation using resource conservation technologies:Pulses crops are invariably grown under moisture stress which leads to sub-optimal productivity levels. Scientific scheduling of irrigation, an estimate of quantity of water to be applied and deployment of water saving irrigation methods can lead to enhanced yield, higher water and nutrient use efficiency and larger area coverage under irrigation. Use of sprinkler irrigation has enormous potential for saving irrigation water and expanding area under irrigation. The method has gained popularity in many districts with limited water resources. Drip irrigation and fertigation hold promise for widely spaced crops like pigeonpea. These devices can expand irrigation area by 30-50%.

Pulse farmers of Gujarat normally irrigate the crop at branching, vegetative and pod formation stages. The irrigations are provided using rain gun, ridge and furrow and flood methods. For cultivation of pulses, very less irrigations are required than other crops and therefore, even in very adverse conditions, pulse crops give better yields.

Nutrient regimes: Nitrogen requirement of pulses is much higher than that of cereals. However, most of the requirement is met through biological N-fixation. It is, therefore important that farmers are encouraged to adopt agronomic practices that facilitate N-fixation. These include seed treatment with crop specific rhizobium strain, integrated nutrient management, ridge-planting of *Kharif* (rainy season) pulses, balanced use of plant nutrients (including micro-nutrients) and minimization of magnitude and duration of moisture stress.

Nutrient imbalance is one of the major abiotic constraints limiting productivity of pulses. The inbuilt mechanism of biological N_2 fixation enables pulse crops to meet 80-90% of their N requirements, hence a small dose of 15-25 kg N/ha is sufficient to meet the requirement of most of the pulse crops. However, in new cropping systems like rice-chickpea, a higher dose of N (30-40 kg/ha) showed beneficial effect. Phosphorus deficiency is wide spread and most of the pulse crops have shown good response to 20-60 kg P_2O_5/ha depending upon nutrient status of soil, cropping system and moisture availability. Response to K application is location specific. In the recent years, use of 20-30 kg S/ha and some of the micronutrients such as Zn, B, Mo and Fe have improved productivity of pulse crops. Band placement of phosphatic fertilizers and the use of biofertilizers enhance efficiency of applied and native P. Foliar nutrition of some micronutrients was effective. Fortification of fertilizers with specific nutrients like S, Fe, Zn, B etc., in specific regions will be much benefited

Integrated Approach for Biotic Stress Management

Pest and Diseases Management

Seed treatment:Biotic and abiotic stresses are the major barriers in realizing the yield potential, as about 87% of the area under pulses is rainfed and mainly confined to marginal and sub-marginal lands. Losses due to biotic and abiotic stresses in pulses vary from 30 to 100% depending on the magnitude of their severity. To ensure sustainable pulse production under the impacts of changing climate, integrated package of practices are required for different regions of the country.Seed treatment with fungicide (e.g. thiram) at the rate of 3 g per kg seed should be undertaken to avoid early seedling mortality. Now a days antogonist fungi viz., *Trichoderma herzianum* or *T. viridi* is found effective to control the early seedling mortality due to *Rhizoctonia, Sclerotium* or *Fusarium*. The culture of *T.harzianum* or *T.viridi* is now available and its seed treatment @ 5g/kg seed is equally effective to the fungicidal seed treatment. Use of carboxy-methyl-cellulose (CMC) @ 1g/kg seed as an adhesive, makes the treatment more effective.

Plant protection:Pulse crops are highly susceptible to pestswhich cause them maximum damage. Crop wise estimated loss incurred in agro climatic zones by pests, Losses are also incurred by diseases.

- Advanced forewarning and forecasting systems for pest and disease outbreaks
- Promotion of IPM technologies against *Helicoverpa*
- Ensuring timely availability of biopesticides-HaNPV, Trichoderma & herbicides e.g. Pendimethalin
- Seed dressing of fungicides for controlling seed borne diseases
- Providing safe storage structures like Pusa Bin and warehouse facility
- Creation of production units of quality bio-fertilizers and bio-pesticides

Pest Surveillance mechanism and pest management practices:

- Demonstration of IPM module in farmers' participatory mode.
- Capacity building of farmers, Subject Matter Specialists and Extension functionaries.
- Conduction of roving as well as fixed plot surveys on weekly basis so as to provide real time data base for use by National Pest Reporting and Alert System established at NCIPM.
- Periodic release of pest advisories using electronic media.
- Ensuring that the advices are complied with through provisioning of the needed biological or chemical pesticides.
- It is therefore suggested to adopt the model with defined priorities.

Control of damage by blue bull & wild pig: The damage caused to pulses crops by blue bull has been on the rise in the extent and magnitude. The problem has become so acute that area of pulses in general and *summer* mungbean in particular has witnessed drastic reduction in the states of Punjab, Haryana, Rajasthan, Uttar Pradesh and Gujarat. Pulse growers continue to suffer heavy economic losses. The issue is very serious and warrants attention of the policy makers, administrators, social workers, as it has assumed social, economic and ecological dimensions.

Management of weed

It is learnt that about 17-20% losses in pulses are caused due to weeds. Weed infestation of pulses has been observed to cause heavy yield losses in *Kharif* and *Rabi* pulses. Use of chemical herbicides particularly during *Kharif* season needs to be promoted through incentives and appropriate extension strategy as frequent rains and too wet soil conditions do not allow mechanical/manual weeding. A number of cost-effective herbicides are available in the market. Local research stations can provide accurate recommendation in this regard. Technologically advanced private sector companies with a wide distribution network must be involved in pesticide and herbicide propagation for yield expansion.

Selective herbicide:Pulse crops tend to be poor competitors with weeds, so early weed control is important. At seeding, herbicide applications can be made either pre-seed or pre-emergent. There are several factors pulse growers need to consider when making selective herbicide selections.

- Crop yield losses due to weeds in chickpea have been estimated to range from 30 to 50 %.
- Hand weeding at 25 and 50 days after planting has been very effective in controlling weeds.
- Pre emergence application of 1.5 kg a.i/ha of nitrogen or 0.5 kg a.i/ha of prometryne are effective.
- Pre-plant incorporation of 1 kg a.i/ha of basaline showed good weed control.
- Pre emergence application of 1 kg terbutryne (80% WP) also highly promising.
- No single herbicide is effective for all conditions and the choice of herbicide as well as its rate of application will very depending on the nature of weed infestation and the soil type.

Shallow intercultivation: Intercultivation operation in *Kharif* season was very crucial as deep cultivation make submerge condition in heavy rainfall zone which ultimately adversely affect the plant population many time cause severe mortality of more than 80 % at the same time weed should also be controlled in time. Pulses which having wider spacing and slow initial growth like pigeonpea is more severely affected by competition of weed so intercultivation is must required but its should be shallow in depth.

Cultivation of weed smother crop:While demand for pulses continues to rise, domestic supply is perennially falling short. The real problems with pulses are the low productivity of existing strains, a virtual absence of technological progress and the inability of modern science to address the problem of high vulne*Rabi*lity of pulses to weed problem.Most of the pulses in India are grown in low fertility, problematic soils and unpredictable environmental conditions. More than 87% of the area under pulses is rainfed. Further weed is a major problem that competes with major resource of main crop. Short duration short stature and fast growing crop like cowpea, mungbean, and urdbean can be grown as smother crop in wider spacing crop like pigeonpea.

Value Addition and Post Harvest Technologies

Value addition of pulses

Parching of pulses:Legumes such as Bengal gram and peas are parched, to give highly acceptable products. Bengal gram is tied in a moist cloth and kept overnight before it is parched. Peas are soaked in water for 5 minutes dried partially in the sun for 15 minutes and then parched. Salt and turmeric powder are sometimes added to the steeping water or the grains smeared with the paste of the same before they are parched. Parching is done in a hot iron vessel containing sand at 190-200°C for 60-80 seconds. Parching Bengal gram has been used in the treatment of protein calorie malnutrition in children

A. Food processing benefits all the sections of the society. It helps the:

- **Farmers -** get higher yield, better revenues and lower the risks drastically,
- **Consumers -** have access to a greater variety, better prices and new products,
- **Economy -** gets benefitted with new business opportunities for the entrepreneurs and the work force gets employment.

Crop products and their uses: Pulse crops provide grain and residues. On an average, about 158.23 lakh quintals of grains of pulses and 3,27,53,828 tonnes of crop residues (straw and stalk) are received per year. In India, pulse grains are converted into split pulses (Dal) for consumption. This Dal is used for making many products like sweets, Dalmoth, Dal, Sauce etc. Many of processing machines are engaged in processing of pulse grains and it's by products. Residues of pulses are used for animals and making toys, green manure etc.

Popularization of small dal mills: Procurement of pulses grains by Govt. authorized organizations will considerably reduce the need for storage at farmer level. Small Dal-mills should be popularized and promoted through various incentives.

Encouragement of private sector for pulses processing: Private sector should be encouraged to establish' Dal Mill's in rural areas/ districts with large acreage under pulses on the pattern of sugar mills. Private companies need to be involved in processing, packing and marketing of pulses. The public sector procurement agencies are severely handicapped for funds and expertise in this area.

Credit and market related facilities

Attractive Price to Producers

- Value addition and by-product utilization
- Production of organic pulses
- Improvement of nutritional quality through genetic and processing options
- Promotion of export of pulses like lentil and *kabuli* chickpea

Pulses seed should be subsidized

Private sector companies should be involved in production and marketing of certified seed of improved pulses varieties by extending advantage of production and distribution subsidy.

- Announcement of MSP well in advance
- Assured procurement and creation of procurement centres in production zones
- Development of organized markets for pulses
- Linking farmers with markets
- Establishment of single window input supply centres for cluster of villages

Policy intervention: Regarding stock limits, the concerned Food and Supply Department of State Government who is implementing pulses control order need to be approached. Different states have different license requirements and stock limits imposed on pulses. Only Madhya Pradesh does not have a stock limit imposed on domestic pulses. Gujarat has done away with control order license but has a stock limit. Due to these reasons, none of the big trading companies deal in domestic pulses. Applying through the right department in every state for EC license as well as obtaining the EC license is a complex and time consuming exercise. States like Delhi are not issuing Pulses Dealer license for over one year. All channel partners have to also apply for licenses. Generally, the official time limits vary from 1-2 months, while the actual time taken is much longer. New methods for marketing should be devised to supplement some of the shortfalls in specific pulses crops. For example, Yellow Dal is being aggressively promoted by Ministry of Consumer Affairs through publicity campaign (Anonymous, 2013 and Singh *et al*., 2013a).

Formal seed supply system: A formal seed supply system characterized by a vertical organized production and distribution of improved and high yielding varieties, using strict quality control can further maximize the pulses productivity and it is estimated that quality seed can increase the yield levels by 15-25% in comparison to the yield of local seed available with farmers. The share of formal seed sector is about 3% as against the desired level of 10-15%. Visualizing the importance of pulses in human and soil health, it is utmost importance to stream line the seed multiplication chain of these crops

Efficient Transfer of Technology

Massive FLD and seed village scheme: To upgrade the quality of farmer-saved seed, which is about 80-85% of the total seed used for crop production programme, financial assistance is provided for distribution of foundation/certified seed at 50% cost of the seed of crops for production of certified/quality seeds only and for training on seed production and technology to the farmers.The seed produced in these seed villages are preserved/stored till the next sowing season. In order to encourage farmers to develop storage capacity of appropriate quality, assistance is given to farmers for making/ procuring of Pusa Bin/Mud bin/Bin made from paper pulp for storing of seed produced by the frames on their farms.

Mobile Apps and Cooperative Society Approach

Better extension for adoption of improved pulse production technique: Improved and better pulse production technique to be disseminated have to be not only region/agro-climatic zone-specific but should also match the resource-base of the farming community (Singh *et al*., 2014a). Innovative ways of institution building that aggregates the produce of scattered legumes farmers and links them up with the businesses for better quality of inputs and for efficient marketing of the produce need to be found. Similarly, extension strategy to be followed should take into account the prevailing socio-economic status of farmers (Singh *et al*., 2014b).

Conclusion

Though India is the largest producer of most of the pulses, its productivity levels are generally low and it does not figure among top five countries in terms of productivity of major pulses. India did not figure in major technological break through in the world. Wherein other countries achieving averages of around two tones per hectare in pulses productivity. This relative stagnation in pulses productivity in the country is a matter of concern.

India is world's largest producer of pulses, its cultivation remains restricted to only small and marginal farmers and so unless and until it reach to professional intensive mechanized farming system, it is difficult to meet future needs and limited scope for exports of pulses from India.

Best agronomic practices (BAP) and their different components shown potential to excel under change climate condition, there is need to adopt the all the component of advocated technology as a unit. In order to understand the challenges in raising production of pulses in the country the relative profitability and risk involved in pulses cultivation it needs to be given more weightage for supporting all input and policy decision.

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New Paradigm in Maize for Doubling Farmers' Income in India by 2022

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In India, maize is the 3rd most important cereal crop after rice and wheat. It has wide adaptability to diverse environments such as, temperate, tropical, sub tropical, highlands and grown in all parts of country during summer winter, spring seasons. Besides its highest productivity among all cereals and multifaceted uses as food, feed fodder, fuel, industrial products, and several specially maize products like sweet corn, pop corn, baby corn, corn for green ears, waxy corn, quality protein maize (QPM), this crop has flexibility to fit in crop diversification, cropping system/farming systems and maize is known as miracle crop and called 'Queen of Cereals'.Globally maize is presently grown in about 165 countries, in an area of 184 mha with total production of 1065 MMT and 5.52 t/ha productivity (FAOSTAT 2014) due to its very high demand, mainly as animal, poultry and piggery feed. It has emerged as a most cultivated crop in the world, surpassing rice with twice the annual growth rate that of rice in 1996 and three times that of wheat in 1997. In India it is mainly used as feed (59%), industrial raw material (17%), food (10%) and abouty 10% for other purposes like export, seed etc. Increased demand of maize for feed and industrial uses contributed significantly to increase in the maize area, resulting in compound annual growth rate of 4.98%. In last 16 yearsmore than 10 MMT maize has been added reaching a total production of 26 MMT.

Future Maize Demand

Demand for Feed: Currently with a total production of 26 MMT the country is able to meet the domestic demand of maize. Out of this total production, about 15 MMT (60%) is being utilized as feed, of which 12.5 MMT (84%) is used as poultry feed alone and rest as animal & piggery feed. With 8-10% growth in the poultry sector and 1.3% in livestock sector the total requirement of maize as feed is likely to go up to 32-33 MMT by 2022.

Demand for Poultry Feed: Due to fast growing Indian poultry sector in last 16 years (2000 to 2016), the broiler meat production increased from 0.8 mt to 4 mt and egg production form 37 billion eggs to 70 billion eggs. Maize is ideal for poultry and used extensively the main source of poultry feed as the main source of calories and crude fibre content. However, due to major cost about 60-70 % incurred on feed component alone the poultry sector is facing major challenges which can be substantially reduced to half using reduced quantity of QPM maize offering best sources of poultry, livestock, piggery and fish feed as well energy with doubled the biological value. The annual demand of maize is expected to increase due to consumption of pultry meat and eggs at 9 per cent and 5 per cent, respectively, over the next few years.

Animal Feed and Fodder: Dairy farming is fast emerging as a potential business in rural and periurban India. It has one of the largest livestock population (500 million), expected to grow at the rate 1.3 per cent in coming years. It is estimated that by 2022 a total of 526 mt of dry matter, 855 mt of green fodder and 56 mt of concentrate feed comprising 274 mt of cereals including maize as main component, 4.0 mt of pulses, 20.6 mt of oil seeds, oil cakes and measl and 3.6 mt of manufactured feed would be

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required. The quality of maize fodder in considered better than that of soghum and pearl millet as the latter crops posses anti quality component such as NCN and oxalate, respectively. Therefore, there is a tremendous pressure of livestock on available feed and fodder as land available for fodder production is decreasing and part of which can be fulfilled by using maize crop residue such as dry stock and shanks as feed, besides the maize plants as fodder and specially corn i.e. sweet corn, baby corn, corn for green ears after harvest of green cob as fodder and silage for lean season.

Demand for Food: The demand for maize as direct human food is likely to increase from 1.3 to 3-4 MMT. This increased demand will come more from availability of specialty corn products like sweet corn, baby corn, popcorn, corn for green ears and QPM products besides traditional use of maize flour, multigrain flour and other dry milling and alkali processing products. The rising interest in above products is especially arising in the urban areas. The consumption in the rural areas can further be increased if the maize is provided in the public distribution system (PDS) in the states like Bihar, Odissa, Rajasthan, Jharkhand, HP, J&K, Gujarat etc. where it is part of staple food along with other cereals.QPM offer very good opportunity and cheapest source of quality protein to address food and nutritional security. Normal maize protein is known to have a biological value of 40% of that of milk and therefore need protein supplementation from legumes and animal products. The essential amino acid like lysine, tryptophan and theonine are in reduced quantities, lysine being the most limiting followed by tryphothan. QPM has nearly twice the amount of lysine and troptophan, which makes the protein of QPM equivalent to 90% of the milk protein. QPM is to provide solution to the worst victims of malnutrition in human beings as superior food for infants, pre school children adolescents, lactating women, pregnant women and old aged persons. Due to availability of high yielding single cross hard indosperm QPM maize hybrids without yield penalty now at par in yield with normal maize with double biological value higher than wheat and rice matching with skim milk for true protein digestibility, the need is to exploit potential of QPM as health food for the vulnerable segment of the society. QPM is considered as miracle maize because all cereals except QPM are deficit in lysine, an essential amino acid and all pulses deficient in mithioninean other essential amino acid. Due to above qualities, the demand as food is expected to increase more than double, by 2022.

Sweet corn and baby corn possess high quality phyto nutrition profile comprising of dietary fibre, vitamins and antioxidants in addition to minirals in moderate proportion. Besides proteins, vitamins and iron, sweet and baby corn are one of the richest sources of phosphorus. Baby corn is high in folate, B-6 vitamins, riboflavin and vitamin C. it contains two coratenoids like zeaxanthin and lutein which help to prevent cataract, thus keep eyes healthy. In sweet corn the level of sugar content is around 15-20% compared to 3-5% in field corn.The demand for sweet and baby corn is rapidly increasing in urban areas of the country. It has potential for export in domestic and international market. The crop can be grown round the year and 3-4 crops can be taken up within a year. India has emerged as one of the potential baby corn and sweet corn producing country because of the low cost of production.

Demand for Industrial Uses: Corn starch is generally processed by wet milling method as primary product and the other products are corn oil, corn steep, liquor, glutin etc. The average recovery of various products during wet milling is - starch (60-62%), glutin (8-9%), germ (6-7%) and husk (22-24%). The glutin and germ are mainly used for poultry feed and corn oil, respectively. The by products of dry and wet milling industries are being used as raw material for the preparation of series of products like: formulated feed, sweetener products such as corn syrups used in bakery and dry products. Non-food uses of corn syrups are bodying agents in inks, shoe polish, textile finishes, adhesive formulations, pharmaceuticals in tanning leather and as humectants in tobacco. Dextrose is a major component of tabulated candies, chewing gums, gum confections, fondants and hard candy formulations. Sorbitol is used in the production of synthetic vitamin C, and high fructose corn syrups and used in a variety of ways such as confections, baked goods, table syrups, sweet beverages etc.Corn oil a highly desirous vegetable oil is commercially produced from corn germ isolated by wet milling or dry milling, used due to its high content of unsaturated fatty acids recognized as a dietary component for reducing blood cholesterol levels. Maize is being utilized extensively in fermentation industry as beverages to produce beer and distilled liquors, wines (sweet “pop wines” and “wine coolers”), antibiotics, enzymes, fuel alcohol and chemicals etc. Maize cob granules are used as carrier for pesticides, fertilizers, vitamin, extraction of crude petroleum, hand soaps, cosmetics etc. The per capita consumption of starch and industrial products in the country is expected to increase from present level of 4.25 MMT to 15 MMT by 2022, and maize being the major source of industrial starch, its demand will also increase proportionately.

Maize for Export: Maize was in short supply due to fast growing poultry industry in the country and its domestic demand could not be met up to 1980s. Now, the situation is reverse and country is exporting maize to South East Asian Countries, such as, Indonesia, Vietnam, Malaysia etc. due to cheep transportation and better competitive price. The Middle East countries also offer very good opportunity to export maize. By 2022, the total maize demand is likely to go up to 50-60 MMT due to steep rise in the demand of maize as feed, industrial requirement, food products and for export and to meet this the maize production has to be doubled.

Productivity challenges: Though productivity of *Rabi*/spring maize is more than double of *Kharif* maize, the *Kharif* maize represent over 83% maize area. To enhance maize production, the productivity of *Kharif* maize needs to be increased substantially. About 75% *Kharif*area is under rainfed condition, while *Rabi* maize is predominantly grown in favourable ecologies. With the increase in irrigation facility some area of *Kharif* maize is also grown under irrigated condition due to its comparative advantage in productivity than other *Kharif* crops. Although the crop can be grown in all sorts of environment due to its very wide adaptability but primarily due to tropical and sub tropical environmental conditions in the season such as, shorter day length, early maturity, hot night temperature, poor quality sunshine, cloudy weather etc. prevailing in the country during *Kharif* the potential productivity is not realized. Also, extreme weather events due to climate change exacerbate uneven rainfall, drought, flooding, temperature, high wind etc., is adversely affecting maize productivity. Heat stress at flowering and grain filling stages in spring maize causessubstantial yield loss. Biotic stresses such as, post flowering stalk rot (PFSR), leaf blights, banded leaf &sheath blight (BLSB), downy mildews (DM), ear rots (ER), borers, and weed problems adversely affect maize productivity. Non-availability of quality seed of single cross hybrids is another important factor contributing low productivity of rainfed*Kharif* maize. Mostly the private sector is focusing on development and production of single cross hybrids suitable for low risk-high potential irrigated ecologies. This calls for immediate attention to address above mentioned challenges to increase productivity of *Kharif* maize.

Emphasis was given to develop improved cultivars having tolerance to mentioned biotic and abiotic stresses with resilience to climate changes. In some parts of the country specially in north-west plain region where rice-wheat cropping system is dominant, the crop suffers due to decline in total factor productivity. These ecologies require crop diversification through introduction of maize. Adoption of good agronomical practices like integrated nutrient management, integrated farming system approach to improved nutrient use efficiency, conservation practices, water management and integrated pest management along with availability of single cross hybrid seed are the viable option inrainfeds to stabilize the yield in both low potential and high risk environment, as well as, high potential and low risk environment. Maize is very much vulnerable to the post harvest problems, which accounts for more than 20% losses. These losses intensify due to poor drying and storage leading to weevil damages and formation of mycotoxins. Innovative extension mechanism is required to outscale technologies to the farmers to counter low adoption of improved technologies to bridge the productivity gaps.

In the next 5-6 years maize area is expected to increase from 9.2 Mha. to maximum up to 11-12 Mha, especially in the peninsular India, owing to the favorable ecology for maize production in this region. The major increase in the *Kharif* area about 1.8 Mha and 1.2 Mha in *Rabi*may come from the states of Karnataka, Andhra Pradesh, Odisha, Maharashtra and Tamil Nadu. However, to meet the increased demand of maize, the major focus should be to increase the productivity rather than area with an annual growth rate of 7-8 %. The target to achieve average productivity level of 5-6 tonnes/ha is possible to achieve with above growth rate by enhancing area under irrigation, crop diversifications and improved agronomical practices during *Kharif*.

Prospects for Doubling Maize Production and Farmers' Income by 2022

Mission mode approach is required to meet the domestic demand of maize to double production by 2022 and to make maize farming a respectable profession, more efficient, economically viable, knowledge based, environmentally sustainable and viable enough to attract local youth to ensure rural livelihood security. This will require 7-8% CAGR in yield without much increase in area. This is attainable with 80% coverage of area with most productive single cross hybrids resilient to climate change to increase productivity from current level of 2.56 t/ha to 5.0 t/ha. Demand scenario especially for feed and industrial uses is quite encouraging to attract farmers to cultivate maize as there exist assured market and strong techno–economic competitiveness. The gap between realized and potential yield clearly indicates the availability of suitable technologies, however, the need is to effectively demonstrate the innovations in farmers field to bridge the yield gaps, especially in *Kharif* maize.Initiatives taken by central Government for doubling farmer's income by 2022 and policy initiatives to conserve natural resources (soil, water), improve resilience and reduce risks, such as, Prime Minister Irrigation program (PMIP, Harkhetkopani), Prime Minister Agriculture Insurance Scheme (PMAIS), National Food Security Mission (NFSM), National Horticulture Mission (NAM), National Mission on Sustainable Agriculture (NMSA), connect farmer's with remunerative markets through e-NAM (one Nation-one Market) and consolidate farmers to derive benefits through farmer's producer organization, moving towards more cash transfer and less public sector distribution of inputs and outputs are praise worthy. Efforts should be made to sensitize maize farmer's to take advantage of efficient use of resource saving improved technologies, good management practices, small farm mechanization, etc. and create an enabling environment to promote the available technologies reach to the farmers of both rainfed and irrigated ecologies in cropping or farming system mode including diversification to higher value crop or animal and beyond the farm through value added chains.

Strategies for Enhancing Productivity

Farmers are facing numerous problems of productivity challenges in each agro-ecologies in their cropping/farming systems. Therefore, the research agenda should be decided considering the problems faced by the farmers to address productivity issues emerging from their field, for both upscaling and outscaling innovations. Also, action plan is to be developed involving all stake holder, *viz.*, planners, researchers, farmers, processors and traders in Public-Private-Producer-Partnership (PPPP) mode to address the issues in a holistic manner, ensuring management of natural resources. The agenda for technology development in PPPP mode can play a very important role and reach to the unreached through technology agents for disseminating innovations and supply, such as quality inputs, seed etc. A mechanism should be evolved to continuously upgrade the knowledge of all stake holders right from researchers, technology agents, farmers etc. and the progress should be evaluated to access the progress in a time boud manner.

Strategies for Enhancing Breeding Efficiency

Strengthening the pre-breeding activity: Considering the productivity challenges, the aim is to have genetically diverse portfolio of improved maize cultivars (SC hybrid) suited to a range of agro-ecosystems and farming practices, resilient to climate change, as the genetic diversity will improve the adaptability, and the greater resistance to biotic and abiotic stresses to improve cropping system resilience. The research agenda should focus on development of the new hybrids which should be responsive to the external inputs, use nutrient and water more efficiently, greater resistance to biotic and abiotic stresses, adapted to unfavourable areas and production system, produce economic yield with higher nutritional value and desirable to organolyptic properties. To attain the above goal, it should be ensured that the available diversity in gene banks and also in farmers' field is to be characterized. Donor alleles or traits of economic importance such as, resistant sources to reduce genetic vulnerability resilient to climate change and nutritionally enriched traits for germplasm diversification are to be made available for pre-breeding activity to mobilize them efficiently and effectively in a timely manner with emphasis on per day/per unit productivity increase. This can be achieved in collaboration with institutions involved in breeding and with farmers' participation for sustainable maize production intensification

(SMPI). It would be more appropriate to have bottom up approach considering the farmers' need in a particular agro-ecosystem to focus on resources important to enhance productivity, improved quality and adaptation to climate change for sustainable intensification with required financial support for pre-breeding.

In this context it is of utmost importance to constitute heterotic pools on the pattern of stiff stalk synthetic and lancaster in USA. Such heterotic pools are to be developed in three maturity groups, i.e. long, medium and short, by infusing newer germplasm from diverse sources in maize breeding programmes. A systematic programme to screen available germplasm such as, pools, populations, varieties, inbred lines etc., both exotic and indegenous, are to be thoroughly screened for the traits of economic importance and constituted into heterotic groups using parents of best single cross as testers for each maturity groups. This used to be a continuous activity of the project in past and the constituted heteroticpools were kept as open ended with an idea to introgress new gramplasm in their respective group to broaden the germplasm base to provide novel traits for enhancing breeding efficiency for the development of superior single crosses. The information on germplasm gone in to each pool are to be made available in the pedigree book, to be broughtout in every 2-3 years, to ensure that the material introgressed once are not reinfused in the pools and a balance of introgressed materials are maintained in each heterotic pool. In this context six heterotic pools in three maturity groups developed by project and two heterotic pools in full season maturity group developed at the Ludhiana center, known as Ludhiana Stiff Stalk and Ludhiana Lancaster are worth mentioning. The above pools are the treasure of the project to extract inbred lines to develop new single cross hybrids with very high magnitude of heterosis.

Genetic Enhancement for Stress Tolerance Maize Germplasm

In the past one decade drastic climate changes have taken place and are likely to take place in coming years as well. The crop suffers due to sever and erratic abiotic stresses leading heavy yield losses. This requires development of climate resilient maize germplasm by incorporating traits which can tolerate drought, high temperature, water stress etc. There is need to execute breeding programme to make simultaneous selections under combination of stresses to develop cultivars. Efforts should be made to recollect maize germplasm adapted under severe stress condition in past few years from farmers field and screen thoroughly under controlled stress conditions to be used in the breeding programme. For this, managed screening sites and standardized protocols to screen germplasm for combinations of stresses under controlled conditions suited for a target environment should be developed. Also, genetic engineering, RNA interference and targeted mutagenesis techniques provide us new tools to engineer maize germplasm resistant to biotic and abiotic stresses in long run. There is a need to develop breeder ready markers for resistance to major diseases of maize.

Use of Frontier Technologies for Enhancing Genetic Gains

So far, conventional breeding has helped to develop high yielding maize hybrids. However, advances made in breeding techniques, with ability to develop a cost effective and time saving maize cultivars with high yield potential, adaptive to biotic and abiotic stresses resilience to climate change, offer good opportunity. Double haploidy (DH), molecular marker-assisted (MAS) breeding, high throught put precision phenotyping of traits of interest, year round nurseries and decision-support systems/tools offers new opportunity for enhancing genetic gains and breeding efficiency. A time has came to strengthen public breeding programme to integrate with DH tools/techniques to improve breeding efficiency besides reducing costs and simplied logistics. Maize breeding cycle can be reduced significantly with available new genomic selection technologies. This has become feasible due to drastic reduction in genotyping costs. Genome wide association studies (GWAS) implemented with high throughput precision phenotyping has emerged as a powerful strategy for dissecting complex traits and identifying superior alleles contributing to improve phenotype in maize. Breeding assisted with MAS is very effective. It efficiently helps development of cultivars with combination of relevant adaptive and quality traits and tolerance to stresses. There is need to develop facilities to undertake precision phenotyping particularly under repeatable and representative levels for stress in the field. Now low cost easy to handle tools are available for field phenotyping of appropriately selected traits, and it should be the integral part in the maize breeding programme. There is need to establish phenotyping network for comprehensive and efficient characterization of genetic resources and breeding materials for an array of target traits particularly tolerance to biotic, abiotic and nutritional quality traits. This would greatly help in genomics assisted breeding diversification of genetic base of elite breeding materials, creation of novel varieties resilience to climate change.

Adoption and Development of Genetically Modified (GM) Maize

Research programme should be strengthened to develop GM maize with enhanced productivity and profitability of farmers by controlling insect pest, and weeds in the field. However, utmost care should be given to ensure biosafety issues before promoting the events as cultivar. This will go a long way to improve environment safety and health problems caused by residue of chemicals used by the farmers.

Production Technology for Enhanced Productivity

Agronomy being the location specific activity, all centers of the project are involved in development of location specific agronomic practices to enhance productivity. Special emphasis is to be given to workout non-monetary output practices, such as, date of sowing, plant population density, method of sowing and fertilizer application etc. Package of practices developed for eachagroecology of the country, which pay very rich dividend are to be propagated among maize farmers. A mix of inorganic and natural resources (manure, nitrogen fixing crops) should be included in the package of practices for better yield. In the context of the present day problems like decline in total factor productivity making soil hungry and thirsty due to decrease in soil biota like beneficial microbes, arthropods, anelids etc. and decreased organic carbon in the soil is hampering nutrient utilization efficiency in the field. Degrading soil and other natural resources, polluted water and air etc. also adversely affect total productivity. Thus, there is a need to develop production technologies with bottom up approach considering the farmers' field conditions. The biggest challenge is to produce more from less land and water. Depletion of groundwater and deterioration of water quality calls for crop diversification and use of appropriate water savings technologies in irrigated maize.

There is a need to critically analyze rainfall pattern and moisture problem in rainfed maize to establish production constraints and to take up an integrated location specific judicial approach. Deep rooted genotypes, improving water infiltration and water storage capacity at root zone and practices to minimize evaporation and lengthening the duration of soil moisture from organic mulching and control weed in field are some of the strategies to be followed to augment moisture related issues. The agronomic recommendation made earlier with top down approach are no longer valid today due to extreme weather events and climate changes. There is need to revisit agronomic practices for summer winter and spring maize after critically analyzing data on productivity constraints, such as biotic and abiotic stresses, socio-economic factors etc. in the farmers' fields. Application of fertilizers including micronutrient based on soil test reduces cost of cultivation. Supplementation with organic manure improves nutrient use efficiency, soil health and reduces environmental footprints.

The production technologies of specialty corn are the same as normal maize. However, the baby corn cultivation practices differ due to planting of early maturing prolific single cross maize hybrid in higher plant population denisities with higher dose of mitrogen, detasselling or planting with male sterile hybrids, and harvesting of unfertilized cobs within 1-3 days of silk emergence. It is all the more important to continuously generate information on date of sowing, nutrient-genotype interaction and plant density. Selection for shorter plant type opens up scope to increase population density for higher yield in different maturity group of material. Further additional information should be generated on effect of mixed and inter-cropping on total productivity and benefit-cost (B: C) ratio.

Kharif Maize in Flood Prone Areas

Flood is of common occurance in the middle of August in kahrif maize, particularly in the eastern region of the country. With proper planning for flood prone areas this recurrent threat can be converted in to an opportunity. This can be achieved by advancing planting of speciality corns like sweet corn, pop corn, baby corn and corn for green ears. Since monsoon breaks in the first week of June in eastern region, it provide an advantage of planting maize 20-25 days earlier and harvested as green cob about 20-25 days earlier than fully mature grains. Additionally, soon after harvest of green cobs the green stalks can be used as fodder and/or silage making. Baby corn and sweet corn can be canned at local level and exported to big cities, other states and countries.

Resource Conservation Technologies (RCT)

RCT offers an opportunity for planting of full season maturity cultivars, reducing time between *Kharif* harvest and sowing of *Rabi* crop, reducing cost on fossil fuel, improving organic carbon, enhancing nutrient use efficiency, conserve moisture to help to reduce pollution due to burning of fossil fuel, and improve environmental safety. Normally farmers till their land using tractors several times after harvest of *Kharif* crop. This takes about 15-20 days to prepare land. In this process field moisture is lost and farmers need to irrigate the land before or immediately after sowing for proper germination. Zero tillage technology provide an opportunity for planting full season maize hybrid which result in higher yields owing to extending the crop season and also lower down the tillage cost by 3000-4000/ha and hence improve farm profitability. A special thrust was given by National Agriculture Technology Project (NATP) to promote this technology in plain and peninsular regions of the country. The retention of residues and crop rotation practices in maize based cropping system due to crop diversification helps in arresting soil erosion, improvement in soil organic carbon content, improvement in soil health and moisture conservation. The use of Laser leveler is also reducing requirement of irrigation water by 20-30%. The adoption of site specific nutrient management practices and placement of nutrient in root zone along with sowing by the zero till cum fertilizer seed drill has further enhanced the crop productivity and nutrient use efficiency. A large scale adoption is expected to improve profitability of farmers along with soil health, environmental safety and productivity. RTC is gaining momentum in indo-gangetic region and in peninsular India.

Development of Protection Technology

Maize protection technology should include ecosystem based measures to control insect pests and diseases. Since pesticide kills pests and also natural enemies, it's over use harm farmers, consumers and environment. Utmost care should be taken to control major pest or disease outbreaks which threaten food security. Pesticide residue should not persist in the economic yield (grain and fodder) addressing food safety issues, human health hazards and environmental pollution. Mis management and proliferation of obsolete stock piles of pesticides can harm the beneficial soil born microbes, insect species and soil biota. The most desirable control measure is to develop cultivars resistant to insect pests and diseases. It requires judicious and selective pesticides or biopesticides to be used to control pests. Effective control measures of borers have been recommended. It is suggested that in maize no pesticides needs to be used to control insect pest after three weeks after germination or the crop attain knee high stage. This is more pertinent in specialty corns. As far possible, biological control and IPM control methods should be used to control of insect pests. Farmers earn more if specialty corns are produced organically than under chemical control. While screening of large number of indigenous germplasm and AMONG those imported was found that materials received from Caribbean region specially from Antigua has high degree of resistance to borers, when Screening was carried out by artificial infestation. Similarly, germplasm were also screened under artificial inoculation or by growing in hotspots for diseases like leaf blights, stalk rots, PFSR, downy mildews etc. and promising genotypes were used in breeding programme. However, the process needs to be repeated.

Post-harvest Losses

Normally maize crop is harvested at 18-20% moisture level. The grain has to be stored at 12% moisture to protect them from store grain pests and fungal infection. About 5% losses are estimated during harvesting, threshing, winnowing, transportation, cleaning and storage level. In fact, there are no proper grain storage facilities available in the country. Thus, the maize grains are damaged during the normal storage condition owing to the hygroscopic nature of the grains. Sun drying, particularly during *Kharif* season is not possible due to cloudy weather and high humidity and maize grain become vulnerable to aflalotoxins and weevil infestation. Since every farmer cannot afford to establish dryer and silos there is need to install dryers and made available to the farmers and metal silos and storage facilities installed at community level for safe storage of grain.

Maize Processing and Value Addition

Maize grain serve as basic raw materials for three major processes viz. dry milling, wet milling and alkali processing. The end products of these are being utilized as raw materials for other small, medium and large enterprises for the production of more than thousand products which cater the need in one and other form in every day life of the people. The products of dry milling are grids (40%), coarse meal (20%), germ (14%), fine meal (10%), flour (5%), and hominy feed (10%). The grids are being used for preparation of products like ready to eat snacks such as corn flakes, porridges, wall paper paste, manufacture of glucose by direct hydrolysis etc.

Although India is self sufficient in food production but the fact remains that large and vernarable section of our society is suffering from macro and micro nutrient malnutrition due to one or other reasons. The infants, preschool children, adolescents, pregnant and lactating women and elderly persons are the worst victims of malnutrition. QPM offer very good solution to the above problems in combination of other food naterials, such as complimentary foods, health foods, snacks and savoury items. Convenience foods and specialty products are developed after the alkali processing due to which the digestibility and palatibity increases and makes the bound niacin free to get it available to the body. Complementary food are ready to eat food can be prepared at home with QPM along with pulses, nuts, oil seeds, to serve the infants after 6 months when mother's milk Is not available in sufficient quantity. Health food in the form of mix and other nutritious food including ladoo, toffees, and chocolates can be speciafically prepared for school children, pregnant, lactating women and aged persons. Snacks and savory products are well suited to all age groups contributing balanced amount of nutrients. Large number of products are already developed and many in pipetine by Dr. Rajender Prasad Central Agricultural University, Pusa Samastipur, Bihar, which can replace at least one or two menu from the plate of consumer with maize recipe to secure nutritional security.

There is a huge potential to increase entrepreneurial skill for maize processing and value addition by involving local women and youth to use in maize food chain. Maize also offers good opportunity to develop small scale industries at local level through alkali processing to develop maize-based products, like pasta, vermicelli, corn flakes, Jelly, ice cream cone, sewaian, and functional foods and nutraceuticals. Dry milled QPM-based products like roasted flour, dalia, suji, multigrain flour, maize grid, namkeen products etc. offer immense promise for local youths and women. Primary processing of speciality corns like sweet corn, popcorn, baby corn at local level has potential to improve household job opportunities, profitability to the farmers and most importantly engage them at local level. Maize starch is processed by wet milling processes and used as an adhesive in textile and paper industry, thickener in food industry, filler in pharmaceutical industry, feedstock for manufacture of glucose, dextrose, ethanol, sorbital, nutraceutical industry, and number of other products. In past one decade many starch industries have been established in India which has increased the maize demand in the country.

Out Scaling Innovations involving Local Women/Youth

Policies should be initiated for retaining youth in agriculture for effective dissemination of knowledge and out scaling innovations. Unemployed agricultural graduates of nearby village should be encouraged and trained to be as paid 'technology agents' to ensure efficient farm advisory services to the farmers. A system in PPPP mode should be evolved to keep technology agents informed of current research innovations and accomplishments. Also, technology agent should be supported by banks to provide credit to establish agri-clinics including soil testing facilities to identify the problem in farmers' fields and provide needed advisory to use demand-driven productive resources such as seed of single cross hybrid resilient to climate change, good agronomic practices such as integrated nutrient management, water management, integrated crop management crop diversification with maize, pest management, conservation agriculture etc. to the farmers to bridge the productivity gaps.

Local youth including school dropouts/ uneducated should also be involved to provide needed services required by the farmers after proper training –as detailed below:

Input providers: to provide seed fertilizers, pesticides, biofertilizers etc. after proper training. They should be provided certificates after training and only certificate holders should be authorize to sell the inputs.

Input producers: at village level by educated local entrepreneur to produce inputs such as biofertilizers, biopesticides, vermicompost, compost, soil amendments, production of cattles/poultry feed concentrates, minimal mixture, complete feed etc

Implement providers: to provide services and implements for tillage, seed drills, weed control, plant protection harvesters, dryers etc on custom hire basis, especially to small and marginal farmers.

All these will help to improve efficiency and engage the local youth, to provide services and farmers will have more confidence in their own children/kith and kins.

Way Forward Doubling Production and Farmers' Income by 2022

Improving Productivity

(a) *Thrust on genetic enhancement*

- Recognizing the productivity advantage of S.C. maize hybrid including QPM emphasis should be given for strengthening Pre-breeding activities for diversification of germplasm base by channelizing traits of economic importance including nutritionally enriched traits for exploitation of higher magnitude of heterosis with heterotic grouping to improve adaptability, introgressing resistant sources for biotic and abiotic stresses to reduce genetic vulner*abi*lity resilient to climate change.
- Integrating the use of new tools and breeding techniques are required to save on time and reducing breeding cycle for genetic enhancement such as, DH, MAS, GWAS with high throughput and precision phenotyping of traits of interest, target mutagenesis to engineer germplasm resistant to stresses by strengthening of decision support system, round the year nurseries and needed infrastructural facilities to develop hybrids for wider adaptability resilient to climate change. This will help to saturate area under SC hybrids from present 22% to 80% in the country to increase productivity and production.
- Farmers should be sensitized about newly developed QPM S.C. hybrids having same yield level as normal maize without any yield loss and encouraged to use QPM as food and feed by poultry sector than normal maize. Since maize is the main cereal for feed the quantity of normal maize can be reduced to half if replaced by QPM due to its double biological value for true protein digestibility. Also, QPM maize should be procured and provided though public distribution system (PDS) in the states predominated by tribals and poor masses where maize is directly consumed as food to ensure their nutritional security.
- A mechanism should be developed for upscaling and outscaling of cutting age technologies including GM maize after ensuring biosafety measures to increase productivity and profitability by reducing cost on pesticides, herbicide etc. of resource poor farmers. The current mistrust on GM products is detrimental for future growth.
- There is need to reduce gender gap envolving women to raise farm yield by 20-30% and reduction in malnutrition problem by 12-17%. Also they contribute for the sustainable intensification, employment generation through value chain, insure livelihood security and environmental safety in addition to increased productivity and profitability.

(b) *Thrust on Seed Production of Single Cross (SC) Hybrids*

- Since maize can be grown in almost all parts of the country, a suitable area and season for developing seed production hub should be identified in each state with all necessary infrastructural facilities, like processing plants, cold chains, safe storage facilities, uninterrupted power supply etc. in PPPP mode. This willhelp to cut down transportation cost, availability of quality seeds on time on cheaperrate at the farmers' doorsteps. This facility can be used by the agencies producing seed on rent in that area.

- A mission mode approach on seed production of single cross maize hybrid is needed to bridge the productivity gaps. A rolling plan for seed production for atleast 5 years should be prepared to outscalebetter S.C. hybrids suitable for a specific region, jointly decided by a committee under the leadership of eminent scientist, seed sector representatives and a group of progressive farmers.
- A policy paper should be developed to encourage private sector to invest more in R&D to develop S.C. hybrids and produce enough seed for *Kharif* maize considering vast area and seed replacement rate (SRR) to cover 70-80% *Kharif* maize area and phasing out old cultivars. Seed purchase on quotation tender basis to provide on subsidy should be discouraged and the seed of best hybrid should be purchased selected by maize scientists, farmers after joint visit of maize plots planted with newly developed hybrids in technology parks/ government farms.The benefit of subsidy should be extended to the best hybrid irrespective of notified or truthfully labeled (TL) developed by public or private sector. This will help to increase area under SC best hybrid and ensure higher productivity.
- Necessary storage facilities to establish seed bank in each region should be developed as contingency measures to manage maize crop in *Kharif* during unforeseen situations. Crop insurance in case of disaster to cover loss caused by abiotic stresses should be ensured.
- It is necessary to have coordination and convergence among seed companies to take up production on basis of maturity to avoid contamination in seed production area. Also, only progressive farmers should be involved in production of hybrid seed with proper training.
- A mechanism already in place should be taken advantage of PPV&FR Act providing protection to produce seed of public sector bred hybrids by the private sector by paying 3- 5 % royalty negotiated on sale proceeds on exclusive/non-exclusive basis.
- Indian seed sector is very well established and has potential to grow beyond boundaries of domestic market and capable to capture global market such as Africa, SAARC countries, South East Asian countries. For this, enabling environment should be created to promote export of seed for better earning.
- Adequately trained human resources should be engaged for seed certification to ensure quality standard. Also, the quality testing laboratory should be equipped with equipments for testing of transgenic seeds, QPM apart from normal seed.

(c) *Thrust on Production and Protection Technologies*

- *Realizing* drastic effect of climate change in last 10-15 years of warrant to bring in resilience to biotic and abiotic stresses and revisit agronomic recommendations towards sustainable intensification by adopting CA for reducing cost on inputs, improving soil health, water use efficiency, human nutrition, by linking IFS, crop diversification, for improved production and farmer's income and reducing environmental foot print.
- Priorities should be given to control biotic stresses by developing host plant resistance, IPM approaches, biological control methods, selective use of pesticides, biopesticides to reduce loss of beneficial insects/soil biota, less pesticide residue causing human health hazards, polluting environment and improving farmers income by less expenditure on purchase of chemical.

Development of Maize Value Chain

- Maize value chain development should focus mainly in efficiency improvement considering consumer demand which becomes driver for innovation and value creation, leading to continuous improvement in food supply and benefits to consumers. Encourage maize processing for value addition involving local women and youth for making winning food, processing and packaging of dry milling maize products, feed etc. to offer considerable of-farm job opportunity for better profitability to the farmers.

Outscaling Innovations

- There exists huge gap between potential and realized yield of maize. This calls for vigorous efforts to be made to bridge the productivity gaps. An innovative mechanism with PPPP mode has to be developed to disseminate the production technologies involving local agriculture graduates as paid technology agents, and to retain local youth to provide services such as inputs (seed, fertilizer, chemical pesticides, bioproducts implements etc. required by the farmers. In the absence of local entrepreneurship at village level, the opportunities are hijacked by outsiders leading to exploitation and deprivation of employment to the local youth forcing them to migrate to the cities for jobs.
- More investment is needed in maize R&D for upscaling and outscaling innovations by developing infrastructural facilities such as, roads, cold chains, cleaning, grading, processing, packaging, storage, community drying facilities to reduce grain losses and wastage amounting to an estimated one third of production. Such investment would yield higher returns in terms of productivity and economic growth in long term than input subsidies.
- There is need to revitalize producers companies, cooperative societies, contract farming and institutional mechanism to organize credit and other services for farmers and local entrepreneurs.

Linking Maize Farmers to Market (LFM)

- It is important to improve market efficiencies by reducing price spread and raise producers share in consumers' rupee by removing middleman and encourage direct marketing for better profit to the farmer. In this regard, e-Nam, ICT, print and electronic media offer new marketing opportunity.
- Farmers cannot safely store maize grain without proper drying after harvest for long time due to hygroscopic nature of maize grain. They are compelled to sell the produce as a result the prices dip drastically. For better profit to farmers, the storage facilities at Tehsil level should be develop with PPPP mode to store the produce preferably graded and labeled signifying quality standard. This will help farmer to get credit against the receipt of the stored produce to buy necessary inputs for next crop. This will ensure credit widening (to more farmers) instead of credit deepening (to big farmers only) and avoid distress sales and help farmers to realize better prices when prices go up. This will also minimize storage losses and bring efficiency in trade as the traders can lift the produce from one place instead door to door from the farmers.
- A new mechanism should be developed in PPPP mode to make producer companies, S.H.G.s, contract farming more farmer friendly under which buyer can provide the farmer access to technology, quality inputs, more support, in business skills, capital investment, credit facilitation, risk management and guaranteed better price. A comprehensive and progressive credit policy should be framed and implemented to free farmers from the clutches of money lenders.
- Involving rural women and youth in LFM will be of great advantage for their active role in maize value chain to engage them in village itself. They should be encourage to sell through small outlets/shops at highway roadside in nearby town/cities specialty products such as frozen sweet corn, baby corn, roasted green ear, and packaging of pop corn, readymade QPM products, dry milling products, feed etc. which is produced and prepared at village level.
- There is considerable scope for export of value added dry milling maize products, feed, certified organically produced specialty corn with good packaging meeting quality of international standard. A strategy to link farmers with local and wider market should be evolved for the participation of buyer across the country without restriction in movement of product and harmonization of tax laws/GST. Proximity to the national/international airports needs to be exploited for export of value added products, feed etc for better income.

Capacity Building

- Strengthen periodic capacity building programs for field officers, technology agents, other field functionaries involved in maize development programmes and organize regularly vocational training programs for farmers including women farmers. Overloading with other work such as distribution of subsidy etc, to the last functionary like village level workers (VLW) involved in development work should be avoided.
- Deployment of local youth and women require knowledge empowerment and guidance in business skills and to manage risk. Also, investment to establish unit for maize value chain in a PPPP mode can play a very important role by forming self help groups (SHGs) of producer companies, farmers' cooperative and assisting local youth to arrange credit from bank to establish above units. Success of such endevours will depend on integrity and competence of leaders involved with good professional support.
- Awards and incentives should be instituted to the progressive farmers, maize scientists, development workers including NGOs and private sectors for their outstanding work and involved them in decision making bodies.

Institutional Reforms and Enabling Policies

Farmer's should be sensilized by the initiatives taken by central government for doubling farmer's income and policy initiative to conserve natural resources such as, PM Irrigation programme, PM Agricultural Insurance, NFSM, RKVY, NHM, National Mission on Sustainable Agriculture, eNAM etc.

(a) Planning for Maize Research for Development

- The maize research and development planning should be done involving all stakeholders such as farmers, scientists, development and private sector personals, policy makers ensuring their support and commitment and to facilitate harmonized action keeping in view the inclusive growth of maize in a eco-regional perspective with small holder focus.
- Maize based cropping system, mechanization, value addition, reduction in food wastage, should be encouraged in PPPP mode with supportive policies by Government as coordinator and facilitator ensuring reliable and efficient supply of productive resources, services and delivery system enrolling women and youth engagement by providing aggressive training for skill upgradation for their empowerment and creation of non-farm rural employment.
- Summer (*Kharif*) maize research agenda should emerge from the farmer's field problems taking into consideration the Farmers led innovation by researchers to generate cost effective technology options built on farmers traditional knowledge to address the needs of farming areas to benefit small holders by helping to diversify maize farming system from supply driven to demand driven for overall growth for increasing productivity, profitability and environmental safety.

(b) Promoting Sustainable Intensification Practices

- The integrated resource conserving maize based farming system need to be scaled up urgently which has generated significant social, economic and environmental benefits. The small holder maize farmers have benefited and increased production, productivity and improved their livelihood, and income, while conserving natural resources, enhancing ecosystem services and adapting to and mitigating the effect of climate extremes under difficult farming conditions of water scarcity, soil hunger.
- There is need to review current programmes of support for adoption of RCT sustainable practices to maize with a view to eliminating 'perverse subsidies' that encourage harmful practices – such as over use of fertilizer, pesticide, water, that leads to loss of genetic resources.

Conclusion

There is enormous possibility to double maize farmer's income by improving productivity using new tools and techniques for developing most productive single cross normal and QPM maize hybrids having resilience to climate change and covering 80% maize areas in country. Also, integrating sustainable intensification of production and protection system is required by adapting CA and reducing cost on inputs, improving soil health, water use efficiency, by linking IFS, crop diversification and reducing environmental foot prints. Thrust on processing and value addition should be given involving gender and youth for outscaling demand driven innovations on new products, new information having bottom up approach through innovative extension, training and connecting farmers in PPPP mode to develop entrepreneurial skill in local youth alongwith enabling policies and institutional reforms.

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Paradigms in Vegetable Production for Doubling Farmers' Income

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Horticulture plays a vital role in our agricultural GDP and economy of India. Whereas, GDP from agriculture in India averaged Rs 3899.02 billion from 2011 until 2016 reaching at high of Rs.5217.45 billion. Horticulture is the largest group of valuable crops and providing employment to huge population of rural areas. Around 83.31crores (68.84%) Indian population live in 6,40,867 villages. Out of which, 58% depends on agriculture (Economic Survey, 2015-16). As per the land holding about 85% Indian farmers comes under category of small and marginal (Abdel Rahman *et al.,* 2016). Today, famers are facing new challenges in agriculture sectors, and getting nervousness due to low profit. Among agriculture, maximum production per unit area has been realized from vegetables. Hence, production of vegetable is attractive for small farmers but it can be done with supports to farmers through different government schemes.

It may be possible to double the farmer's income by producing vegetables and reducing postharvest losses with the help of new scientific technologies with current level of vegetable production (169.48 million tonnes) and considering about 20% post-harvest loss and 5% export and processing, per capita availability of vegetables (Fig.1) in our country is 227g as against 300g recommended dietary

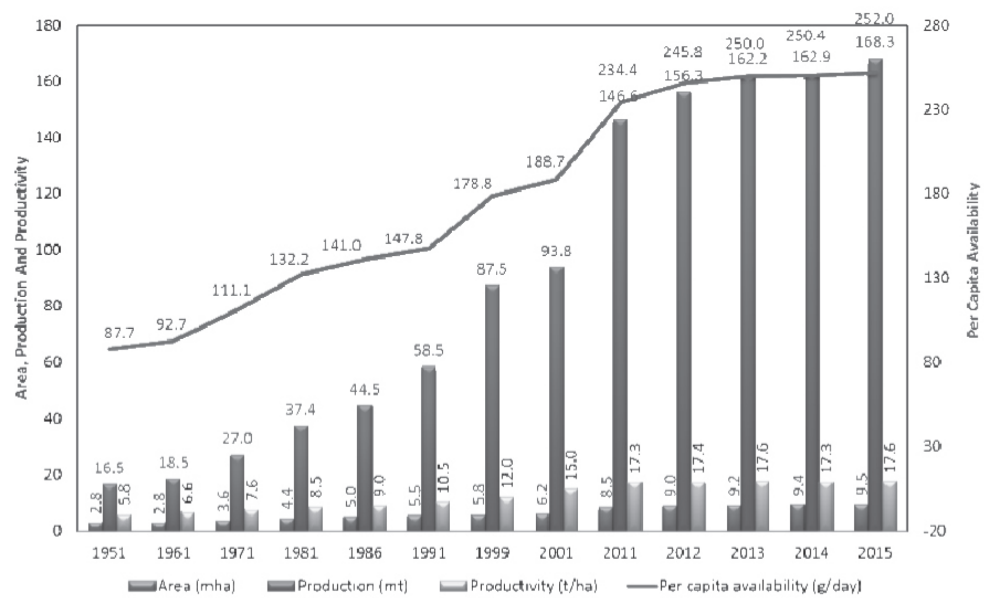

Fig. 1: Area, production and productivity of vegetable crops

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allowance (RDA). Thus now also we have shortage of about 50 million tonnes of vegetables. With the projected populations, the demand of vegetables in our country would be 190 million tonnes in2020, 210 million tonnes in 2030, 225 million tonnes in 2040 and 240million tonnes in 2050 (Vanitha *et al.*, 2013). In this context vegetable cultivation can play a key role to enhance the livelihood of farmers by doubling income through technological intervention (Report of Indian Council of Food and Agriculture, 2016). There is a need to develop the technologies at region wise as per farmers need and they should be motivated to adopt them for getting increased vegetable production and better profit.

Realization of yield potential in vegetables

Yield potential is also an issue in way of doubling farmer's income. There is large gap between experimental and yield harnessed by the farmers. In comparison of world vegetable productivity, India is far behind in most of the crop at present, which may be achieved by using good quality seeds and modern production technologies. The productivity of okra, cauliflower, onion and potato is at par with world productivity, while other vegetables having lower productivity (Table 1). The experimental productivity of most of the vegetables is higher than the world average productivity. There is urgent need to follow the strategies to enhance the present productivity upto level of potential productivity by, utilizing specific techniques which in turn will contribute to enhanced income of farming communities.

Table 1: Gap in Productivity (MT/ha) of major vegetable crops

Crop	India	World	Gap (MT/ha)
Okra	11.90	7.8	-4.1
Peas	8.90	8.35	0.55
Melons	22.47	24.88*	2.41
Cucumber	6.34	33.72*	27.38
Pumpkin	9.61	13.72*	4.11
Cabbage	22.6	29.2	6.6
Cauliflower & Brocli	19.8	18.2	-1.6
Onion	21.2	19.3	-1.9
Tomato	16.10	33.9	17.8
Eggplants	19.10	26.7	7.6
Chilli	1.9	14.4	12.5
Potato	21.1	18.9	-2.2

Source: *NHB, 2014-15; *FAO, 2015*

Ways for getting more profits from vegetables production

The cultivation of vegetables is getting more attention due to maximum net returns as compare to cereals in India. Many advance production and protection technologies including varieties/ hybrids have been developed and demonstrated, which has enabled India to double the vegetable production in last 15 years. There techniques are describes very briefly in the following section of manuscript.

Selection of newly developed hybrids and varieties

The ICAR research institutes, CAU's and SAU's have developed a number of varieties/hybrids of different vegetables for cultivation in various agro-climatic regions of the country having higher yield potential, earliness, improved quality (shape, size and colour) and better nutrition quality as well as better resistance to insect pest and adverse environmental condition. Many vegetable varieties and hybrids released and notified in India but resistant varieties and hybrids are limited. With quick multi-location testing facility available after the establishment of All India Coordinated Vegetable Improvement Project in 1970-71 and as a result of evaluating the promising breeding material developed at various research centres under multi-location testing programme of this project, a fast progress was witnessed in vegetable varietal improvement. As a result the AICRP (VC) has made strides in development and production of vegetables in a very short span of time. In four decades, 511 varieties in 27 vegetables crops have been identified for cultivation in different climatic zones. Among these, 311 are high yielding open pollinated, 148 are hybrids and 52 are resistant to diseases. The most important varieties developed by ICAR-IIVR are mentioned below.

Salient Features of Varieties/hybrids Developed by Indian Institute of Vegetable Research

Table 2: List of vegetable varieties/hybrids of ICAR-IIVR, Varanasi and their salient features

Crop and Variety /hybrid	Salient features
Tomato	
Kashi Vishesh	Determinate, fruit red, circular in shape, size medium to large, resistant to tomato leaf curl virus resistant yield 400-450 q/ha.
Kashi Amrit	Determinate, round or circular fruit shape, colour attractive red, suitable for cultivation under tomato leaf curl virus infested area, yield 620q/ha
Kashi Anupam	Determinate, fruits large, slightly flattened (indented at blossom end of fruit, >4 locules, medium maturity yield 500-600 q/ha.
Kashi Hemant	Determinate, concentrated fruit with attractive red colour and round or circular fruit shaped, yield 400-420 q/ha.
Kashi Sharad	Indeterminate, slightly oval shape, firm, and thick pericarp suitable for longer shelf life, yield 400-500 q/ha.
Kashi Abhimaan*	Determinate, moderate resistance to tomato leaf curl virus, fruits colour deep red, firm, yield 800-900 q/ha.
Brinjal	
Kashi Sandesh*	Fruits shape round, medium size, light purple, yield 750-800 q/ha.
Kashi Prakash	Fruit shape oblong, light green spotted colour, yield 650-700 q/ha.
Kashi Taru	Fruits long, glossy dark purple colour, suitable for summer and autumn seasons cultivation, yield 700-750q/ha.
Chilli	
Kashi Anmol	Determinate, fruit pendant, colour attractive green, suitable for green fruit production under chilli-wheat/ chilli-potato cropping system, yield 200 q/ha.
Kashi Surkh*	Fruits colour light green, suitable for green as well as red fruit production, green fruit yield 240q/ha, red fruit yield 140 q/ha.
Kashi Gaurav	Bushy plant, 50% flowering in 35-40 days after transplanting, tolerant to thrips and mites dark green and dark red colour, suitable for autumn-winter season cultivation, red ripe fruit yield 100 q/ha.
Kashi Sinduri (paprika type)	Plants determinate, moderately resistant to anthracnose, 50% flowering in 30-35 days after transplanting, fruits green at immature and dark red at ripe stage non-pungent and high oleoresin content (15 per cent), red ripe fruits yield 140 q/ha and green fruit yield 200-225 q/ha
French Bean	
Kashi Param	Determinate, fleshy Pod, round, colour dark green, green pod yield 120-140 q/ha.
Cowpea	
Kashi Gauri	Bushy plant, photo-insensitive, early maturing, suitable for sowing in both spring summer and rainy season, flowers in 35-38 days and pods get ready for harvest in 45-48 days, pods 25-30 cm long, light green, resistant to golden mosaic virus and *Psedocercospora cruenta*, green pods yield 100-120 q/ha.
Kashi Unnati	Bushy plant type, photo, insensitive, early variety suitable for sowing in both spring summer and rainy season, individual plant bears 40-45 pods, resistant to golden mosaic virus and *Psedocercospora cruenta*, green pods yield 100-150 q/ha.
Kashi Kanchan	Bushy plant, photo, insensitive, early maturing suitable for sowing in both spring summer and rainy season, produces 40-45 pods per plant, average pod length of 30-35 cm. pods dark green, tender, pulpy and less fibrous, resistant to golden mosaic virus and *Psedocercospora cruenta*, green pod yield 150-200 q/ha
Kashi Nidhi	Plant dwarf, medium maturing, sowing in both spring summer and rainy season, 25-30 pods per plant, average pod length 25-30cm, pod colour green, moderate resistant to golden mosaic virus, green pods yield 35-140 q/ha.
Pea	
Kashi Nandini	Early (50% plants bears flowers at 34 days after sowing), 7-8 pods per plant, pods length 8-9cm, pod filled with 8-9 seeds, shelling percentage 47-48, yield of 110-120 q/ha.
Kashi Udai	Early (50% plants bear flowers at 35-37 days after sowing), 8-10 pods per plant. Pods length 9-10 cm, pod filled with 8-9 bold seed, selling percentage 48, yield 100-110 q/ha.
Kashi Shakti	Medium maturing (50% plants bear flowers at 54-56 days after sowing), 11-12 pods per plant, Pods length 10-11 cm, pod filled with 7.5-8.5 bold seed, selling percentage 48-49, yield 140-160 q/ha.
Kashi Mukti	Early maturing powdery mildew resistant variety. Plant height is 50-53 cm and 50% plants bear flowers at 35-36 days after sowing. Foliage light green, pods are 8.5-9 cm long, attractive filled with 8-9 bold, soft textured seeds, selling percentage 48-49 and yield 11-12 t/ha.
Kashi Samridhi	Late maturing (60-63 days for 50 % flowering), powdery mildew resistant, Pod green in colour, 13-14 pods per plant, shelling percentage 46-48, yield 120-140 q/ha.

Crop and Variety /hybrid	Salient features
Dolichos Bean	
Kashi Haritima	Pole type, 250-300 pods per plant, average pod length of 14-15cm, pods colour green, soft in texture, free from parchment layer, yield 350-375 q/ha.
Okra	
Shitla Jyoti*	Flowering starts 30-40 days after sowing, resistant to YVMV and OLCV, fruit colour green, length 12-14 cm at marketable stage and yield 20-22 t/ha.
Kashi Vibhuti	Flowering starts on 4th to 5th nodes after 38-40 days after sowing, resistant to YVMV and OLCV, individual plant bears 18-22 fruits with 8-10 length cm at marketable stage and yield 170-180 q/ha.
Kashi Pragati	First flower appears after 36-38 days after sowing, resistant to YVMV and OLCV, single plant bears 23-25 fruits of 8-10 cm length at marketable stage, yield 180-190 q/ha in rainy and 130-140 q/ha in summer season.
Kashi Satdhari	Seven ridges variety resistant against YVMV under field condition, flowering starts 42 days after sowing, individual plant bears 18-25 fruits of 13-15 cm length at marketable stage, yield 110-140 q/ha.
Kashi Lila	Flowering starts 30-34 days after sowing resistant to YVMV, suitable for rainy and summer season cultivation as early crop due to low temperature tolerance, fruits green 13-15 cm long. yield 150-170 q/ha.
Kashi Bhairav*	Fruit colour dark green, resistant to YVMV and OLCV under field condition, length 10-12 cm at marketable stage, yield 160-180 q/ha.
Kashi Kranti	First harvest starts 45-46 days after seed sowing, resistant to YVMV and OLCV, fruits dark green,. Individual plants bears about 17-18 fruits of 8-10 cm length, suitable for cultivation in summer and rainy season, yield 125-145 q/ha.
Kashi Mohini	Plants are tall, height 110-140 cm, flowers at 4-5 node during summer and 5-7 nodes during rainy season after 39-41 days of sowing, fruits five ridges, 11.3-12.6 cm long at marketable stage, suitable for summer and rainy season cultivation; gives yield of 130 -150 q/ha. It tolerate high temperature during summer season and resistant to YVMV under field conditions.
Kashi Mahima	Plants of this hybrid are tall, height 130-170 cm, flowering starts at 36-40 days after sowing at 4-5 nodes, fruits green with 12-14 cm of length at marketable stage and yield 200-220 q/ha. This has shown field resistance against YVMV and OLCV.
Kashi Mangali	Plants are tall, height 120-125 cm, flowers at 4 to 5 node after 40-42 days after sowing, fruits five ridges, light green; yield 130 -150 q/ha. This is resistant to YVMV and OLCV under field conditions and stands high temperature during summer season.
Shitla Uphar*	Plants are medium tall, height 110-130 cm, flowering starts at 38-40 days after sowing at 4-5 nodes. Fruits are green, 11-13 cm long at marketable stage and yield 150-170 q/ha.
Radish	
Kashi Sweta	Early harvesting (30-35 days after sowing), Roots 25-30 cm long, 3.3-4.0 cm in diameter, straight, tapering with pointed tip, yield 450-470 q/ha.
Kashi Hans	Suitable for September to February planting, ready for harvest after 40-45 days of sowing, 10-15 days can tolerate the pithiness, leaves are soft and smooth like spinach, roots straight and tapering type, 30-35 cm long and 3.5-4.2 cm in diameter, yield 430-450 q/ha.
Cauliflower	
Kashi Kunwari	Early maturing group variety, suitable time of sowing-end of June to July, curds semi-dome type, white compact; fine texture, average weight 300-450 g, yield 300-350 q/ha.
Muskmelon	
Kashi Madhu	Fruits round, with open prominent green sutures, weight 650-725 g, half-slip in nature, flesh salomon orange, thick, with 13-14 % T.S.S., medium maturity, long Post harvest life, tolerant to powdery and downy mildew, yield 200-270 q/ha.
Ash Gourd	
Kashi Dhawal	Fruits oblong, average weight 11-12 kg, fruit flesh white with 8.5-8.7 cm thickness, seed arrangements linear, crop duration 120 days, yield 550-600 q/ha, suitable for preparation of Petha sweets due to high flesh recovery.Less seeded fruits with average weight of 10-12 kg with globular in shape, yield 400-500 q/ha, suitable for preparation of Petha sweets due to high flesh recovery.Oblong shape fruit, medium in size (9.5-10 kg), flesh white with 8.5-8.7 cm thickness, 2.5-3.0 fruit per plant, high flesh recovery, suitable for preparation of Petha sweets, yield 700-750 q/ha.
Kasi Ujwal	
Kashi Surbhi	
Pumpkin	
Kashi Harit	Vine short, early maturing, fruits colour green, spherical shape, weight 2.5-3.0 kg at green stage, best for green fruit production, yield 300-350 q/ha.

Bottle Gourd	
Kashi Bahar*	Long fruit, single plant bears 12 light green straight fruits of 30-32 cm length and 780-850g weight, suitable for both season cultivation (rainy and summer), yield 500-550 q/ha.Fruit light green, 30 cm length, 7cm diameter, fruit weight 800-900g, yield 480-550 q/ha, suitable for *Kharif* and summer season cultivation.
Kashi Ganga	
Sponge Gourd	
Kashi Divya	Fruiting starts 48-50 days after sowing, single plant bears 10-12 light green fruits of 15-16 cm length, each of 80-85g, suitable for rainy and summer season cultivation, yield 250-300 q/ha.
Ridge Gourd	
Khashi Shivani	Fruits are green, long straight (20-30 cm and may increase on bower up to 40cm) with a diameter of 3-4 cm. Average fruit weight ranges from 100 g to 150g. Fruits will be ready for harvest after 50-60 days from the date of sowing. The yield potential of this variety is 180-200 q/ha.Resistant to Anthracnose and tolerant to downy and powdery mildew disease under field condition. It is also tolerant to leaf minor, fruit fly and red pumpkin beetle under field condition.
Pointed Gourd	
Kashi Alankar	Fruits colour green, spindle in shape and striped at distal end of the fruit, single plant bears 120-130 fruits of 6.7 cm length and each weighing 25-27g, yield 180-200 q/ha.

*Hybrid

Besides the development of a number of high yielding varieties, efforts have been made to develop several packages of practices for getting maximum economic return. According to vegetable statics published by ICAR-IIVR (2015), profit by production of major vegetables *viz.* tomato, brinjal, chilli, and cowpea etc., recorded from last five years and showed a satisfactory results in income generated and net return (Table 3).

Table 3: Impact of vegetable varieties /hybrids over last five years (2010-2015)

Crop	Variety/F_1hybrid	Area covered (ha)	Net Return (Rs. In Crore)
Tomato	Arka Vikas	401308.00	2006.00
Tomato	Arka Rakshak (F1)	150.00	1.50
Tomato	Utkal Kumari	35525.00	850.00
Tomato	Utkal Dipti	13125.00	200.00
Brinjal	Arka Keshav	159215.00	796.00
Brinjal	Utkal Anushree	17410.00	345.00
Cowpea	Kashi Kanchan	839524.39	41976.25
Chilli	Arka Lohit	5,88,880.00	4711.00
Chilli	Arka Meghana (F_1)	60.00	1.56
Chilli	Utkal Ava	13550.00	340.00
Chilli Hybrid	CH-1	35000.00	144.00
Pea	Punjab-89	30000.00	112.00

Technological Interventions to Increase the Profit of Farmers

Identifying and selecting the profitable cash vegetable crops to grow is the most crucial factor in a successful commercial farming business. The selection of underutilized vegetables for cultivation especially nearby cities gives good profit. The production of vegetables in Indian utilizing modern techniques like precision farming, healthy seedling management, mulching and fertigation, bower system, protected cultivation, grafting and use of pollinators needs to be follow to get better returns.

Precision farming techniques: Precision farming provides opportunities for attracting and retaining youth in vegetable farming. It can be adopted by a group of vegetable farmers who can organise themselves into a precision farming group. This would help to reduce expenditure and enhance productivity and profitability. A farmer of Pullagoundan pudur village, Coimbatore district, Tamil Nadu practiced the precision farming as a group for growing vegetable crops (Source: NAIP Sub-Project, 2017). He planned to cultivate onion, tomato, brinjal, cauliflower, chilies and turmeric. He got high yield and quality farm produce by using sufficient water and fertilizers at regular interval. Particularly onion fetched high price in markets because of good quality. Retailers came to field to take the produce directly. He spent Rs. 3, 35,400 for cultivation practices and got high profit of Rs. 9,66,000 per hectare from turmeric, onion, chillies and coriander. Other farmers of his area are also practicing precision farming and getting benefits.

Healthy seedling management: The supply of nursery on demand to the farmer's door is one of the latest business model adopted by the farmers of the Punjab. This practice may generate the employment and reduce the cost of production by minimizing the seed cost and time. Modern nursery raising under protected conditions gives disease free plants particularly viruses. Many vegetable crops are grown through seedling but some vegetables don't like to be transplanted which in include cucurbits and many of the root crops, such as carrots, beets, turnips, and parsnips etc. Crops like corn, beans, and peas are also growing better by direct-seeding in the field. Either seed of these crops can be grown in pro-trays using sterile cocopit growing medium for a short time compared to permanent potted plants, their fertilizer requirements are more immediate. These plug trays should be kept under poly or net house. Before sowing the seeds, the growing media should be watered and allowed to dry for 24 hrs. Don't over harden your plants. Whereas, in other vegetables like chilli, brinjal, tomato etc. seeds direct shown on bed or in pots, and at proper stage these seedlings transferred to main field. Usually seedlings will be ready for transplanting in 18-21 days after sowing. Hardening of seedlings under open sunlight should be done for 2-3 days before transplanting. Certain crops, such as cabbage and broccoli, can *bolt* (before flowering) quickly if seedlings over three weeks old are repeatedly exposed to temperatures lower than 4°C for a couple of weeks. For healthy seedling sprays the insecticides and fungicides timely as require.

Mulching and drip irrigation to maximize the profitability: Healthy vegetable crops are grown by using polythene mulch and drip irrigation. Fertilizers are given with help of drip irrigation. This insures uniform application of fertilizer and water near root biosphere. Critical stages when moisture stress is more critical are (a) at transplanting, b) early flowering stage and c) fruit development stage. Moisture stress at flowering stage results poor fruit set and bitterness of fruits in ridge gourd. Moisture stress during fruit development greatly reduced fruit size. Black polythene mulch should be used during winter season (low temperature) whereas reflective mulch is used during summer (high temperature). Reflective mulch also repels aphids and jassids. The use of mulch reduces the weed infestation; increase water and nutrient use efficiency and reduce fruit rotting. About 40-80% higher marketable yield has been reported in mulch and fertigation culture as compared to without much and drip irrigation makes vegetables more profitable. In rainfed areas, where water is limiting factor, gravity operated drip irrigation system may be helpful to get optimum yield in vegetable crops.

Bower system for growing cucurbits and high density planting: Generally farmers grow vegetable crops on ground in open field or in pot under control conditions. Therefore, the using of bower facilitates in vegetables for low cast of irrigation, easy pest management, uniform fruit shape, colour, increase harvesting efficiency and high yield. Small farmers are using these methods for low cost trickle irrigation system, less labour requirements, for better yield and quality of vegetable crops. In case of cucurbits it has been observed that if vines are allowed on the ground, nearly 25-30% less yield has been recorded and 8-10% fruits become unmarketable due to misshaping and discoloration. The planting distance of crops can be reduced and plant population per unit area increased by training of plants on bower system, which increases the fruit yield.

Protected cultivation: Protected cultivation of vegetables is providing opportunities for improving quality, productivity and favourable market price to the growers by reducing climatic extremes (temperature, rainfall, pest incursion) in hot and cool areas. The National Horticulture Board provides financial support for developing protected cultivation infrastructure. Although Vegetable growers can substantially increase their income by protected cultivation of vegetables in off-season as the vegetables produced during their normal season generally do not fetch good returns due to large availability of these vegetable in the markets. Insect proof net houses can be used to reduce pest and pesticide levels and make virus-free cultivation of tomato, chilli, sweet pepper and other vegetables during the rainy season (Singh and Sirohi, 2006). Parthenocarpic cucumber production under protected cultivation gives very high yield with quality fruit. Low cost greenhouses can be used for high quality vegetable cultivation for long duration (6-10 months) to obtain appropriate price of produces.

Grafting to boost vegetable production: Grafting is the union of two or more pieces of living plant tissue that grow as a single plant. Grafting vegetable plant onto resistant rootstocks is an effective tool that may enable the susceptible scion to control soil-borne diseases, environmental stresses (resistance against low and high temperatures) and increase yield and quality of vegetable fruit (Rouphael *et al.*, 2010). Besides, it is also used to alter hormonal production which in turn influences sex expression and flowering order of grafted plants. The cultivated area of grafted vegetables, as well as the kinds of vegetables being grafted, has been consistently increased. At present, most of the watermelons *Citrullus lanatus* (Thunb.) Matsum. & Nakai, oriental melons (*Cucumis melo* var. makuwa Makino), greenhouse cucumbers (*Cucumis sativus* L.), and several *Solanaceous* crops like tomato, chilli, and brinjal are used for grafting before being transplanted to the field or greenhouse (Lee*et al.*, 2010). The purpose of grafting also has been greatly expanded, to increasing low-temperature and salt and wet-soil tolerance, enhancing water and nutrient uptake and increasing plant vigor and extending the duration of economical harvest time (Lee *et al.*, 2010).

Hydroponics: A soilless vegetable production system: Hydroponics refers to the practice of growing plants in nutrient solutions. This can be done either in liquid systems or in aggregate systems in which the plants are planted in a soilless media consisting of substances such as vermiculite, peralite, sand, coconut coir, expanded rock, gravel, rockwool or peat to provide mechanical support. Here roots of the plants are floated in nutrient solution provided with circulating air or bubbling air. This technology is also suited for high value vegetable like tomato, capsicum, cucumber and for leafy vegetables etc. Using hydroponics systems, mineral nutrients are dissolved in water and feed directly to a plant's root system allowing the plants to focus their energy into growing mostly upward, promoting quicker growth, faster harvests and higher yields. Hydroponics systems are used year-round both indoors and outdoors for growing vegetables. The main advantages of hydroponics are soilless cultivation, less use of water, nutrient, safe vegetable and high yield. Whereas disadvantage is high moisture levels associated with hydroponics and overwatering facilitate occurrence of some diseases and initiating cost of infrastructure is more. If you have limited space and cannot form a full-fledged vegetable garden, hydroponic gardening would be a rewarding experience. In India, the Defence Laboratory, Haldwani in Uttaranchal is doing extensive research work on hydroponics.

Post-harvest technology and supply chain assured better price: Due to 15-20% post harvest losses, an efficient post harvest management has become an absolute necessity. This loss is not only in form of produce in money but also wastage of labour, energy and inputs involved in production of vegetable crops. If farmers can be trained for pre and post-harvest management and value addition, can increased the incremental advantaged over actual income. In India, consumption of fresh vegetable is more preferred as compared to frozen or refrigerated. This is due un-affordability of refrigerator by households living in the rural areas. Even in urban areas, modern consumers do not want store vegetable products for longer periods within the household due to concern of taste, flavour, and texture and health consciousness. Therefore, challenges are to refine methods for short term storage, so that premium quality is retained rather than to focus on longer term storage for prolonged marketing. Harvesting at right maturity is the most important determinant of storage life and finally its quality. Many vegetables, for example, leafy vegetables and fruit vegetables which is harvested for consumption at immature stage (such as cucumbers, bottle gourd, okra, brinjal, pumpkin, beans, peas, and green chilli), attain optimum eating quality prior to reaching full maturity. Delay harvesting of these vegetables leads to low quality produce.

Most of the fresh vegetables are harvested by hands. Better management during harvesting operations, have a major impact on the quality of harvested vegetables. Proper management practices include selection of optimum time to harvest in relation to crop maturity and time of harvesting. Immediate cooling after harvest, maintenance of optimum temperatures during transportation and storage are important factors in the successful post-harvest handling of vegetables. It should be noted that any practice that reduces the number of produce handling steps will help minimize losses. Field packing (selection, sorting, trimming, and packaging) of produce at the time of harvest can greatly reduce the number of handling steps in preparation vegetables for marketing. The use of mobile field packing stations with adequate shading should be encouraged for broccoli, cauliflower, cabbage, cowpea, etc., beans because these vegetables, do not require washing before transporting to market. Low cost safe storage structures for small and intermediate scale farmers need to be promoted. Over the last few years, there has been a positive growth in ready to serve beverages, juices, dehydrated and frozen vegetable products, pickles, convenience veg-spice pastes, processed mushrooms, and curried vegetables. Besides processing of major vegetable for various value added products, Indian processing industries are also looking for value added products from minor or underutilized crops also. There are few ICAR- IIVR vegetable products *viz.* ,vegetable slices, steeping preserved carrot, french bean, pointed gourd and cauliflower etc. using for ready to eat.

Year-round supply of vegetables to get continuous income through off season production: Many vegetables have now a gross over-supply during a very concentrated production season while, during off season, supply is very less. Vegetables are highly perishable products, restricting the ability of producers to store them in order to cope with price fluctuations. The year-round provision of safe, nutritious vegetable crops to consumers can be assured through better transport facility of locally-produced vegetable, extending the production season and good storage condition. Development and expansion of supermarket chain can also play an important role to increase the availability of vegetables. Popularization of indigenous vegetable and production under greenhouses should be also considered.

Protected cultivation is providing opportunities for improving productivity by reducing climatic extremes (temperature, rainfall, pest incursion) in hot and cool areas. The National Horticulture Board provides financial support for developing protected cultivation infrastructure. Although systems are expensive but yield increases of up to 300 % for high value and high quality produce compensate costs. Walk-in tunnels (including low-cost structures) have been evaluated for off-season vegetable particularity and seedling production. Insect-proof houses are also being used to reduce pest levels, pesticide use and virus incursions. Parthenocarpic cucumber, capsicum and indeterminate tomato production under controlled condition gives very high yield with quality fruit.

Integrated pest management: Insect pests are the major biotic constraints in vegetables production in India. Apart from causing direct damage they also act as vectors for several viral diseases. Average yield loss due to major insect pests in different parts of the country is reported to vary from 33 to 40 per cent. Among these tomato fruit borer (*Helicoverpa armigera*), brinjal shoot and fruit borer (*Leucinodes orbonalis*), chilli thrips (*Scirtothrips dorsalis*) and mite (*Polyphago tarsonemus latus*), fruit and shoot borer (*Earis* spp.) on okra, diamondback moth (*Plutella xylostella*) on cole crops, fruit fly (*Bactrocera cucurbitae*) on cucurbits are important ones. In recent context of changing agro-ecosystems and climate, several other insect pests such has serpentine tomato leaf miner, brinjal gall midge, okra stem fly, white fly, *Maruca*, fruit fly, giant African snail and bitter gourd leafhopper gradually attaining the major pest status in different regions of the country and adding to heavy loss of crops. Earlier gall midge known to be a minor pest is gradually becoming a regular problem in chilli, capsicum and brinjal in the states of A.P., Karnataka and in brinjal in Chattisgarh, whereas *Hellula undalis* on cabbage and red spider mite on okra, brinjal, cowpea, Indian bean, etc., have intensified the severity of occurrence. Few new pests have emerged and are of great concern to vegetable growers.

Among farmers, chemical method of control still enjoys first choice because of its easy availability and quick action. In India, only 25-30 per cent of the total cultivated area is under pesticide cover. Per hectare consumption of pesticide in India is around 381g a.i./ha which is lower than the world average of 500g a.i/ha. It is estimated that around 13-14 % of total pesticides used in the country are applied on vegetables, of which insecticides account for two-thirds of total pesticides used in vegetables (Kodandaram *et al.*, 2013). However, some of the tolerant varieties/lines have been identified against major insect pests and being used as one of the major components of Integrated Pest Management (IPM). Research conducted under All India Coordinated Research Programme (AICRP) on Vegetable Crops (AICRP-VC), Indian Institute of Vegetable Research (IIVR), Varanasi and Indian Institute of Horticultural Research (IIHR), Bangalore have developed several regional/location specific IPM technologies for many important pests of vegetables. Through AICRP (VC) alone a total eighty six technologies have been developed in 11 important vegetable crops (Fig. 2).

Integrated disease management: Vegetables are short duration crops and amenable to attack by various kind of diseases during their production. Occurrence of the disease is based on interaction of crop, environment and pathogen types. A huge crop loss is expected when all the three factors are favourable. In general, 30-80% crop losses have been recorded in different vegetables due to diseases. Among the diseases, wilt and leaf spot are considered to be the major threat to vegetable cultivation. *Phytopthora*, *Fusarium*, *Verticillium* and *Ralstonia* are predominant genus causing wilt diseases while *Alternaria*, *Cercospora*, *Colletotrichum, Pseudosperanospora, Erysiphe, Phomopsis* and *Xanthomonas* are causal agents of leaf spot diseases. Apart from this, major menace to vegetable production is due to viral diseases especially caused by leaf curl and spotted wilt viruses.

Use of pollinators: Honeybees, mainly *Apis mellifera*, remain the most economically valuable pollinators for vegetables grown in protected or open field conditions worldwide. In most developing countries, crop production is by small scale farmers, who mainly produce for their own consumption and the extra for market. One of the reasons of not managing pollination is the lack of understanding of its economic value. Generally, 3-4 bee hives are required per acre in vegetable crops for proper pollination and fruit set has been recorded 15-20% which was increased. For better fruit yield and quality, 81 bee visits per flowers are required. Farmers should use pesticides very judicially and only if necessary, pesticides should be applied in the evening. In an experiment many pollinators was used to increase the yield of *Solanum lycopersicum*, *Capsicum frutescens* and *Solanum melongena* and results indicated that these crops are found with greater fruit set (Kasina *et al.*, 2009). Almost 40% of the annual value of crops increased from bee pollination while more than 99% of this benefit is attributed to pollination by feral bees.

Issues and Challenges

Although the future of vegetable production seems very bright with the adaptation of some techniques for increasing farmer income but the issues that hinder a smooth walk for the adaptation of these techniques in the vegetable sector, are listed below:

- Inadequate supply of quality seed/planting materials of improved cultivars.
- Lack of maintenance breeding of released and notified varieties.
- Lack of vegetable varieties suitable for processing and value addition.
- Non-exploitation of off-season vegetables production technology.
- Lack of anticipatory research to mitigate the global climate change.
- Lack of adequate storage facilities of vegetable produce and seeds.
- Lack of branding and marketing intelligence.
- High incidence of pest and diseases.

Conclusion

The farmers are shifted towards vegetable farming due to more profit as compare to cereals cultivation. Being high perishable nature of vegetables, there is needed to generate the storage and marketing facilities. India has about 6000 cold storage units and they are not very well suited for the fresh vegetables except potatoes. Just after harvesting, farmer's has to sell their produce in current market price, unlike grains that can be hold for a longer time. The cool chain facility should be increased, so produce can be marketed in other part of country where demand is more. Vegetable commodities should be supported by minimum hold price, it will help to reduce the holding of stocks by middleman and farmers will also get better price in open market and may be escape from price volatility. Vegetables are more vulnerable to adverse weather, leading to higher risk of crop failure. Therefore, crop insurance scheme to the farmers may be friendly.

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New Paradigm in Fruit Production and Management for Doubling Farmers' Income

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India stands 2nd in fruit production after China which is due to the favourable agro-climatic conditions so that a wide range fruit crops such as temperate, tropical, subtropical and arid zone fruits are being cultivated. There is an increasing trend in area, production, and productivity of fruit crops from 2001 to 2015 (4.01 million ha to 7.21 million ha, 43.00 to 88.97 million tonnes and 10.70 to 12.30 t/ha) (Anonymous, 2015). Out of the total production, the contribution of each fruits viz., banana (33.4%), mango (20.70%), papaya (6.30%), guava (4.1%), grapes (2.9%), apple (2.8%), sapota (2.8%), pineapple (2.0%), pomegranate (1.5%), litchi (0.7%) and others is (11.1%). There is a growing awareness about the climate change and its impact across the globe and at present the cultivation of fruit crops are not easy due to various factors such as shrinking land and water resources; high input and labour cost; uncertainties of market prices and highly perishable nature of fruits. According to global climate change prediction models, the area under grain crops are going to decline, on the other hand there will be increase in area under horticultural crops. High value commodities, particularly horticulture, livestock, and marine products, are highly expenditure elastic compared with grains (Kumar *et al*., 2007). Given rising incomes and higher expenditure elasticity for these commodities, future growth is likely to come from the high value sector (Gulati and Ganguly, 2008).

The horticultural crops based diversification is becoming attractive due to adoption for many poor farmers around the world. Among horticultural crops, the fruit trees are typically multipurpose in that they provide not only fruits but also has varied uses viz., for medicinal products, livestock fodder, as well as fuel wood and timber at the end of their productive lives. In addition to economic benefits, fruit trees provide greatly to ecosystem services. The Government of India has come out with a slogan "Doubling farmer's income by 2022" by focusing not only on increasing crop yields but also on reducing the cost of cultivation to increase the net income of farmers. The following are some of the varieties and technologies, which can increase the farmers' income many folds. Thetechnologies such as hybrid seeds, use of rootstocks, quality planting material production, precision farming, ultra high density planting, protected cultivation, drip fertigation, canopy management and post harvest and value addition technologies can increase the farmers income to many folds. The details are discussed here under;

Hybrids/hybrid Seed Technology

Hybrid seed production involves prevention of self and interline pollinations and effective cross pollination of the female line with the pollen of the male line in hybrid seed production plots. The success of hybrid seed technology depends on the cost of producing hybrid seeds which is largely determined by the method used for management of required pollinators. During hybrid seed production, many methods can be used to prevent self-pollination of the female line: mechanical removal of anthers or male flowers, application of male-specific gametocides, or use of genetic cytoplasmic or nuclear-encoded male sterility. There are many

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hybrids in vegetable crops, fruit crops, flower crops and plantation crops. In fruit crops, a total of 210 varieties/hybrids have been released over the last 100 years of fruit breeding of which 89 varieties have been released in last 25 years. Among the released, 70 per cent of the varieties are from clonal selection and 30 per cent are hybrids. The prominent selections are L-49 (Sardar Guava), Coorg Honey Dew Papaya, Nagpur Mandarin, Coorg Mandarin, clones of Anab-e-Shahi (Tas-e-Ganesh, Sonaka & Manak Chaman) & Kishmish Cherni (Sharad Seedless, Saritha Seedless & Krishna Seedless) grapes, jamun (Konkan Bahadoli & Dhupdal) and Jack fruit (PLR-1 & Dubgere), lime (Vikram, Balaji, Primalini, Jai Dev& Saisharbathi) popular in farmer's. Several excellent high yielding hybrids of mango (Amrapali, Mallika, Pusa Surya, Ambika & Arka Udaya) papaya (CO7, Arka Surya & Arka Prabhat) , banana (Udayan & Co1), guava (Arka Kiran, Lalit & Swetha), pomegranate (Bhagwa & Ruby), custard apple (Arka Sahan) and passion fruit (Kaveri) have been released for cultivation by the various research institutes and SAU's to meet the domestic and international need. Seed is the commercial and practical means of multiplication of certain fruit crops *viz*., papaya, mangosteen & phalsa. At certain times during the cropping period there are many instances when farmers do not get price for their commodities. Seed production, quality assurance and marketing are highly important in the present scenario. To meet the seed demand the seed village concept can be well adopted with this method a particular variety may be multiplied in whole village which can solve the problem of isolation in case of cross pollinated crops and genetic purity. The hybrid seed production and nursery business both are considered to be the profitable venture.

Use of Rootstocks

The rootstocks are recommended against a particular situation for successful fruit production. However, the multiplication of those rootstocks in sufficient numbers with assured quality is not available for large scale propagation in those regions affected by abiotic stress viz., as salinity, alkalinity and drought and biotic stresses such as nematodes and pests. While these rootstocks possess the resistance / tolerance attributes, the quality of the produce by using these root stocks may become another problem in certain situations. This has led to the situation at present wherein the plants produced by private nurserymen are procured by majority of the growers as alternate sources for raising the planting materials. The need in rootstock today is the creation of variability for rootstocks. An example that can be quoted here is the case of 'Dogridge' rootstock which has revolutionized the grape industry in India. Out of 1.2 million ha, about 90 per cent of the grape growing area is under 'Dogridge' rootstock as it possess tolerant drought, salinity and nematodes. Similarly, the polyembryonic mango varieties such as Vellaikolumban, Olur, 13-1 & Kurukan are gaining the popularity in India. In guava, the var.Pusa Srijan and *Psidium molle* are commonly used to induce dwarf and wilt tolerance.

Quality Planting Material Production

The production and supply of genuine high quality-planting materials either seeds or grafts is of great concern due to the high demand from the farmers. The working group on horticulture under 'Nithi Ayog' has projected 4 fold increase in demand for planting materials of horticultural crops. The plant tissue culture technology has been very successful as an industry and has greatly contributed to the success, as it has advantages such as large-scale multiplication in lesser time, production of virus-free plants and year-round production. The demand for tissue culture banana has increased at a very high rate of 25-30% and there is growing awareness of superiority of tissue-cultured plants. The demand for crops like banana, grapes, papaya, ginger, turmeric, cardamom, vanilla, and potato, Jatropha is increasing. In 2006, Government of India established the "National Certification System for Tissue Culture Raised Plants (NCS-TCP)" authorizing the Department of Biotechnology, Ministry of Science & Technology as the certification agency vide the Gazette Notification dated 10th March 2006 under the "Seeds Act, 1966" for ensuring production and distribution of quality tissue culture planting materials. The purpose of NCS-TCP is to ensure production and distribution of quality tissue culture planting materials. NCS-TCP is a unique quality management system, first of its kind in the world, which ensures recognition of tissue culture production facility for the production of quality planting material and certification of end products. The technique of micro-grafting is now routinely applied to the recovery of Citrus clones from virus diseases. It consists of "*in vitro*" grafting of an excised shoot tip apex onto *in vitro* raised and decapitated seedlings as rootstock (Navarro *et al.,* 1981). Applying this technique numerous clones of Clementine, sweet orange, lemon and of other species of Citrus have been recovered from all the virus diseases by various research workers. In India, this technique has been standardized for Nagpur mandarin. Protected cultivation of fruit crops viz., papaya in certain regions of the country help in overcoming the problem of 'PRSV'. This will help in the quality production of fruits.

Ultra high Density Planting

Due to urbanization and population explosion there is a continuous decline in the availability of cultivable land. The rising input costs together with the mounting demand for horticultural produce, has led to the adoption of high density planting (HDP) in fruit crops. HDP is one of the important methods to achieve high productivity per unit area both in short duration and perennial horticultural crops. The five important components of HDP are (i) dwarf scion varieties, (ii) dwarf rootstocks and inter-stocks, (iii) training and pruning, (iv) use of chemicals/PGR, and (v) suitable crop management practices being followed in a successful HDP method. Mango plants are generally planted at a distance of 10 to 12 m, which can accommodate about 70 to 100 plants/ha, while Amrapali variety has been recommended by IARI to be grown at 2.5 x 2.5 m (triangular method) and accommodating 1,600 plants/ha yielded up to 22 t/ha. The high-density orchard provides several times (8-9) higher yields than the traditional densities (Gunjate *et al.,* 2009). Dashehari mango at 2.5m x 3m (1,333 plants/ha) can also be raised under HDP with pruning and dehorning after the harvesting. HDP has also been achieved with the application of paclobutrazol. Successful HDP (666 plants/ha) plantations of different commercial varieties viz., Kesar, Alphonso, Tommy Atkins, etc. has been demonstrated by the Reliance Agro Ltd. at Jamnagar (Gujarat) under arid agro-climate (Bhosale, 2012). In guava, meadow orcharding was foundsuitable for ultra high-density system of planting at CISH, Lucknow. The meadow orchard system of guava accommodates 5000 plants/ ha, at a spacing of 2.0 x 1.0 m and managed with regular topping and hedging during initial stages, which help in controlling tree size and extending fruit availability (Singh, 2008). Dwarf Cavendish and Robusta are fit to be planted under high density at a distance of 1.2m X 1.2m (6,944 plants/ha) in a rectangular system. Yield realization varies from 86 t/ ha in Basarai at 1.5 x 1.5 m to 174 t/ha in Robusta planted at 1.2 m x 1.2 m spacing (Athani *et al.,* 2009; Prabhu, 2012). Dwarf varieties of papayalike Pusa Dwarf, Pusa Nanha and Ranchi make possible to grow papaya under the HDP concept. Normally, papaya varieties are planted at a distance of 2.5 m X 3 m or 2.5m X 2.5 m, which accommodates 1,333 to 1,600 plants/ha, while Pusa Nanha may be planted at a distance of 1.25 x 1.25m (6,400 plants/ha). Such orchards may give 3 to 4 times higher yields (60 to 65 tonnes/ha) in comparison to the yield of the traditional orchards (15 to 20 t/ha) with the superb combination of drip irrigation with dwarf varieties. Other varieties like CO-1, CO-2, Pusa Dwarf and Honey Dew-1 are also suitable for high density planting (Bhosale, 2012). In Citrus, high-density orchard is also possible using Troyer Citrange rootstocks at closure planting (1.8 x 1.8 m) accommodates 3086 trees/ha. Kew and Queen cultivars of Pineapple are suitable for HDP using double row method of the planting suckers or slips spaced at 25 to 30 cm in the rows at a distance of 45 to 60 cm with spacing of 90 to 105 cm between the beds (63,000 plants/ha). There is ample scope for expanding area under HDP for the benefit of the fruit growers through higher productivity. The average productivity of pineapple is 15.4 ton/ha but with the adoption of HDP and modification of planting system higher yield can be obtained. The highest fruit yield (61 ton/ha) in Kew cultivars may achieve with a population of 63700 by following 22.5x60x75cm (Plant x Row x Trench) spacing.

Canopy Management

The basic concept in canopy management of a perennial tree is to make the best use of the land, the climatic factors for an increased productivity in a three dimensional approach. The major objective is to achieve maximum productivity in a shortest period without adversely affecting tree health and bearing of the orchard. The natural tree canopy of the fruit tree varies greatly from species to species and cultivar to cultivar. The size, shape and volume of canopy are affected by climate, planting density, rootstock, method of propagation, training, pruning, regularity of bearing, soil type, nutrition, irrigation, intercrop, growth regulators used, diseases, pests, environmental pollution etc. In order to obtain more yields per unit area of the land, it is desirable to have the required surface area per canopy volume by increasing the canopy height. But due to inconvenience in carrying out the cultural operations including harvest, the canopy height should be at manageable level.

Protected cultivation

In the recent past, the cultivation of high value crops such as cole crops, capsicum and flowers under protected structures which controls the wind velocity, moisture, temperature, mineral nutrients, light intensity, and atmospheric composition. The technologies for protection (windbreaks, irrigation, soil mulches) or structures (greenhouses, tunnels, row covers) may be used with or without heat. The intent is to grow crops where otherwise they could not survive by modifying the natural environment to pro- long the harvest period, often with earlier maturity, to increase yields, improve quality, enhance the stability of production, and make com- modities available when there is no outdoor production. The primary emphasis is on producing high-value horticultural crops (vegetables, fruit, flowers, woody ornamental, and bedding plants). However, the protected cultivation of high value fruit crops emerges as an interesting and profitable alternative for areas in which greenhouse cultivation of vegetables loses interest.

Drip Fertigation

Fruit crops because of their deep root systems can use nutrients from deeper layers of the soil. Therefore, the general soil-testing programme in which fertility status of 15 cm soil layer is assessed is not useful for fruit crops. Soil sampling from different layers up to 1.5 m will provide a better assessment of soil fertility status for fruit crops. Nutrient status of plant leaf is a better indicator of proper plant nutrition. Fertigation through micro-irrigation system provides a technique of application of water and nutrients to an area of the soil where most of the roots are active for absorption of nutrients requirement by the trees. It has been well demonstrated that the fertigation is expected to increase the nutrient uptake efficiency (30-40%), thereby minimizing leaching losses compared with the application of fertilizer in dry granular form broadcast over a large soil area at less frequent intervals (Narayanamoorthy, 2006). Several studies also proved that fertigation enhances the yield (25-30%) and quality of various fruit crops such as banana (Kavino *et al*., 2002), papaya, mango (Panwar *et al*., 2007), Citrus (Alva *et al*., 2003) and guava (Singh, 2008).

Pollination in Fruit Crops

Pollination is one of the most important aspects in fruit production. Pollinators such asbees, birds and bats affect 35 per cent of the world's crop production, increasing outputs of 87 ofthe leading food crops worldwide. The total economic value of crop pollination worldwide has been estimated at •156 billion annually (Gallai *et al.,* 2009). Studies on crop pollination by insects are becoming increasingly critical because of a perceived global decline in pollinator stocks, with great economical and conservation consequences (Ghazoul, 2005a & 2005b). In the recent years, there has been a concern about declines in both wild and domesticated pollinators, especially honeybees (Reddy *et al.,* 2012a). Verghese and Tandon (1990) studied the pollination behaviour of *Apis florea* on mango and found it to be an important pollinator. Reddy *et al.,* (2012b) recorded four species *viz.Apis florea* (Hymenoptera:Apidae), *Chrysomya megacephala* and *Stomorhina discolor* (Diptera:Calliphoridae), *Eristalinus arvorum* (Dipteral:Syrphidae) as the dominant foragers significantly contributing to mango pollination in Bengaluru, while stingless bee, *Trigona iridipennis* as the most abundant in the *konkan* region in India. Pollinator abundance seems to be influenced by varietal differences. In terms of total pollinator activity, 'Ratna' attracted maximum numbers (3.24/10 panicles) while it was lowest in 'Sindhu' (0.63). Dipterans and bees showed varied preferences to varieties as was evident in case of 'Alphonso', which recorded the highest number of bees (2.6) while dipteran activity was lowest (0.02). In India, Phartiyal *et al.,* (2012) recorded a total of 12 insect visitors on flowers of sweet orange in *Terai* region. Among the pollinators, the Hymenoptera constituted major group of insects including *A. dorsata*, *A.cerana indica*, *Trigona* spp., *Campsomeriella megachalis* F., and *C. collaris.* Among the Dipterans, syrphid flies were the most frequent visitors including *Syrphus corollae* Fab., *Episyrphus balteatus* De Geer, *Spherophoria* spp. L., and *Melanostoma* spp. L. The per cent fruit setting was higher (8.4-12%) in panicles under open pollination as compared to completely bagged panicles (1.2 - 8.0%). There are reports that bees play a significant role in the pollination in fruit crops like aonla, avocado, jackfruit, Macadamia, rambutan, strawberry and tamarind. In papaya, besides wind, sphinx moths and honeybees are given credit as pollinators (Stambaugh, 1960). In case of fig, small wasps of the genus *Blastophaga* are the only insects involved in pollination. The wasps develop in special gall flowers wild fig known as Capri. They emerge from these and accumulate pollen as they exit the fruit. They then enter the "eye" of a Smyrna fig and attempt to oviposit, unsuccessfully, in the long styles of the female blossoms. This activity effects pollination. In commercial plantings the Capri figs containing wasps will be collected and hung on the branches of the Smyrna variety. However, certain new varieties of edible figs are available that do not require this procedure (Free, 1993). Management of native insect pollinators is very important for sustaining agricultural productivity in the long run. Modern beekeeping suffers from attack parasitic mites, honeybee diseases, inability of honeybees to work at low temperature and adverse climatic conditions. These difficulties threaten the honeybees' general utility as a pollinator. Therefore, conservation of biodiversity of honeybees and wild pollinators is important to realize the potential yields of several cross-pollinated crops.

Good Horticultural Practices

The Quality Council of India has prepared the guidelines for the production horticultural produce with the INDGAP standards. Besides, the organically produced products gaining consumer preference the resistance breeding to develop varieties with multiple disease resistance is extremely important. The introgression of genes/ gene pyramiding from wild relatives is one such approach for developing the diseases& pests resistant high yielding varieties which can substantially reduce the production cost. Despite the development of chemical and cultural control measures for the pests and diseases, yet there is significant losses to from production to harvest are still a reality, especially in years where extreme weather is experienced due to climate change. In mango, one of the most significant diseases is anthracnose caused by the fungal pathogen *Colletotrichum gloeosporioides*. The loss due to anthracnose in mango has been studied by various workers and reported to be 25-30%.Bompard (1993) suggested the useof *M. laurina* for incorporating resistance to anthracnose, a fungal disease, and utilizing the genes available in *M. orophila* from Malaysis and *M. dongnaiensis* from Vietnam for developing varieties to make it distant possibility to grow mango in Mediterranean region, since these species grow well in the mountain forests at 1000-1700 metres above mean sea level.*M. altissima* is reported to be free from mango leaf hoppers and tip and seed borers (Angeles, 1991).Besides, there are several Mangifera species possess resistant to fruit fly (*M.camptosperma & M.andamanica*) and tolerant salinity which can be used for breeding purposes. The PRSV (Papaya Ring Spot Virus) is a major problem in papaya production, in order to address this issue; the intergeneric hybridisation has been attempted. The intergeneric hybrids of *C. papaya* × *V. quercifolia* validated for hybridity and resistant to 'papaya ringspot virus' (Mendoza-Garces *et al*., 2010) and similarly the *C.papaya x V.cauliflora* has been validated for hybridity and resistant to PRSV in India (Dinesh *et al*., 2013). There are several well known interspecific and intergeneraic hybrids in citrus (Tristeza, phytophthora, salinity, alkalinity & drought), grapes (mildew, nematode, salinity & alkanity), banana (viruses & fusarium wilt) and in many temperate fruits. More emphasis should be given on these aspects in the coming years to breed the varieties which are having resistant to major pests and diseases. In the recent past, APEDA is promoting the GAP (Good Agricultural Practices) for exporting the mango, banana & grapes where in the pests and diseases resistant varieties are recommended.

Conclusion

The cost of inputs, including seeds, fertilizers, pesticides, fuel to draw out water and machines, is keep on rising every day and the profit made out of the sale of produce is not encouraging on many crops. On the other hand, present-day wholesale markets with long cold chain facility makes the availability of the produce throughout the year. Many State Governments have started the Cooperative marketing (HOPCOMS & TANHOPS) & processing Ltd to procure and sale the fruits and vegetables. There is strong network of crop growers associations (Grapes, Mango, Guava, Amla & Banana) which also take care R&D needs of the crop as well as the farmers welfare. Several private companies such as Reliance fresh, Heritage, Spencers, Adani Groups, MORE, Food World and Nilgiris have entered in to the procurement and they provide technical advisories to support the farmers. Similarly, the SAFAL-a unit of Mother Dairy helps the farmers to get the inputs, credits, capacity building and procurements. In Punjab, Council for Citrus and Agro Juicing has been started to help the Kinnow growers. There are few private companies such as Ion Exchange Environ Farms Ltd, Mother Dairy, Rallis India and Sanjeevani Orchards Private Ltd etc. have entered with contract farming for fruits and vegetables. Besides, as many as 37.2 million farmers were covered under the three schemes namely National Agricultural Insurance Scheme, Modified National Agricultural Insurance Scheme and Weather Based Crop Insurance Scheme which covers only half of them benefitted from it. *Pradhan Mantri Fasal Bima Yojana* (Prime Minister's Crop Insurance Scheme), the latest government initiative which merges existing insurance schemes, reduces the premium to be paid by farmers and removes the limit on government subsidy to insurance. Very recently, e-NAM (National Agriculture Marketing) facility has been created by the Government of India, which links all the APMC (Agricultural Products Marketing Cooperation) in India so that the farmers can get more price for their produce.

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Arid Horticulture: An option for Enhancing Farmers Income in Dry Zones of India

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Arid climate is characterized by stressful edaphic and environmental conditions like low and erratic rainfall, high evapo-transpiration and extreme temperature regimes; besides, limited irrigation resources. Under such environment, the productivity of agriculture crops is far behind the satisfactory level, rendering cultivation of field crops an unprofitable venture. The recent awareness about potential of ecologically fragile lands for cultivation of fruit trees has not only opened up scope for providing economic sustainability for the natives, especially small farmers, but also for bringing new areas under fruit production. The recent awareness regarding the potential of these ecologically fragile lands for production of quality produce has not only opened up scope for providing sustainability for the people of this region, but also for bringing in new areas to increase horticultural production. The area expansion and yield potential of arid horticultural crops has increased many folds because of development of new varieties and advancement in agro-techniques in arid region.

The soils of arid region are very poor in fertility. Most of arid areas (about 64.6%) are duny where the soils often contain only about 3.2-4 per cent clay and 1.4-1.8 per cent silt. Besides this, about 5.9 per cent area is covered by soils having hard pan, 5.6 per cent is under hills and pediments, 6.8 per cent area is alluvial duny and 1.6 per cent is sierozems extending from the soils of Haryana and the Punjab. In the peninsular India, a considerable part of arid region has red sandy soil and some parts have mixed black soils. The soils are poor in organic matter having organic carbon of 0.03 % in bare sand dunes to 0.1 % in the stabilized dunes. The water holding capacity of soil is also poor. Soils are generally rich in total potassium and boron but are low in nitrogen, phosphorus and micronutrients such as copper, zinc and iron. The soils often have high salinity. The ground water resource is not only limited owing to poor surface and sub-surface drainage but is also saline in quality. The irrigation water resources in the region are seasonal rivers and rivulets, surface wells and some runoff water storage devices (e.g., *nadi, tanka*, *khadins*) and canal irrigation in arid region. Thus, the water resources in arid region are limited and can irrigate hardly 4% of the area.

The annual average rainfall in the Indian arid regions is very low and varies from 100 mm in north-western sector of Jaisalmer to 450 mm in the eastern boundary or arid zone of Rajasthan. Most of the precipitation in north western arid region occurs during July-September in about 19-21 rain spells. Due to low and erratic rainfall pattern in arid region, appropriate technology is needed to increase productivity. Water is precious input in hot arid region of the country therefore, adoption of micro-irrigation system is desirable to save water and enhance productivity. For arid environment, the variety is needed which are resistant to biotic and abiotic stresses for sustainable production. In some parts of arid region, occurrence of frost is also common features during winter season which affects vegetative growth of plants as well as productivity, quality of fruits especially in ber, lasoda and aonla. There is no heat tolerance variety of arid horticultural crops which should be developed to achieve higher production.

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One of the major bottlenecks in development of horticulture in arid parts of the country is lack of sufficient quality seed and planting material. Seed is a precious input to increase quality production of vegetable, spices and flowers as well as some fruit crops. Thus, production of quality seed material and their supply to farmers will boost up the arid horticultural crops production. The post harvest management is essential to overcome the losses at different stages of grading, packing, storage, transport and finally marketing of both fresh and processed products. The weak processing infrastructure, as it exists today, has been one of the contributing factors for ineffective utilization of the raw materials resulting in huge post harvest losses. Lack of sufficient processing units for production of quality output is a major bottleneck for the arid fruit crops. Marketing of horticultural produce is a major constraint in the production and disposal system and has a major role to play in making the industry viable. The high capital cost involved in establishing orchards, or rejuvenation of existing old unproductive plantation poses serious constraint in area expansion. The situation becomes all the more difficult in view of the large number of small holdings devoted to these crops which are essentially owned by weaker section, who have no means to invest, nor can afford to stand the burden of credit even if available. Added to this is the long gestation period that the perennial horticultural crops like mango, sapota, citrus and date palm coming to the economic bearing age. High cost of inputs and lack of enough incentives for production of quality varieties /species, product diversification, value addition, etc. also hinder crops development.

Prospects of Arid Horticulture

Vast land resource, surplus family labours, increasing canal irrigated area, developing infrastructural facilities, plenty of solar and wind energy, etc. are the strength in arid region for research and development of arid horticulture. Further, minimum pressure of diseases and insects in the region is good scope for production of seed and planting material. *Ber* is commercially grown under semi arid and arid regions of the country. It requires more attention for value addition. Pomegranate production is increasing very fast in dry part of the country. Since, it has vast scope of export of this crop from semi arid and arid regions of the country. The crops like fig, custard apple, tamarind are also coming very well under dry land conditions. At present, fig is cultivated in more than 3,000 ha area in Maharashtra, Karnataka. Likewise, custard apple is grown in the state of Maharashtra, A.P., Karnataka, Rajasthan and Tamil Nadu. In foot hills of Arawali, custard apple is grown naturally ant its potential should be exploited. Date palm is most suitable fruit tree of hot arid region and it is grown in Rajasthan, Gujarat, Punjab and Haryana in more than 12, 493 ha and producing 85,000 tonnes fresh fruit. However, date is imported to India from Gulf countries due to its meager production. Now, imported tissue culture plants have been planted in districts of western Rajasthan and Gujarat. These plantations are under vegetative growth stage. *Bael* is also an important fruit crop of semi arid and arid region. Earlier there are no systematic orchards of *bael*. Now, looking to its nutritional and medicinal value, attention is being given on its commercial production. India is the second largest producer of vegetables. A survey report of revenue department for the year 2009-10, about 32 thousand ha area under plantation of 86 lakh 90 thousand fruit plants in the State of Rajasthan. The area under *aonla* cultivation has been increased substantially in the state in comparison to pomegranate. In the reported period under major spices, the increase in area and production was recorded to be 6.98 and 83.73 per cent. The per capita consumption of vegetable in the country has increased from 47 kg in 1984 to 76 kg in 2000, with annual growth rate to 2.9 per cent. By the improvement in production technology in arid region, many seed spices likes Coriander, Cumin, Fenugreek, *Ajowain*, Fennel, Dill and Nigella, are being cultivated on large scale and also exported to earn foreign exchange. There is a vast potential of floriculture in some parts of Rajasthan because of low infection of disease/insects good market demand for decorating and other uses. The prospects of floriculture under hot arid condition are also important from seed and plant material production point of view. At present, Roses, Marigold, Chrysanthemum and other flowers are being grown near by cities of Udaipur, Ajmer, Jaipur, Kota and Sri Ganganagar districts of Rajasthan. There is a good scope of Tourism development with development in gardening, landscaping and floriculture in the state besides associated industries.

(i) Genetic Resource Management

Biodiversity conservation of major arid horticultural crops is being done in field repository at ICAR-CIAH, Bikaner. Among 154*ber* (*Ziziphus mauritiana*) genotypes, the *ber* varieties Gola, Seb, Umran, Kaithali and Banarasi Kadaka are performing well under hot arid climate. Out of 92 genotypes of pomegranate (*Punica granatum*), Jalore Seedless, Ganesh, G-137, Mridula, Phule Arakta, Bhagawa are the better genotypes for yield and quality. The varietal evaluation of aonla (*Emblica officinalis*) revealed that the NA-7 (Neelam) is a prolific bearer followed by Chakaiya and NA-6 (Amrit). Among 21*bael* (*Aegle marmelos*) genotypes, NB-5 and NB-9 are performed well under irrigated hot arid conditions. A five-year old budded plant of NB-5 yields about 40 fruits/tree while NB-9 yields about 29 fruits/tree. The fruit size of NB-5 is smaller (1.0 kg /fruit) than NB-9 (1.4 kg/fruit). The fruit quality is excellent in both the varieties. In National repository of date palm (*Phoenix dactylifera*), sixty indigenous and exotic cultivars/genotypes are maintained and evaluated for different horticultural traits. The cultivars Halawy, Khalas, Khuneizi, Barhee, Zahidi and Medjool are found suitable for cultivation in hot arid region. In addition to this, a number of minor underutilized crops are also being conserved and evaluated for different traits (More and Singh, 2008).

Realizing the importance of vegetable crops particularly under exploited and less popular, and having commercial production potentials in arid and semi arid regions, systematic research work on germplasm collection, conservation and utilization was started since 1993-94 at ICAR-CIAH, Bikaner. In this context, intensive crop specific surveys in target variability pockets and explorations were undertaken in arid and semi arid regions and a large number of land races, semi-cultivated and popular types of *mateera*, *kachri,* snap melon, beans and some perennial horticultural species of vegetables potential were made over the years for systematic evaluation, characterization and conservation of indigenous germplasm. A number of varieties of arid vegetables like *mateera*, *kachri*, snap melon, Indian bean and cluster bean have been released for cultivation.

The environmental conditions of arid region are very harsh for sustainability of plants hence; selection of a plant species for such region is an important factor for growth and production. While selecting the fruit species for dry land horticulture, one of the basic requirements is that those crops, which complete their vegetative growth and reproductive phase during the period of maximum moisture availability, should be selected. The fruit such as ber, guava, pomegranate, custard apple, *aonla* and sour lime, conform to this prerequisite. The crops must have xeric characters such as deep root system (e.g. *aonla*, *ber*), summer dormancy (e.g. *ber*), high 'bound water' in the tissues (e.g. cactus pear, fig), reduced leaf area (e.g. Indian gooseberry, tamarind), leaf surface having sunken stomata, thick cuticle, wax coating and pubescence (fig, *ber*, *phalsa*, tamarind), and ability to adapt to shallow soils, rocky, gravelly, and undulating wastelands (pomegranate, *aonla*, *bael*) (Pareek and Sharma,1991).

(ii) Crop Improvement and Varietal Wealth

The Institute has released several improved varieties of arid fruits and vegetable crops which includes, Thar Bhubharaj, Thar Sevika, Goma Kirti of *ber*, Thar Shobha of *khejri*, Goma Aishwarya of *aonla*, Thar Samridhi of bottle guard; AHW-19, AHW-65, Thar Manak of *mateera*; AHK-119, AHK-200 of *Kachri*, AHS-10, AHS-82 of snap melon, AHC-2, AHC-13 of *kakri* and Goma Manjri of cluster bean etc. There are a number of varieties of arid horticultural crops are at prerelease stage which includes AHRM-1 of round melon, sponge gourd, chilli, brinjal, besides the some promising lines in *ber*, mulberry, *lasora* and *bael*, has been identified for evaluation and release (More *et al.*, 2008). At Institute level, Goma khatta, a pomegranate genotype for anardana purpose has released. Goma Pratik of Tamarind and Goma Yash of *bael* and Goma Priyanka of *jamun* has released by the institute for cultivation in semi arid arid parts of the country. Thar Mahi of Sword bean; Thar Kartiki and Thar Maghi of Indian bean have also been released by the Institute. Further, a number of varieties of arid fruit and vegetable crops have recommended for cultivation in different parts of the country after evaluation of germplasm for high yield and quality and given in Table-1.

Table 1: Promising varieties of fruit and vegetable crops for cultivation in semi arid and arid regions.

Crops	Varieties
Fruit crops	
Ber	Gola, Seb, Umran, Mundia, Kaithali, Banarasi Kadaka, Thar Bhubharaj, Thar Sevika, Goma Kirti
Bael	NB-5, NB 9, Pant Aparna, Pant Sujata, Pant Shivani, CISH Bael-1, CISH Bael-2,Goma Yashi, Thar Neelkanth, Thar Divya
Pomegranate	G-137, GKVK-1, Ganesh, Jalore seedless, Mridula, Bhagawa, Phule Arakta, Goma Khatta, Super Bhagwa
Aonla	NA 7, Kanchan, Krishna, Balwant, NA-6, NA-10, Laxmi-52
Sweet orange	Blood Red Malta, Mosambi, Pineapple, Valencia
Custard apple	Arka Sahan, Balanagar, Mammoth, Island, Gem, Red Sitaphal, APK(Ca)-1
Guava	Allahabad Safeda, L-49, Kohir Safed, Safed Jam, Chittidar, Lalit, Hisar Surkha
Date palm	Halawy, Barhee, Medjool, Shamran, Khuneizi, Khadrawy, Zahidi
Sapota	Kalipatti, Cricket Ball
Fig	Poona Fig, Dianna, Dinkar, Conadria, Excel
Mulberry	Thar Lohit, Thar Harit
Mahua	Thar Madhu
Tamarind	PKM 1, Pratisthan, Yogeshwari, Goma Prateek
Jamun	Goma Priyanka, Thar Kranti
Khirni	Thar Rituraj
Chironji	Thar Priya
Karonda	Thar Kamal
Phalsa	Thar Pragati
Vegetables	
Khejri	Thar Shobha
Chilli	Pusa Jwala, Mathania, Pant C-1, Arka Mohani, Arka Gaurav, Arka Basant, Bharat, Indira,Hripur-raipur,
Cowpea	Pusa Dofasali, Pusa Phalguni, Pusa Barsati, Pusa Rituraj, Pusa komal
Cluster bean	Pusa Mausami, Pusa Navbahar, Durga Bahar, Thar Bhadavi
Sword bean	Thar Mahi
Indian bean	Thar Maghi, Thar Kartiki
Onion	Patna Red, Nasik Red, N-53, Pusa Red, Pusa Ratnar, Pusa White Round, Pusa White Flat, Punjab Selection, Agrifound Dark Red, Arka Pragati
Tomato	Pusa Ruby, Pusa Early Dwarf, Pusa-120, HS-102, Sweet-72, S-12, Mangla, Punjab Chhuhara
Brinjal	Pusa Purple Long, Pusa Purple Round, Pusa Kranti, Pusa Anmol, Arka Sheet, Arka Shirish, Arka Kusumakar, Arka Navneet

Contd

Crops	Varieties
Amaranth	Chhoti Chauali, Badi Chaulai, CO-1, CO-2, CO-3
Okra	Pusa Makhmali, Punjab No. 13, Punjab Padmini, P-7, Parbhani Kranti
Pumpkin	Arka Chandan, CO-1, CO-2, Thar Kavi
Muskmelon	Pusa Sharbati, Pusa Madhuras, Hara Madhu, Punjab Sunehri, Durgapura Madhu
Watermelon	Sugar Baby, Arka Manik, Arka Jyoti, Durgapura Meetha, Kesar, Mateera (AHW-19 and AHW 65),Thar Manak
Bottle gourd	Pusa Summer Prolific Round, Pusa Summer Prolific Long, Pusa Meghdoot, Pusa Manjari, Pusa Naveen,Thar Samridhi
Bitter gourd	Pusa Do Mausmi, Arka Harit, Pride of Gujarat
Kachri	AHK-119, AHK-200
Snap melon	AHS-10 , AHS-82
Ridge gourd	Thar Karni
Drumstick	Thar Harsha

Varietal variation in endurance to drought has also been observed in horticultural crops. Early ripening cultivars seem to escape stress conditions caused by the receding soil moisture stored in the soil profile during the monsoon. *Ber* cultivars Gola, Seb and Mundia for extremely dry areas, Banarasi Kadaka, Kaithli, Umran and Maharwali for dry regions, and Sanaur-2, Umran and Mehrun for comparatively humid regions have been recommended. Apart from morphological parameters, plants should also have physiological parameters for endurance to drought for commercial cultivation in this region. Some physiological parameters identified in *ber* are no mid day depression in photosynthetic rate, low rate of transpiration, maintenance of leaf water balance, growth, canopy development, dry matter allocation, high water use efficiency, etc. It has been demonstrated that plant having capacity for drought endurance are able to maintain turgour, dry matter allocation, leaf and fruit growth even under low soil moisture level.

(iii) Biotechnological Approaches for Improvement

Direct morphogenesis of shoot and root formation was achieved in *lasoda* (*Cordia myxa*), mulberry (*Morus alba*) and lime (*Citrus aurantifolia*) using single or double node explant having physiological active axillary buds. Under this *in vitro* system two type of media were used, one for shoot induction in preexisting axillary buds and another for formation roots at the basal of the original explant.In another important study with citrus, direct shoot and root formation was achieved in double node explant within 35 days of culture period. These results conform the production of plantlets within a short period eliminating subculturing process completely. Thus, using this technique of micropropagation, the fruit tree species can be multiply *in vitro* with minimizing inherent problems of tissue culture in greater way to obtain a large number of genetical identical, physiological uniform and developmentally normal plantlets preferably with high photosynthetic or phototrophic potential to survive the harsh *ex-vitro* condition.Attempts have been made for mass multiplication of *ker* through tissue culture technique since it is a hardy plant and suitable for hot arid environment. Work on date palm tissue culture is being done at various places in the country However; some good results have been achieved through organogenesis and embryogenesis in date palm tissue culture at ICAR-CIAH, Bikaner.

(iv) Technological Interventions

i) *Orchard establishment*:The fruit plants propagated in the nursery are generally used to establish orchards. Such plants invariably lose their tap roots as a result of repeated transplanting. Plants raised in containers develop oiled roots. For success in drylands, plants must have root architecture with a strong tendency to penetrate deep into the soil. *In situ* technique of orchard establishment is found suitable under arid conditions (Vishalnath *et al*, 2000). Rootstock seedling of ber are raised in the nursery in 300 gauge polythene tubes (25 cm length and 10 cm diameter, open at both ends), filled with a mixture of farm yard manure (FYM), sand, and clay in 1:1:1 ratio. The seedlings can be budded when about 90-100 days old. These plants become ready for transplanting, 1-2 months after budding. This technique helps to retain the straight growth of the tap root as the tubes are open at the bottom. Thus, the tubes neither restrict root growth nor induce coiling. Budded plants raised by this technique are also suitable for transportation to distant place (Pareek, 1978). Planting of stem cuttings of pomegranate, *phasla*, fig and mulberry in such polythene tubes would also induce straight roots. The pit size 2 x 2 x 2 ft and filling mixtures (FYM + pond silt + soil in 1:1:1 ratio) has standardized for planting of *ber* and pomegranate in arid region.

The plant density mainly depend upon the plant type, soil fertility status and management practices while planting system to be adopted in dry lands depends largely upon the topography of the land, fruit species and soil type. In the plains, planting, is generally done is square or rectangular system. On sloppy lands, fruit trees are planted on contour terraces, half moon terraces, trenches and bunds, and micro-catchments. On marshy and wet areas mounding and ridge-ditch method of planting have been suggested. The trenches and bunds made across the slope are staggered (Saroj *et al*., 1994). In a micro-catchment, which may be triangular or rectangular, trees are planted at the lowest point where runoff accumulates. The planting distance 6 x 6 m or 8 x 8 m for *ber* cultivation is optimum for arid region. Date palm, *bael* and *aonla*is recommended for planting at 8 x 8 m or 10 x 10 m distance under arid conditions.

ii) *Plant architecture and canopy management*: The canopy of plant plays a vital role to increase quality production of fruit trees. Canopy management work has been done for high yield and quality of fruits in guava at CISH, Lucknow and in citrus at NRC on Citrus, Nagpur. Training at initial stages of growth gives proper shape and strong frame to the trees. The bushy pomegranate should be trained keeping 3-5 stems from the ground level while in other fruits; single stem training keeping 3-4 main branches is adopted. However, pruning is essential to regulate reproductive phase of plants. *Ber* is pruned during January in Tamil Nadu, by the end of April in Maharashtra, and by the end of May in North India. The main shoots of the previous season are cut back retaining 15 - 25 nodes, depending upon location, cultivar, and age and vigour of tree. All the secondary shoots are completely removed. As a result of light pruning for several years, long non-flowering shoots develop. To eliminate this, half the number of shoots on the tree should be pruned keeping normal length and remaining half should be pruned keeping one to two nodes to induce new growth for fruiting in the following year. In *phalsa,* the time of pruning should be regulated according to the flowering period and should result in maximum number of new shoots on which bearing takes place. Established *phalsa* bushes should be pruned at 150 cm height once a year during January in north India and twice a year (December and June) in south India. Pruning from ground level is done either to rejuvenate old bushes or to train young plants into bush from. Defoliation of leaves in *lasoda* trees in the month of December-January produces early flowering and fruiting in arid region. High density planting is also beneficial in *aonla* fruit trees to achieve high yield under semi arid conditions (Singh *et al.*, 2009).

iii) *Water management*: In arid region, the major constraint in commercial cultivation of arid horticultural crops is water resources. Hence, the need of the hour is to develop technologies, which not only requires low water input but also have high water use efficiency. Water being a rare commodity in arid eco-system, the first and foremost requirement is to conserve the available soil or rain water. For conservation of rain water both *in situ* and *ex-situ* technologies have been developed. It has been reported that micro-catchment slopes greater than 5 per cent did not significantly affect run off at Jodhpur and that the highest ber yields were obtained when 0.5 per cent and 5 per cent slopes had 8.5m and 7m length of run, and 72 m^2 and 54 m^2 catchment area per tree, respectively. (Sharma *et al.,* 1986). Work done at Aruppukottai (Tamil Nadu) and Anantapur (Andhra Pradesh) has indicated usefulness of *in situ* water harvesting technique for fruit production.

Mulching with organic materials (e.g., hay, straw, dry leaves, and local weeds) has been found highly beneficial in reducing evaporation loss. The practice also suppresses weed growth, prevents erosion, and adds organic matter to the soil (Gupta, 1995). Black polythene mulch is very effective in ber orchards in western India, Although, local organic mulch materials are cheaper than polythene mulches but these require proper care to maintain effective cover thickness. Leaf mulch has been used to conserve soil moisture in sapotaorchards in Karnataka, Tamil Nadu, and Andhra Pradesh. Sugarcane trash mulch in pomegranate, fig, and custard apple was found effective in Maharashtra.

At ICAR-CIAH, Bikaner, the work on *in-situ* water harvesting has been undertaken in Pomegranate, aonla and vegetable. It has been demonstrated that application of black polythene mulch and local weeds helps in conserving soil moisture status in above crops. It has been demonstrated that plant growth and development remains optimum with use of above mulching materials. Mulching studies with respects to soil hydro thermal regimes in brinjal revealed that organic mulches curtailed soil temperature during warm months, while an increase was recorded during the winter month. Significant increase in fruit yield by 66 and 58% could be obtained through *lasoda (Cordia* sp.*)* and *kheenp (Leptodenia pyrotechnica*) mulching (Awasthi *et al.,* 2006).Among the *ex-situ* water conservation methods, in arid ecosystem, emphasis has been given mostly on pressurized irrigation system. It has been demonstrated that fruits and vegetables can be grown economically by use of drip or sprinkler irrigation system. At ICAR-CIAH, Bikaner and its regional station it has been demonstrated that crops such as pomegranate and *ber* can be grown successfully under drip irrigation system. It has been proved that water saving to the tune of 25 per cent can be achieved if pressurized irrigation system is used as compared to conventional flooding or bubbler system.Application of pitcher irrigation was attempted in cactus pear at ICAR-CIAH, Bikaner and it was recorded that growth of cactus pear was better under this treatment as compared to control. The use of double ring system to conserve the moisture applied for production of fruit crops was attempted in aonla. It was observed that by this method the water is applied in zone having functional roots and hence, water use efficiency is enhanced (Shukla *et al*., 2006).Water loss due to transpiration can be reduced by use of radiation reflectants, stomata closing chemicals, and plastic films. Spraying of 4-6 per cent Kaolin, 0.5-1.0 per cent liquid paraffin, and 1.5 per cent power oil, after occasional rains in low rainfall areas, considerably reduce plant water losses (Pareek and Sharma, 1991). Chemicals such as Phenyl mercuric acetate (PMA), Decinyl succinic acid (DSA), Abscisic acid (ABA), and Cetylalcohal cause stomata clousure and thereby reduce transpiration (Jones and Mansfield, 1991; Chundawat 1990). Shelterbelt and windbreaks can reduce evapo-transpiration by reducing the wing speed and stabilizing microclimate (Muthana *et al.,* 1984).

Control of weeds has special significance in rainfed orchards in reducing soil moisture losses. Timely weeding is essential to improve fruit quality even in high rainfall areas. Application of pre-emergence weedicides such as Diuron, Bromacil, and Atrazine @ 2-3 kg ha^{-1} and post emergence weedicides such as Grammaxone (Paraquat) and Glyphosate @ 1 l ha^{-1} have proved effective in checking weed growth in the orchards.

iv) *Integrated nutrient management*: The balanced nutrition in plants is required at appropriate time according to the age of plants. The application methods also play important role for availability of nutrients to the plants. In ber orchards, besides 10-15 kg organic manure, annual application of 100 g N, 50 g P_2O_5 and 50 g K_2O per tree is recommended. Fertilizer doses should be raised according to the age of plants and soil fertility of the region. Application of 15-20 kg FYM per tree has been found beneficial in *aonla*, custard apple, and tamarind. The nutritional trials have been carried out in arid fruits at ICAR-CIAH, Bikaner and centres of AICRP on Arid Zone Fruits. The studies conducted on Date palm at Abohar showed that application of 300-400 g N/tree/year gave maximum number and weight of bunch. Similarly in pomegranate it has been demonstrated that application of 50 per cent recommended dose of nitrogen at monthly interval gave best performance (Anon., 2006).Keeping in view the export potential of pomegranate, attempts have been made to assess the organically production of this crop. In this pursuit, substitution of in-organic with organic fertilizers was attempted. The results have demonstrated that a good crop of pomegranate can be harvested by giving 50 per cent RD of NPK through Vermicompost and 50 per cent through inorganic fertilizer. Thus, the use of inorganic fertilizers can be reduced to half through this technology.

Micronutrients are often found deficient in semi-arid and arid soils. Foliar feeding of nutrients such as nitrogen (0.5-2.0% urea), zinc (0.05-1.0% zinc sulphate), and boron (0.05-1.0% borax) has given beneficial results in these areas (Pareek and Sharma, 1991). In the medium rainfall region of eastern Uttar Pradesh, application of FYM, pond soil, gypsum, and pyrite in sodic soils resulted in better establishment and growth of aonla and *bael* plants. Foliar spray of micronutrients (Fe 0.50% + Zn 0.50% + Cu 0.25%) improved the yield and fruit quality in kinnow mandarin in arid region. Foliar spray of zinc sulphate 0.5-1.0 per cent improved fruit quality in *ber* cv. Seb in semi arid region.

v) *Fruit based cropping systems*: Monoculture in arid zone is highly risk prone due to crop failures, hence a suitable tree crop combinations is essential for alleviating the risk, generation of income, improvement productivity per unit area/volume as a result of efficient use of natural resources and inputs, and ameliorate and improve adverse agro-climate. In areas with large livestock population, horti-pastoral system would be beneficial. In the arid areas, the system could have combinations such as *khejri* (*Prosopis cineraria*)+*ber*+ dhaman (*Cenchrus ciliaris, C. setigerus*) *or* sewan (*Laisurus sindicus*). In semi-arid areas, perennial trees (mango, tamarind, sapota, jackfruit and palmyrah palm) could be grown with fodder crops.

Fruit trees can also be planted in association with forest trees, and they yield wood for packaging and fuel. Multi-storey combinations incorporating large trees, small trees, and ground crops can be used. In low rainfall (300-500 mm) zone, combinations such as *khejri* or *ber* + *ber* or drumstick + vegetables (legumes and cucurbits); in 500-700 mm rainfall zone, combination of mango or ber or aonla or guava + pomegranate or sour lime or lemon or drumstick + solanaceous or leguminous or cucurbitaceous vegetables; and in 700-1000 mm rainfall zone, combination of mango or jackfruit or *mahua* or palmyrah palm or tamarind or guava + sour lime or lemon or pomegranate or *aonla* + vegetables can be adopted.

Mono cropping of either fruit or seasonal crops is highly risk prone in arid areas, hence to mitigate the effect of total crop risk failures, fruit based multistory cropping system such as Aonla-ber-brinjal-moth bean, Aonla- drumstick-senna-moth bean-cumin can be profitably adopted by the farmers of arid region for better cash flow, nutritional and environmental security and sustainable livelihood. In areas where frost is a severe Aonla-Khejri-suaeda-moth bean and mustard can be another lucurative option (Awasthi *et al.*, 2007)

Crop diversification studies in *ber* (*Ziziphus mauritiana*) and *aonla* (*Emblica officinalis*) based cropping studies led to the recommendations that in pre-establishment phase of ber orchard, Indian aloe (*Aloe barbedensis*) and cluster bean (*Cyamopsis tetragonoloba)* are the low input and high returning crops in arid region. In aonla based multi storey cropping system, the model-4 with crop combination of aonla- drumstick- senna- moth bean- cumin recorded highest net return followed by cropping model-I (*aonla* - *ber* - brinjal - mothbean – fenugreek) have been recommended for sustainable and remunerative under arid ecosystem. Under semi arid conditions of Godhra, Gujarat fruit based farming system like aonla / ber + okra / brinjal / cowpea have been recommended to the farming community for sustainable production.

vi)*Integrated insects/disease management*: Besides wild animals, rodents and birds there are many insects and diseases causing loss of horticultural crops. Major diseases of arid horticultural crops and their control measures and presented in Table - 2.Termites cause considerable damage particularly in low rainfall areas. Methyl parathion dust (5%) should be applied in the pits (50 g pit^{-1}) dug for planting fruit trees. Subsequently, water soluble insecticides (Chloropyriphos) should be applied with irrigation water. Fruit fly (*Carpomyia veuviana*) causes serious damage in ber fruits. To keep the infestation under check, the chemical spray schedule should consist of spray at pea stage with 0.03 per cent monocrotophos, second spray after 15 days with 0.1 per cent carbaryl. During maturity of the fruits, if necessary, sprays should be done with 0.5 per cent malathion mixed with 0.5 per cent *gur* or sugar solution. This schedule has also been found effective against fruit borer (*Meridarchis scyrodes*) which causes serious damage in southern and western India. Pomegranate butterfly (*Virachola isocrates*) causes considerable damage to pomegranate fruits. Bagging of fruits with butter paper gives good protection. For control, 0.02 per cent Deltamethrin and 0.2 per cent Carbaryl 50 WP sprayed in rotation at 21days interval starting from fruit set is the most cost effective.

For the control of *ber* powdery mildew, fungicides such as 0.1 per cent Dinocap or Carbendazim or Triademorph or Thiophenate methyl and 0.2 per cent wettable sulphur have been found most effective when sprayed 2-4 times at 15 to 20 day interval starting from initiation of the disease. One spray of the fungicide at initiation of new growth after pruning is an effective prophylactic measure. Black leaf spot (*Isariopsis indica*), found under more humid conditions, can be controlled by 2-3 sprays of 0.2 per cent Captafol or Copper oxychloride or Mancozeb and 0.1 per cent Carbendazim at 15 day intervals. For the control of leaf and fruit spot in pomegranate, four sprays with 0.25 per cent Ziram and 1 per cent Bordeaux mixture at 15 day intervals are most effective. Since, the intensity of the disease is more under humid conditions during mrig bahar as many as 10 sprays at 10 day intervals may be necessary.

Apart from chemical control, attempts have also been made to use bio pesticides for control of pests in arid fruit crops. It has been demonstrated that application of Neem Seed Kernal Extract (NSKE @ 2.5-5%) on various crops effective in controlling pests in pomegranate, aonla, chilli and brinjal. Similarly use of bio-control measures to control ber powdery mildew was also attempted. It has been demonstrated that isolates ICAR-CIAH-196 of *Trichoderma* has potential to be used as bio-control of ber powdery mildew. The isolates thus obtained are resistant even to fungicides and hence can be used in combination with pesticides.

Table 2: Major pests and diseases of arid horticultural crops and their control measures

Crops	Pests/diseases	Control measures
Pests		
Ber	Fruit fly Weevil	Comprising digging of soil in basin, mixing of 50g insecticidal dust, spray of 0.05% Monocrotophos during monsoon, 2-spray of Monocrotophos (0.03%) at pea stage. Management practices and spray of Monocrotophos @0.03% to control the weevil
Pomegranate	Fruit borer	Two spray of Deltamethrin (0.02%) and Carbaryl 50 WP (0.2%) at 21 days interval.
	Barkeating caterpillar	Plugging of holes with mud followed by spray Dimethoate/ Monocrotophos (0.08%).
Aonla	Leaf gall midge	Spray of Endosulphon (0.05%) minimizes the problem.
Bael	Leaf eating cater pillar	Spray of Dimethoate/ Monocrotophos (0.08%).
Diseases		
Pomegranate	Leaf and fruit spot	One spray of Ziram (1.0%) or Bordeaux (1.0%) at flowering or fruit setting and subsequent 4 sprays at 20 days interval.
Date palm	*Graphiola* leaf spot	Spray of Bavistin (0.1%) or Blitox-50 WP (0.4%) minimize the disease.
	Fruit rot	Spray of Carbendazim (0.1%) minimize the rotting.
Aonla	Rust	Three spray of Moncozeb (0.3%) at 15 days interval from diseases initiation under Faizabad conditions. Four spray of Chlorothalonil (0.2%) at 10 days interval.
Fig	Rust	Two spray of Mancozeb (0.3%) is effective.

vii)*Post harvest management*: The value addition signifies the steps and series of operations like delineation of criteria for maturity, pre harvest treatments to reduce post harvest losses, techniques of harvesting to minimize on farm losses, standards for grading and packing for distance transportation, post harvest treatments and conditions of storage to improve shelf life, processing techniques to develop more useful product and utilization of waste to develop byproducts. In real terms, value addition deals with the process of conversion of useless commodity into useful product however, converting a less useful produce or waste material into more useful product is also considered in value addition. In arid region owing to plenty of solar radiation value addition through dehydration technique is more common for vegetable and spice crops. Brining, pickling, beverage making, preserve making, etc. are the other methods of value addition being adapted to various arid commodities. However, post harvest techniques should be commercialized to fetch high price of produce in the market. Some of the value added products prepared from arid horticultural crops at ICAR-CIAH, Bikaner are as follows;

Crops	Products
*BerAonla*Datepalm	Squash, Dehydrated *ber*, Jam,Chyawanpras, Shreds, Candy, Preserve,Squash, Dry dates (Chhuhara), Pind khajoor, Biscuits,
Khejri	Sangri (dehydrated pods), Biscuits
Bael	Squash, powder,
Ker	Vegetable, Pickle
Indian Aloe	Vegetable, Pickle, Laddu
LasodaKachari	Mixed pickle Dehydrated *kachri*, Powder (ingredient of channa masala),

(V) Future Thrust Areas

Although, great efforts have been done to develop technology compatible for commercial production of arid horticultural crops, yet there is a need to address various issues for further refinement of technology, improvement in socio-economic status of peoples of arid region and development of sustainable agro-horti-system. The major issues are as follows:

- Utilization of plant genetic resources,
- Exploitation of Biotechnology in arid horticultural crops
- Protected cultivation and off season production
- Hi-tech crop production
- Efficient utilization of water resources
- Rehabilitation of degraded lands
- Utilization of solar and wind energy
- Organic farming
- Breeding for resistance to abiotic stresses
- Diversified cropping systems
- Post harvest management
- Marketing and export
- Transfer of technology
- Human resource development

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Spices an Option for Enhancing the Farmers' Income

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India, known as the 'Land of Spices', grows as many as 70 spices. However, under the act of Parliament, a total of 52 spices are brought under the purview of Spices Board. Spices are high value and low volume commodities of commerce in the world market and hence have great potential in increasing the farmer's income substantially. Spices are integral to human life especially in Indian society – in tradition, food, aroma, health, and economy. Spicesare the basic building blocks of flavour in food preparations in addition to their use as functional foods, nutraceuticals and sources of many high value phytochemicals.The beneficial properties in herbs and spices are due to presence of phytochemicals. The major phytochemical classes associated with herbs and spices include a diverse array of compounds such as terpenes and terpene derivatives. Both *in vitro* and *in vivo* studies have suggested that dietary spices and herbs maintain human health by their antioxidative, chemo preventive, antimutagenic, anti-inflammatory and immune modulatory effects. Black pepper, ginger, turmeric, cardamom and tree spices such as nutmeg, cinnamon, garcinia and tamarind are the tropical spices of importance in Indian context. Coriander, cumin, fennel and fenugreek are important seed spices. Mintis a herbal spice of great importance in world market. Garcinia, black cumin, ajowain, saffron, mint, oregano, lavender, star anise are the future crops.

The consumption of spices is growing in the country with increase in purchasing power. It is envisaged that everyone in India would be consuming one spice or the other with a high per capita consumption. It is estimated that we may have a population of about 1.69 billion people during 2050 and approximately the per capita consumption of black pepper, cardamom, turmeric, and ginger is expected to be about 148 g, 54 g, 1.6 kg and 1.2 kg, respectively. This may increase further due to rapid urbanization which needs spices as natural food preservatives.

Spices Research and Development

International Organization for Standardization (ISO) listed 109 spices grown around the world. They are classified in various ways. Based on botanical nomenclature, parts used (leaf/seed spices), quantity produced (major / minor spices), climate(temperate/tropical spices), duration (annual, biennial, perennial) and stature(herbs, shrubs, trees) etc., Based on the plant part used, they are classified as (i) rhizome and root spices, (ii) bark spices, (iii) leaf spices, (iv) flower spices, (v) fruit spices and (vi) seed spices. Spices used in medicine and other industrial applications like colouring and flavouring agents besides main use in food preparation. ICAR-Indian Institute of Spices Research (IISR), Kozhikode has mandat to work on tropical spices such as black pepper (*Piper nigrum* L.), cardamom (*Elettaria cardamomum* Maton), ginger (*Zingiber officinale* Roscoe), turmeric (*Curcuma longa* L.), cinnamon (*Cinnamomum verum* J.S. Presl), clove (*Syzygium aromaticum* (L.) Merr. & L.M. Perry), nutmeg (*Myristica fragrans* Houtt), vanilla (*Vanilla planifolia* Andrews), paprika (*Capsicum annuum* L.) and garcinia (*Garcinia gummi-gutta*(L.)Roxb. and *Garcinia cambogia* (Gaertn.) Desr.. The chilli (*Capsicum annuum* L.) works is under taken at ICAR institutes like ICAR-Indian Horticulture Research Institute(IIHR), Bengaluru; ICAR-Indian Agricultural

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Research Institute(IARI), New Delhi and many SAU's. ICAR-National Research Centre for Seed Spices(ICAR-NRCSS), Ajmer, Rajasthan exclusive works on 10 seed spices viz., Ajwain (*Trachyspermum ammi* (L.) ,Sprague, Aniseed (*Pimpinella anisum* L.), Caraway (*Carum carvi* L.), Celery (*Apium graveolens* L.), Coriander (*Coriandrum sativum* L.), Cumin (*Cuminum cyminum* L.), Dill (*Anethum graveolens* L.), Fennel (*Foeniculum vulgare* Mill.), Fenugreek (*Trigonella foenumgraecum* L) and Nigella *(Nigella sativa* L.).

All India Coordinated Research Project on Spices (AICRPS) located at IISR, Kozhikode undertakes research on both tropical spices and seed spices in collaboration with ICAR and SAU's. There are 38 centres located across the country to undertake multi-location testing of varieties and technologies emanated from research centres. AICRPS works in North east frontier states also by covering large cardamom. In addition, the spices development work is under taken by Spices Board and Directorate of Areacanut and Spices Development (DASD).

Trend in Spices Production

Spices cultivated in an area of 3.3 million ha with a production of 6.1 m. tones (Table 1 & 2) that occupies around 13.0% area and 2.0% production of horticultural crops of India. The trend in area and production of spices (Fig 1) is positive, compared to area increase; production increase is an impressive, indicating the R & D effort in spices development in the country. However, there may be fluctuations among different spices between years mainly due to monsoon failure or lack of price in the market. Each state cultivates one or other spices (Table 1). Spices grown as rainfed crop in high rainfall areas and as irrigated crops in less rainfall areas.

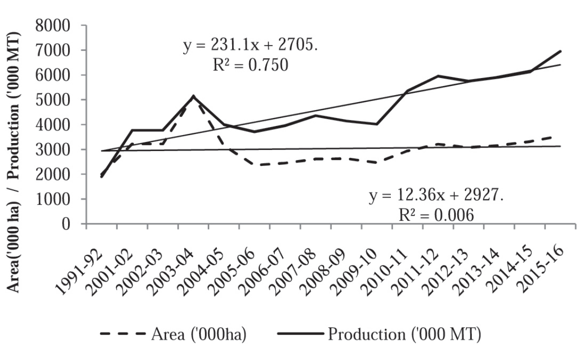

Fig. 1: Trend in spices area and production

Table 1. Area and production of spices in different states (2014-15)

States/UTs	Area('000ha)	Production ('000 tonnes)	% Share in Country's production
Andaman Nicobar	1.68	3.22	0.05
Andhra Pradesh	200.67	918.01	15.03
Arunachal Pradesh	10.17	64.27	1.05
Assam	98.60	321.03	5.26
Bihar	13.01	12.54	0.21
Chhattisgarh	11.69	11.65	0.19
Goa	0.94	0.25	0.00
Gujarat	608.86	1019.96	16.70
Haryana	16.13	82.82	1.36
Himachal Pradesh	7.39	22.29	0.36
Jammu & Kashmir	4.94	1.07	0.02
Jharkhand	0.00	0.00	0.00
Karnataka	206.51	345.52	5.66
Kerala	167.29	140.23	2.30
Madhya Pradesh	340.21	699.12	11.45
Maharashtra	123.24	130.09	2.13
Manipur	10.47	24.14	0.40
Meghalaya	17.50	83.88	1.37
Mizoram	23.30	65.72	1.08
Nagaland	9.77	39.16	0.64
Odisha	123.32	181.50	2.97
Puducherry	0.09	0.38	0.01
Punjab	21.34	91.52	1.50
Rajasthan	866.86	618.32	10.12
Sikkim	34.08	61.14	1.00
Tamil Nadu	107.50	187.91	3.08
Telangana	122.36	493.93	8.09
Tripura	5.69	18.04	0.30
Uttar Pradesh	58.04	221.71	3.63
Uttarakhand	8.09	41.08	0.67
West Bengal	97.56	207.78	3.40
Total	3317.28	6108.28	100

Spices Export and Import

India has been a traditional producer, consumer and exporter of spices in the world and almost all states in the country produce one or other spices. After consuming more than 70% of the spices produced, we still manage to be the largest exporter of spices in all its forms – raw, ground, and processed, and as active ingredient isolates.In terms of export, a total of 8.42 lakh tons of spices and spice products valued Rs. 16238.2 crore (US$ 2482 Million) have been exported from the country during 2015-16 (E), registering an increase of 46% in quantity and 66% in value terms over last five years with value added products forming an integral part of our export basket.During 2012-13, 17,436 t of curry powder blends valued at Rs. 275.16 crores has been exported. Export of spice oils and oleoresins has recorded an all-time high of 9515 t valued at Rs. 1558.9crores in 2012-13. The estimated growth rate for spices demand in the world is around 3.19%.The spice industry in India and trade has shown stunning progress, over the last 5 years - there has been a 120% increase in revenues which is expected to touch $ 3 billion by 2017. East Asia is the major market, followed by the Americas and the European Union. But the world spice trade is expected to cross 17 billion by 2020. With equitable distribution of profits spices can increase the farmer's income and social status substantially and hence where ever possible spices should become part of our farming systems either as pure crop or as mixed crop. Spices as commercial crop offers great potential for agro entrepreneurship thus increasing the socio economic status of our agrarian communities

India exports spices to more than 100 countries, however, our main customers are U.S.A, China, Vietnam, Malaysia, U.A.E, U.K, Germany, Singapore, Saudi A*Rabi*a, Thailand, Netherlands, Sri Lanka, Mexico, Bangladesh, Nepal, Brazil, Indonesia, Pakistan, Japan, France, Egypt(A.R.E), Spain, South Africa and Australia. On an average (Table 3), 7.0 Lakhs tonnes of spices are exported both in whole and value added forms to the tune of Rs. 11,474.39 Crores per annum. Spices contribute around 3.0% of agricultural product export from India. Out of our total production of spices, we export only 10 to 15.0% and remaining are consumed in India and it indicates there is strong domestic market exists here. Among the spices, the maximum export is from chilli in terms of quantity i.e., 2,88,300.0 tonnes to the value of Rs. 2,459.92 crores which shares 40.73% in quantity and 21.44% in value of total spices export from India, whereas, in terms of value mint products stands first by accounting Rs. 2796.13 Crores sharing 24.37% of spices export (Table 3). We also export the value added products like Spice Oils and Oleoresins around 9454 tonnes to the tune of 1483.608 Crores. We are not only exporting spices, we are also import huge quantity of spices for

Table 3. Export and import of spices in India (Mean of 2010-11 to 2014-15) (Quantity in Tonnes & Value in Rs. Lakhs)

Spices Exported	Mean (2010-11 to2014-15)		% Share		Spices Imported	Mean (2010-11 to 2014-15)		% Share	
	Quantity	Value	Quantity	Value		Quantity	Value	Quantity	Value
Pepper	20722.6	80957.35	2.93	7.06	Pepper (1)	17249	61925.01	14.41	25.54
Cardamom(S)	3118.4	26296.24	0.44	2.29	Cardamom(Small)	803.2	2474.126	0.67	1.02
Cardamom(L)	940.4	6782.508	0.13	0.59	Cardamom(Large)	3346	15126.5	2.80	6.24
Chilli	288300.0	245992.00	40.73	21.44	Chilli / Paprika	854	1043.926	0.71	0.43
Ginger	24641.4	22004.74	3.48	1.92	Ginger Fresh / Dry	30992	8851.86	25.90	3.65
Turmeric	76152.6	68063.62	10.76	5.93	Turmeric	5074	4674.7	4.24	1.93
Coriander	39250.4	28049.17	5.55	2.44	Coriander	4710	4335.762	3.94	1.79
Cumin	88120.4	112634.5	12.45	9.82	Cumin Black / White	414	565.274	0.35	0.23
Celery	4764.2	3173.358	0.67	0.28	Mustard Seed	318	132.026	0.27	0.05
Fennel	11622.2	10686.1	1.64	0.93	Poppy Seed	14451	23618.68	12.08	9.74
Fenugreek	25719.4	10327.48	3.63	0.90	Garlic	165	136.29	0.14	0.06
Other Seeds (1)	20008.4	10911.21	2.83	0.95	Clove	11026	47443.35	9.21	19.57
Garlic	17926.4	6366.238	2.53	0.55	Nutmeg	808	3564.02	0.68	1.47
Nutmeg & Mace	3575.2	21909.86	0.51	1.91	Mace	552.4	4559.122	0.46	1.88
Other Spices (2)	33329.6	33003.83	4.71	2.88	Cassia	15797	11840.68	13.20	4.88
Curry Powder/Paste	19617.2	32306.49	2.77	2.82	Star Anise	3358	5346.116	2.81	2.21
Mint Products (3)	20497.8	279613.6	2.90	24.37	Other Spices (2)	7998	21172.89	6.68	8.73
Spice Oils & Oleoresins	9454	148360.8	1.34	12.93	Oils &Oleoresins (3)	1756	25614.86	1.47	10.57
TOTAL	707760.6	1147439	100	100	Total	119671.6	242425.2	100.00	100.00

(1) Include Bishops Weed (Ajwanseed), Dill Seed, Poppy Seed, Aniseed, Mustard Etc.
(2) Include Tamarind, Asafoetida, Cinnamon, Cassia, Cambodge, Saffron, Spices (Nes) Etc.
(3) Include Menthol, Menthol Crystals And Mint Oils.

1) Include White Pepper, Light Pepper And Black Pepper
(2) Include Aniseed, Asafoetida, Cinnamon, Pepper Long, Cambodge, Herabal Spices And Spices Nes.
(3) Include Spices Oils & Oleoresins And Mint Products.

Source: DGCI&S., Calcutta/Shipping Bills/Exporters' Returns. Spices Board, Kochi consumption as well as re-export after processing or value addition. On an average (Table 3), we imported 119671.6 tonnes to the value of Rs. 2424.252 Crores per year. Around 25.9% of the import in quantity and 25.54% in value accounts for ginger and pepper, respectively.

The involvement of Indian Institute of Spices Research (IISR), National Research Center for Seed Spices (NRCSS) with support from sister agencies like All India Coordinated Research Project on Spices (AICRPS), Spices Board, Central Food Technological Research Institute (CFTRI) and Directorate of Arecanut and Spices Development (DASD) has resulted insubstantial increase in production of spices, their mechanization, post-harvest processing, value addition and product development.Research activities on spices has resulted in establishment of world collection of spices germplasam, development of improved varieties of spices, integrated nutrient, disease and pest management, farm mechanization, post-harvest technologies for most of the important spices.

Improved Varieties

There are over 200 improved varieties of various spices available in the country capable of doubling the farmer's income directly or indirectly. High yielding varieties enhances the income by increasing the yield from 10-30 % compared to the local cultivars. The problem of pest and diseases, pesticide residues, increased cost of production and quality deterioration in many spices are our serious concerns, in these circumstances, selection of varieties should not be only for yield, the preference have to be given for selection of resistant/tolerant varieties rather than yield while taking up cultivation in the vulnerable areasor in case of organic cultivation. Being a high value, low volume and export oriented commodity, marketed in the form of value added products, the industry seeks varieties with high quality for extraction of oils oleoresins, curcumin etc. Hence, cultivation of high quality varieties boosts farm income significantly through realizing premium price. Varieties suitable for high density planting in perennial spices double the income from unit area through increased yield and efficient use of farm inputs and labour. Short duration varieties in case of turmeric and seed spices are helpful for enhancement of income not only through saving water and escaping drought situation, but also through making the land available early for growing the subsequent crop. Dual purpose varieties and the varieties suitable for off-season production in case of coriander and fenugreek offers high income to the farmer by giving a choice to sell the produce based on market preferences. The determinate types in fenugreek and the uniform maturing type in fennel will help to reduce the harvesting cost and these varieties are suitable for mechanized harvesting. The list of varieties in spices with specific trait is enclosed in Annexure I.

Technologies

The technologies developed from research station have to be effectively transferred for realizing full benefit. The faster multiplication techniques for meeting quality planting material or seed requirement, precision farming technologies such as site specific nutrient management based on soil test values, need based irrigation and spot application of water to crops with micro-irrigation techniques, timely and adequate plant protection techniques, on-farm processing technologies are available for efficient use of precious resources, reduce nutrient and water losses, reduce the pesticides loads on produce and reduction in post-harvest loss. The technologies evolved over the time for different spices are listed in Annexure II

Spices Production – Meeting the Challenges

There are challenges that threaten the spices production, marketing and consumption. High cost of production, problems in supply chain, rising demand v/s raw material storage, low yield, market instability, reducing quality and active ingredient content, increasing incidence of contaminants (Aflatoxin, Pesticides, Illegal Dyes, microbes *etc.,*) stringent food safety standards,overwhelming regulations and ecological sustainability has affected spice industry and trade. This is further complicated by uncompetitive production costs in comparison to other countries such as Vietnam and China.In view of this, greater efforts focused on sustainable increase in production through high production technologies integrating improved varieties, disease, pest and nutrient management, cropping system approach and organic farming is needed.Many facets of spices cultivation, harvesting, storage and processing can be mechanized.Greater efforts focused on increasing production and productivity levels through Good Agricultural Practices (GAPs) in spices to make them more sustainable and safe.Maintaining hygiene and cleanliness at different points on the supply chain, right from the supply of agricultural inputs to consumption through mechanization is important. This will help to create a final product that is acceptable as 'safe food', one need to be able to control all the elements on the supply chain, and with the support of all the stakeholders. This is further supplemented by harmonization of Global Standards on bio-safety, ensuring sustainability of supplies and to bridge the Demand and Supply imbalances without adversely affecting the environment involving producers, traders, industry and consumers and adjusting to emerging market trends.

The intrinsic quality and flavour and other components of spices are dependent of the agro climatic conditions in which they are grown. Hence development of Geographical Indication (GI) for spices and targeted production of industrially efficient quality spices in identified production hubs and important for getting the best spices and for better pricing. Establishment of Spices Parks and Enabling infra-structure to develop end-to-end capability is another positive development. Up gradation of technology across the entire supply chain – a key driver of growth

Spices Value Addition

Value addition needs a greater thrust and innovation to achieve greater commercial importance. In a world with many lifestyle diseases, spices with its chemo preventive, antioxidant, anti-inflammatory, antimicrobial and insecticidal properties, bio-enhancer potential are gaining importance as functional foods and are used as dietary supplements. With greater amounts of biomolecules with important health notes the spices need to be exploited towards problem solving approaches to enhance the human health.

The demand for organic spices is growing @ 20% annually. Spices are finding newer applications in food, cosmetics and pharmaceuticals. Sustainability and food safety are of crucial importance today and need serious deliberation, proactive action and an active coming-together of all the stakeholders. Global initiatives need to be intensified by bringing together the global spice industry to define and set an implementable pathway to secure a sustainable future for the industry and the agriculture system which supports the industry, while also examining the industry's ecological and social impact. The rise of e-commerce must help in alternate price discovery mechanisms. If we utilize these opportunities the spices industry and marketing is poised for exponential growth.

Focus

Increasing the productivity per unit area through spice based farming systems, development of varieties with high degree of resistance to biotic and abiotic stresses, development of agro technology towards low input management, precision farming, developing ecofriendly IPM strategies, post harvest technologies with value addition and exploiting its medicinal properties, and popularization of proven technologies though extension network are the major areas. Besides, the new areas on nanotechnology, bioinformatics, carbon (C) and water foot prints and knowledge management would further strengthen the research programmes on climate resilient agriculture. These technological advancements will bring out the surge in productivity of spices, and 2-5 fold increase in all major spices, to meet the consumption and export demand.

Creating awareness on production technologies is essential. Harmonization of global standards on bio-safety, ensuring sustainability of supplies and bridging the demand and supply imbalances without adversely affecting the environment by involving producers, traders, industry and consumers and adjusting to emerging market trends are also imminent needs.

Nanotechnology has great potential in developing new tools for rapid disease diagnosis and to combat pathogens, enhancing nutrient absorption, developing efficient pesticides, separation, identification and quantification of biological molecules, soil and water management, bio processing, post-harvest technology, monitoring the identity and quality of agricultural products and precision agriculture.

Web based interactive data bases providing expert systems and instant information on, for example, weekly analysis for spices, future predictions on demand, supply and pricing, directories of products, buyers, sellers, agents, and statistics etc. are available for traders but more are needed especially for supporting farming community also.

Finally governmental involvement is also required in providing incentives to agriculture, industry and trade, to remove trade barriers in the form of unfair regulations simplification of policies and procedures and in export– import trade agreements with emerging markets is an area that requires governmental involvement. If we utilize these opportunities the spices industry and marketing is poised for exponential growth

Our mission is to capture India's preeminent position as *'spice bowl of the world'* by producing and exporting the best spices and spice products the world can get. This translates to enhancing the productivity and quality of spices and spice products for meeting growing domestic demand and to be the global leader in spices export by utilizing the scientific, technological and traditional strengths for sustainable spice production. This can be achieved by obtaining high productivity of clean spices through varietal deployment, plant and soil health, optimal and safe technologies, better storage and processing, product development for food as well as pharma industry, mechanization, better market intelligence and aggressive marketing. The objective is also to have doubled the spice export. The initiatives under secondary agriculture and development of new products that find way into nutraceuticals and pharmacological applications paves way for value addition. The modern tools of science using several '*omics*' is helping us to unravel several metabolic pathways that contribute to the intrinsic quality of spices. Most technologies needed are either already available or in advanced stage of development. They just need to be fine tuned and implemented with the urgency needed.

Initiatives to Achieve the Targets

1. Accredited nurseries for multiplying and supply of disease free planting materials of improved high quality varieties with wide adoptability.
2. Increase production of black pepper 3 fold in next 10 years by extensive deployment of superior high yielding high quality varieties in newer areas of coffee and tea gardens in Tamil Nadu, Odissa, Assam and West Bengal, provide summer irrigation and micronutrient application based on soil testing in collaboration with planters, Spices Board, DASD (MIDH) and state Departments.
3. Reduce pesticide residues in cardamom by deploying thrips resistant, vazhukka types and increase production by deploying high yielding high quality varieties, precise mechanized fertigation, supply of micronutrients. These will double the present production.
4. Ensure monthly returns to small farmers and house holders through tunnel and off season cultivation of leafy coriander and fenugreek supplemented by 'micronutrient fortification'. This also helps the micronutrient deficiency (hidden hunger) in communities.
5. Develop wilt and blight resistant varieties of cumin and aggressive implementation of GAPs to avoid Mancozeb contamination in cumin.
6. Introduce Spices including seed spices as inter crop in existing gardens where ever possible and in new plantations at least in 20% area for increasing the production as well as income for unit area.
7. Establishing mechanized storage, processing and Business Planning and Development (BPD) facilities in the model of spices parks for value addition and better remuneration in PPP mode and establish producer companies for synergic team effort.
8. Market driven product development, identifying, isolating and patenting new high value compounds with high pharmaceutical values for low volume high value exports.
9. Involvement of all concerned under one umbrella for better information and intelligence sharing for sustainable growth of all stake holders.
10. Aggressive implementation of GAPs to produce clean and food safe produce at farm gate.
11. Mechanization at various levels in supply chain from farm gate to consumers to mitigate labour shortage and introduce cleanliness
12. Development of facilities for accredited analytical labs for ensuring food safety, pesticide residues and development of MRLs.
13. Compliance to world (Codex) standards on quality and ensure food safety
14. Value addition through product development, identification isolation and commercialization

of new high value compounds for increased market utilization and income.

Conclusion

There is an ever increasing demand for spices owing to diverse use in pharmaceutical and cosmetic industry other than traditional. Crop production and protection technologies for different production systems need to be developed for sustained yield of these crops. There is a great scope for organic production and export of spices.The contribution of spices becomes substantial in the total export earnings by agricultural commodities. The estimated export during 2015-16 was 843,255 tonnes with a value of 1,623,822.60 Lakhs. We export around 10.0 to 15.0% of our production only that plays vital share international spice market. It implies that there is strong domestic market for spices. The forecasted spices production of 5417 thousand tons during 2025 is expected to be achieved with an annual compound growth rate (ACGR) of less than three per cent. As the gap between the present national average productivity and the potential productivity is much high, the targeted production can be achieved without much difficulty. The growth of spices production will lead to a significant growth in on-farm employment opportunities. The spice industry is expected to create 950 million man days per annum of employment potential in production alone as spices are labour intensive crops. Further, there is substantial scope for creating new jobs through value addition in spices. Less than 2% of spices produced in the country under go value addition. The envisaged increase in share of value added products in the export basket of spices needs strengthening of processing facilities, both on farm and outside. Thus the development of downstream processing, packaging and distribution activities can generate millions of additional off-farm jobs. Thus the spice industry will help the country to achieve its goal of more than 10% growth rate in GDP and to sustain the same.The consumption of spices is growing in the country with increase in purchasing power. It is estimated that we may have a population of about 1.69 billion people during 2050 and approximately the per capita consumption of black pepper, cardamom, turmeric, and ginger is expected to be about 148 g, 54 g, 1.6 kg and 1.2 kg, respectively. India expected to have the second largest urban population (0.9 billion) in the world by 2050. These will double domestic and industrial water use, not to mention climate change and bioenergy production. Our aim is to significantly enhance spices production without increasing the area under the crop. The objective is also to have a 20% increase in spice export. The challenges are many - weather aberrations, less water, inadequate labour, emerging pests and diseases, lack of logistics like store houses, no or poor support price etc., would affect the production system. The technologies developed have to be effectively transferred to sustain the spice production and doubling the farmers income in the country and new technologies required to tackle the emerging challenges.

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Annexure I. Spices varieties

Varieties for high yield	
Black Pepper	Panniyur 1(1242kg/ha), Panniyur 2 (2570), Panniyur 3(1953), Panniyur 4 (1277), Panniyur 5(1110), Panniyur 6 (2127), Panniyur 7(1410), Panniyur 8 (5760), Panniyur 9(3150), PLD 2 (2475), Sreekara(2677), Subhakara (2352), Panchami (2828), Pournami (2333), IISR Sakthi (2253), IISR Thevam(2148), IISR Girimunda (2880), IISR Malabar Excel (1440),ArkaCoorg Excel (3150)
Small cardamom	Mudigere 1(275kg/ha), Mudigrere 2 (475kg/ha), PV 1(260kg/ha), PV2(982 kg/ha), PV 3(611kg/ha), ICRI 1(325 under rain-fed and 656 kg under irrigated condition), ICRI 2 (375 under rain-fed and 766 kg under irrigated condition),ICRI 3(440 under rain-fed and 790 kg under irrigation),ICRI 4(455 under rain-fed and 960 kg under irrigation)), ICRI 5(1543),ICRI 6(1200) ICRI 7, ICRI – 8, IISR Suvasini 745(potential yield 1322), IISR Avinash-847 (potential yield 1473), IISR Vijetha-643(potential yield 979),
Ginger	Suprabha(16.6 t/ha fresh), Suravi(17.5) Suruchi(11.6), Himgiri(13.5), IISR Varada(22.6),IISR Mahima(23.2), IISR Rejatha(22.4), Aswathy(23), Athira(21), Karthika(19), Subhada(18), GCP-49 /Mohini(14),V_1S_1-2 /Sourabh(14.3),
Turmeric	Co.1(30.5 t/ha fresh), BSR 1(30.7), BSR-2 (32.7), Krishna(9.2), Sugandham(15), Roma (20.7), Suroma (20.0), Ranga (29.0), Rasmi (31.30), Suranjana (29.0), Rajendra Sonia (42.0.Pot. Yield), Megha Turmeric - 1 (23.0), Pant Peethabh (20.0), Suguna (29.3), Sudarshana (28.8), Suvarna (17.4), IISR Prabha (37.47), IISR Prathiba (39.12), IISR Alleppy Supreme (35.4), IISR Kedaram (34.5), NarendraHaldi – 1 (30-35), NarendraHaldi – 2 (35-40), NarendraHaldi – 3 (32.50-35.0), Duggirala Red (25.0), Surangi (24.3), NDH-98 (35-37), IISR Pragati(33.19), Kanthi (37.65), Sobha (35.88), Sona (4.02dry), Varna (4.16 dary),
Nutmeg	KonkanSugandha, KonkanSwad, IISR Vishwashree (1000fruits/tree),IISR Keralashree(2000fruits/tree)
Cinnamon	KonkanTej(80 g/tree/year dried bark), IISR Navashree (200 kg dry quills/ha), IISR Nithyashree(200 kg dry quills/ha), Sugandhini (1.2 Kg fresh/tree/year), PPI (C)-1980 (Fresh bark), YCD. 1, 360 (dry), KonkanTejpatta (1.6 kg/tree and 7.68 t/ha dried leaves)
Clove	PPI(CL) 1
Coriander	Co.3 (6.50 q/ha), RCr 20 (9.00), RCr 435 (10.00), RCr 436 (11.00), RCr 684 (9.90), RCr-446 (12.00), RCr-480 (18.0), Sadhana (10.25), Swathi (8.55), Sindhu (10.00), Sudha (7.50-10.00 under rain-fed 12-15 under irrigation), HisarAnand (14.00), HisarSugandh (14.00), HisarSurabhi (18.00), HisarBhoomit (Green leaf 180 –200 , Seed14-15), Sudha (LCC-128), Suguna /LCC – 236 (7.5-13.5), Suruchi,/LCC – 234,DH 220, CS 287, Narendra Dhania-2 (17-19),RCr 475 (17.40),Susthira (12-17.5),RD 385
Cumin	Guj. Cumin 2 (6.20q/ha), Guj. Cumin 3 (6.20), Guj. Cumin-4 (12.50), RZ-209 (6.50), RZ-223 (6.00), RZ-341/UC-341 (4.05 ,Yield potential – 5.86), Ac-01-167 (5.15)
Fennel	Guj. Fennel 2 (19.40), RF 101 (15.50), RF-178/UF-178) (16.00, Yield potential – 28.33), HisarSwarup (16.00), Azad Saunf-1 (18.00), Pant Madhurika (18.00), Gujarat Fennel – 11 (24.87), RF- 205 (10-12), RF 143 (12.00), JF-444-1 (25.88), Ajmer Fennel 2 (17.90), RF-157 (21.67),
Fenugreek	HisarSonali (17.00q/ha), HisarSuvarna (16.00), HisarMadhavi (19.00), HisarMukta (20.00), Guj. Methi 1 (18.60), Guj. Methi-2/Guj.Fenu.-244 (19.20), RMt.1 (14.00), RMt 303 (19.00), RMt-305 (13.00), RMt-351/UM-351 (18.40), RMt- 361/ UM- 361 (18.41), HM – 348 (20.00-22.00), HM – 219, Ajmer Fenugreek 3 (13-14), Lam Methi 3/LFC-103 (12-26), RMt-354 (15-16), NarendraMethi 2 /NDM 69 (13-15), HM 444.
Varieties resistant to biotic stress	
Black Pepper	*Phytophthora* foot rot is one of the major constraints in pepper cultivation and crop improvement programmes has resulted in development of 3 varieties *viz.,* IISR Shakti, IISR Thevam and Panniyur 8) which are field tolerant to this disease. Pournami variety of black pepper is tolerant to root knot nematode (*Meloidogyneincognita*).
Small cardamom	*Katte*disease of cardamom is one of the very important diseases and it leads to reduction in the yield. There are 2 improved varieties/hybrids with resistance to katte virus. IISR Vijetha is the first *katte* virus resistant variety and Appangala 2 is the first hybrid resistant to *katte* virus. IISR Avinash is tolerant to rhizome rot suitable to cardamom growing regions of Karnataka and Wyanad of Kerala. Thrips is one major pest in cardamom and it affects the appetence and ultimate market value of capsules. Research work is in progress for the development of varieties tolerant to thrips and some of the genotypes are under field evaluation.
Coriander	HisarBhoomit and HisarSugandh are resistant to stem gall disease which severely affects the coriander crop. RCr 684 is resistant to stem gall and less susceptible to powdery mildew .The Co.3 variety of coriander is field tolerant to powdery mildew, wilt & grain mould. Sadhana is an improved variety with field tolerance to diseases and white fly, mites & aphids. HisarSurabhi is less susceptible to aphids.
Cumin	Gujarat Cumin (GC 4) is the first high yielding wilt resistant cumin variety which covers over 70% area in Gujarat and majority areas in Rajasthan also. GC- 3 is also resistant wilt and frost. Ac-01-167 is a bold seeded variety resistant to wilt. RZ-223 is another wilt resistant variety with wider adaptability, superior in yield and seed quality.

Fennel	Azad Saunf-1 is resistant to blight and root rot diseases and it escapes attack of aphids due to early maturity. Ajmer Fennel-2 (AF-2) is moderate resistant to *Ramularia* blight
Fenugreek	There are many high yielding varieties of fenugreek which shows various degree of resistance to pest and diseases. RMt-305 and RMt-351 are, resistant to powdery mildew and root knot nematodes. HisarSonali is moderately resistant to root rot and aphids. HisarMadhavi, HisarMukta and RMt-354 are moderately resistant to powdery mildew and downy mildew..Guj. Methi-2 is tolerant to powdery mildew and resistant to root rot and downy mildew. RMt.1 is moderately resistant to root knot nematode. NarendraMethi 2 (NDM 69) is moderately resistant to *Cercospora*leaf spot and downey mildew.
Varieties for resistance to abiotic stress	
Black Pepper	Drought is one of the limiting factors in black pepper cultivation in India and the varieties *viz.,* Panniyur 6 and Panniyur 8 are field tolerant to water stress.
Small cardamom	ICRI-5 and ICRI-6 varieties are tolerant to drought.
Turmeric	Short duration varietiy: IISR Pragati is short duration variety with high yield potential helps in overcoming the drought situation.
Cumin	Gujarat Cumin 3 (GC-3) is a frost resistant variety suitable for winter season.
Varieties for high quality	
Black Pepper	Quality black pepper is measured in terms of piperine, oil and oleoresin content. There are varieties which are rich in these parameters. PLD 2 variety high quality cultivar contains oleoresin 15.45% and essential oil 4.8%. Sreekara and Subhakara are rich in essential oil with 6.0 and 7.0% respectively. IISR Malabar Excel is rich in oleoresin 13.5%.
Small cardamom	Market value of cardamom is decided by its appearance and size. Malabar types are characterised by globose-oblong shaped capsules and Mysore types are of ovoid, bold and dark green capsules.
Ginger	*Varieties for Fresh ginger:*Varieties with low fibre*viz.,* Suprabha, Himgiri and IISR Varada are suitable for fresh ginger. EssentialOil is one of the major quality character of ginger and varieties such as Athira, Karthika and Aswathy are rich in essential of >3%.
Turmeric	Curcumin is one of the important quality parameters and varieties rich in curcumin content are Roma, Suroma, IISR Prathiba, IISR Prabha, Megha turemric-1, IISR Alleppy Supreme and IISR Pragati.
Coriander	*Dual purpose varieties:*-HisarAnand, HisarBhoomit, Sadhana, Co.3, Narendra Dhania-2 are some of the important dual purpose varieties*Seed purpose varieties:* The varieties RCr 20, RCr 435, RCr 436, RCr 684, RCr-446, RCr-480, Swathi, Sindhu, Sudha (LCC-128), HisarSugandh, HisarSurabhi,Suguna (LCC – 236) Suruchi, (LCC – 234), DH 220, CS 287,RCr 475, Susthira and RD 385 are mainly grown for seed purpose.*High quality lines*: RCr-480 (0.425%), Sudha (0.40%) Sindhu (0.40%) are some of the coriander varieties with high yield and comparatively high volatile oil content.
Cumin	Guj. Cumin 3 (4.4%), Guj. Cumin 2 (4.0%) and RZ-341 (3.87%) are the varieties with high volatile oil. RZ-223 is a variety with long bold attractive seeds. Ac-01-167 is another bold seeded variety.
Fennel	RF- 205 (2.48 %) Guj. Fennel 2(2.4%) and RF-178 (2.13%) are the varieties with high essential oil. RF-157 is a variety with long, attractive, bold seeds and a volatile oil content of 1.95 %, *Sweet seeded type*: Pant Madhurika is a variety with sweet seeds and green fine ridges
Fenugreek	*Dual purpose varieties*:HisarSonali, HisarSuvarna, HisarMadhavi*Green seed colour*: HM 444 is a high yielding variety with unique green coloured seed.Guj. Methi-2 (Guj.Fenu.-244) and RMt-351(UM-351) are varieties with bolder lustrous grains and uniform in size
Varieties suitable for high density planting	
Small cardamom	Mudigere 1 and Mudigere 2 varieties are suitable for high density planting. IISR Suvasini is suitable for high production technology and responds well for nutritional inputs.
Uniform maturity types	
Fennel	*Synchronised maturity*: JF-444-1 and Gujarat Fennel 12 are high yielding varieties with synchronised maturity.
Fenugreek	*Determinant type*: RMt-305 is a determinant multi-poded type with early maturing and wider adaptability

Annexure – II. Technologies for sustainable production of spices

Water saving technologies- More crop per drop

Sl.No.	Crop	Technologies
Micro-irrigation - Increased Water Use Efficiency		
1.	Black Pepper	• Drip irrigation from December to April @ 2 lit./day increased the green berry yield of black pepper
2.	Turmeric	Application of water through drip system at 80% pan evaporation (once in a day for 45 minutes) helps in getting maximum fresh rhizome yield (43.52 t/ha), dry rhizome yield (7.79 t/ha), curcumin content (4.26%), essential oil content (3.67%) and oleoresin content (8.69%) with Cost benefit ratio of 1 : 4.98
3.	Coriander in rainfedvertisols	If water is available for only one irrigation then irrigating the crop with Raingun/Sprinkler at flower initiation is beneficial. If water is available for two irrigations, irrigating with Raingun/Sprinkler at flower initiation and grain filling stages is highly beneficial
4.	Fennel	Application of irrigation water by drip at 0.8% IW/ CPE ratio on alternate days with paired row planting helps in saving water to an extent of 19% compared to surface irrigation and increases the yield by 49.3%. Cost benefit ratio is 6.98
5.	Fenugreek	Application of irrigation water by drip at 0.6% IW/ CPE ratio on alternate days with paired row planting helps in saving water to an extent of 35% compared to surface irrigation and increases the yield by 107.4%. Cost benefit ratio of is 2.57

Fertigation -Precision Nutrition and Labour Shortage Mitigation

1.	Small cardamom	Technology for fertigation in Small cardamom saves 44% water and 25% fertilizer by the application of 9 litres of water per clump with 75% of recommended dose of fertilizers.
2.	Turmeric	Application of 100% RDF with urea and potash as straight fertilizers and P as water soluble fertilizer weekly once gives a yield of 49.11 t/ha with BC ratio of 2.94. This technology saves labour and 40% of water.

Integrated Nutrient Management- Soil & Plant Health Management

Sl.No.	Crop	Technologies
1.	Black Pepper	Application of FYM 10 kg, *Azospihllum* 50g, Phosphobacteria 50g, *Trichoderma* 50g, *Pseudomonasfluorescens* 50g, NPK 50:50:200 g/vine per year from 3rd year onwards increases the yield
2.	Small cardamom	Application of boron in the form of disodium tetraborate @ 20 kg/ha or molybdenum in the form of sodium molybdate @ 0.25 kg/ha mixed with appropriate quantity of FYM @ 2 kg/plant at the onset of monsoon (May 1st or June first week)increased the yield by 20%.
3.	Ginger	For integrated nutrient management in ginger the fertilizer dosage of FYM @ 30t/ha + NPK 80:50:50 kg/ ha under Bihar conditions was recommended.Application of neem cake 2 tonnes/ha together with inorganic fertilizers increased the availability of nutrients in soil, increased yield and reduced incidence of rhizome rot.
4.	Turmeric	Soil application of FYM @30 t/ha + Vermicompost@ 20 q/ha + Neem oil cake @ 8 q/ha resulted in 68% increase in yield over control and C: B ratio of 1:3.64. Soil application of inorganic N @150 kg/ha + *Azospirillum* @1.5 kg/ha + FYM @ 5 t/ha results in 35% increase in yield over control and C: B ratio of 1:5.27
5.	Nutmeg	Application of 100 kg FYM, 400 g N, 300 P_2O_5 and 1200 g K_2O/tree/year and 50 g in each of *Azospirillum* and *Phosphobacteria* recorded highest yield.
6.	Clove	Application of 50g each of *Azospirillum* (10^{-6} CFU) and phosphobacteria (10^{-5} CFU) with 400 g N, 350g P_2O_5 and 1200 g K_2O/tree/year in two equal splits namely in May - June and October - Novemberresulted in the highest green bud yield/buds per cluster.
7.	Coriander off season coriander	Soil application of inorganic N @ 33 kg/ha + *Azospirillum* @1.5 kg/ha + FYM @ 5 t/ha resulted in yield of 1.98 t/ha (56% increase in yield over control) and C: B ratio of 1:1.77.Application of NPK @ 30:40:20 kg per ha along with spraying of GA @ 15 ppm at 20 DAS give maximum leaf yield of coriander (4824 kg/ha) with yield increase of 25% over control.
8.	Fenugreek	Soil application of inorganic N @ 13kg/ha + *Azospirillum* @ 1.5 kg/ha + FYM @ 5 t/ha resulted in highest yield
9.	Cumin	Application of 100% in organic nitrogen + *Azospirillum* @ 1.5 kg/ha as seed treatment + 5 t FYM /ha resulted in highest seed (320kg/ha) at Jobner

Micro nutrient- Balanced Nutrition

1.	Black Pepper	Foliar application of Zn (0.25%) twice, once in June and again in August is recommended for increasing the yield. Basal soil application of 6 kg Zn and 1.0 kg Mo for higher yield and quality of black pepper under deficient conditions
2.	Ginger	Soil application of borax @ 5 kg/ha recommended for increased yield in West Bengal
3.	Turmeric	For Iron deficient soils of Bihar (1.73ppm), foliar application of Ferrous sulphate @ 0.5% at 60 & 90 days after planting is beneficial for yield enhancement.
4.	Coriander	Soil application of $MnSO_4$ @ 25 kg/ha and $CuSO_4$ @ 0.50% and soil + foliar application of $FeSO_4$ @ 5 kg/ha + 0.125%, $MnSO_4$ @ 12.5 kg/ha and $CuSO_4$ @ 12.5 kg/ha +0.25% gave significantly higher yield. For the saline soils where there is zinc deficiency (less than 2 ppm), spraying of 0.5% of zinc sulphate (2 spray- 45 and 60 days after sowing) resulted in seed yield of 772.44 kg/ha with BC ratio of 2.10 in coriander.
5.	Fennel	Application of $ZnSO_4$ (0.50%), $FeSO_4$ (0.25%) + 0.125% and $MnSO_4$ (12.5 kg/ha +0.25%) increases the yield
6.	Crop specific micronutrient mixtures for spices (Black pepper, Ginger, Turmeric)	Recommended @ 5g/L water and applied as foliar spray at 60 days after planting and 90 days after planting for ginger and turmeric; spraying twice in a year at April – May and August – September for black pepper. Yield increase of 15 to 25% and improvement in quality recorded and realized by farmers in black pepper, ginger and turmeric.

Organic Production Technologies – Food Safety

Sl.No.	Crop	Technologies
1.	Black Pepper	• Mulching the basins of pepper vines with saw dust, coconut husk or dry leaves or polythene sheets reduced the causality of vines, reduced spike shedding and increased the yield by 30.70%.
2.	Turmeric	Soil application of FYM @30 t/ha + Vermicompost@ 20 q/ha + Neem oil cake @ 8 q/ha resulted in 68% increase in yield over control and C: B ratio of 1:3.64. Recommended for Bihar.Mixed cropping with chillies, colocasia, brinjal, cereals, (maize &ragi) for Andhra Pradesh and K_2chillies as border crops in Tamil Nadu are recommended. Crop rotation: turmeric – maize (Tamil Nadu), turmeric rotated with maize or paddy (Andhra Pradesh & Orissa), turmeric and radish (Maharashtra). Sequential cropping – turmeric – banana – sugarcane – turmeric, turmeric – banana – paddy – turmeric (Tamil Nadu).
3.	Coriander	Application of FYM 50% + vermi compost (50%) resulted in seed yield of 753.25 kg with the B:C ratio of 2.05.Seed pelletizing with IISR PGPR strains either FK-14 [*Pseudomonasputida*] or FL-18 [*Macrobacteriumparaoxydans*] or combination of both increases the yield and disease tolerance.
4.	Cumin	Three years crop rotation *i.e.*, cluster bean-cumin-cluster bean–wheat-cluster bean- mustard
5.	Seed Spices	An environment friendly, seed coating technology using PGPR FK 14 and FL 18 isolates resulted in increased yield (10-30%), enhanced seed germination and quality and reduces storage pests of seed spices

Rapid Multiplication of Planting Material – Faster Spread of Improved Varieties

Sl.No.	Crop	Technologies
1.	Turmeric &Ginger	**Single bud portray method**: Rhizome bits of 5-6 g with a bud planted in portray requires 1/4th of planting material requirement of conventional propagation. It saves 60% cost of seed rhizome.

Integrated Pest and Disease Management – Sustainable Eco-friendly Technologies

Sl.No.	Disease	Technologies
1.	*Phytophthora* foot rot of black pepper	Application of antagonistic organisms like *Trichoderma viride* @ 150 g/vine along with 5 kg of FYM to the basin of black pepper vine during June helps in controlling *Phytophthora* foot rot. Solarized potting mixture fortified with *Trichoderma harzianum*(1 g/kg) and VAM (100 cc/kg)of potting mixturewas effective for the management of *Phytophthora* infections in the nursery.Application of metalaxyl-mancozeb (2.5 g/l), *T. harzianum* (50 g/vine) and neem cake (1 kg) was effective for controlling *Phytophthora*foot rot disease in the field.New fungi toxicant molecule Fenomidone (10%) + Mancozeb (50%) @ 2 l/vine as spray and 3 l/vine as drenching along with Trichodermaharzianum 50 g with 1 kg of neem cake as soil application during 1st week of June and 3rd of August reduced leaf infection, yellowing, defoliation and death of vines.Black Pepper grafted on resistant root stock –*Piper colubrinum*- an eco friendly way to manage *Phytophthora* foot rot.
2.	Slow decline of pepper	Application of carbofuran 3G or phorate 10 G (30 g/vine) plus Bordeaux mixture spraying and copper oxychloride (0.2%) drenching plus soil application of neem cake @ 2 kg/vine check the infection

Contd

3.	Pseudostem rot in small cardamom	Chemical control by drenching of Carbendazim @ 2 g/l (5 l/ plant) at monthly intervals from Feb-May or biological control by combined application of *Trichoderma harzianum* (50 g with 1 kg neemcake) + *Pseudomonas fluorescens* (2 % spray) helps in chcking disease
4.	Rhizome rot of ginger	Crop residues of mustard and cabbage incorporated in soil (Biofumigation) and rhizome treatment with Metalaxyl + Mancozeb (1.25 g/litre) of water for 15-20 minutes helps in controlling soil borne pathogens and is environmentally safe.
5.	Stem gall of coriander	Seed treatment with IISR *Pseudomonas* talc formulation @ 0.40% followed by its foliar sprays @ 0.40% at 40, 60 & 75 days after sowing is found to be effective in control of stem gall of coriander in the susceptible variety Rajendra Swati
6.	Powdery mildew of coriander	A cost effective ecofriendly biocontrol method by spraying of neem seed kernel extract (NSKE) @ 5% thrice, first spray immediately after the appearance of disease and the subsequent two sprays at 15 days interval.
7.	Wilt of Cumin	Integrated management by *T. harzianum*application as seed treatment as well as soil application along with spraying of topsin (0.07%) or mancozeb (0.3%) and neem oil controls the disease
8.	*Phytophthora* in spice crops	*Trichodermaharzianum* can be used successfully to manage *Phytophthora*in spice crops. Significant reduction in disease incidence and increased productivity by 10-15%.

Pest and Disease Management – Chemical Control

Sl.No.	Disease	Technologies
1.	*Phytophthora* foot rot of black pepper	Spraying Bordeaux mixture (1.0%) and drenching copper oxychloride (0.2%) twice during June &Septembe checks the disease
2.	Black berry (Pollu) disease of pepper	Spray Bordeaux mixture (1.0%) or captofol (1%) once before flowering starts (July) and at berries formation stage (August). A combination spray of quinalphos 0.1% and zineb 0.2% once in June and again in September to control pollu fungus and pollu beetle.
3.	Anthracnose of black pepper	A combination of fungicides Carbendazim (0.1%) and mancozeb 0.1%. Carbendazim 2 g/l followed by SAAF 2g/l (Carbendazim + Mancozeb) controls the diseases
4.	Scale insects of Black pepper	Two sprays of monocrotophos (0.05%) or dimethoate (0.05%) or quinalphos (0.05%) or fish oil and neem oil at 15 days interval after harvest of berries.
5.	Rhizome rot of small cardamom	Spray and drench with Bordeaux mixture 1% or copper oxychloride 0.2% before onset of monsoon (May/ June) and after the end of monsoon (August) controls the diseases
6.	Rhizome rot of ginger	Seed treatment with mancozeb (Indofil M-45 - 0.25%) + carbendazim (0.1%) for 60 minutes; dry under shade for 24 hours before sowing/storage. Dip seed rhizomes in copper oxychloride (blitox-50 - 0.3%) before storage controls disease
7.	Bacterial wilt of ginger	Treatment of seed rhizomes with streptocyclin 200 ppm for 30 min. and shade dried before planting. Beds should be drenched with Bordeaux mixture 1% or copper oxychloride 0.2%.
8.	Shoot borer of ginger	Spray dimethoate (0.1%) or quinalphos (0.1%) at bimonthly intervals or malathion (0.1%) or monocrotophos (0.075%) during July– October at monthly intervals.
9.	Leaf blotch of turmeric	Spray 1% Bordeaux mixture or copper oxychloride or carbendazim (0.1%) or mancozeb (2.5 g/l) at 500 lit/ ha or captan (0.2 ml) at monthly interval. Treat seed rhizome with carbendazim, mancozeb and carbendazim (0.2%) for 60 minutes and shade dry before planting.
10.	Rhizome rot and wilt of turmeric	Treat seed rhizome with mancozeb (0.25%) or carbendazim (1.0%) for 30 minutes prior to storage and at the time planting. Drenching of infected plants/ beds with copper oxychloride (0.3%) or mancozeb (0.3%) or 1% Bordeaux mixture controls the diseases
11.	Shoot borer of turmeric	Spray malathion (0.1%) or monocrotophos (0.075%) or dimethoate or quinalphos during July to October at monthly interval
12.	Powdery mildew of coriander	Two sprays of 250 litres with Karathane 48EC/Dinocap/ Carbendazim (0.01%) at disease initiation and 10 days after with carbendazim (0.1%) or Two spray of wettablesulphur (@ 2.5 g/lits.), one at the time of flower initiation and seed 15 days later or (3) dusting of sulphur @ 25 kg/ha thrice controls the disease

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Floriculture as an Option for Enhancing Farmers' Income

K.V. PRASAD

Floriculture is a multifaceted enterprise in India. It is characterized by growing traditional flowers (loose flowers) and cut flowers under open field conditions and protected environment conditions respectively. Other floricultural segments like fillers, indoor plants, landscaping plants, seeds and planting material, turf grass and value added products also contribute their share in the overall growth of the sector. The traditional flower cultivation, comprising of growing loose flowers mostly for worship, garland making and decorations, forms the backbone of India floriculture, which is mostly in the hands of small and marginal farmers. About 2.50 lakh ha of area is under loose flower cultivation producing 1658000 MT of loose flowers and 484000 tonnes of cut flowers annually (NHB2014-15). The major production comes from Karnataka, Tamil Nadu, Andhra Pradesh, Uttar Pradesh, Rajasthan, West Bengal, Bihar, Jharkhand, Kerala and Telangana while the major markets are in Chennai, Bengaluru, Kolkata, Hyderabad, Kadiyam, Pune, Mumbai and Delhi. The marketing network for loose flowers comprises of growers, middlemen, wholesalers, retailers and the consumers. The marketing yards for flowers are mostly on the pavements with primitive infrastructure for postharvest care and processing leading to poor shelf life. A small portion of loose flowers is being exported to Middle East, UK and USA for the expatriate Indians.

In India nearly 98.5% of flowers are grown under open cultivation and hardly 1.5% flowers are grown under greenhouse cultivation. The euphoria generated by the sector during 1990s for cut flower production in greenhouses subsided after some hard lessons learned by the industry. West Bengal, Karnataka, Uttar Pradesh, Maharashtra, Gujarat, Himachal Pradesh, Uttaranchal are the major producers of cut flowers. The marketing network for cut flowers comprises of growers, exporters, auction houses, retailers and consumers. In the domestic markets, dedicated marketing infrastructure for cut flowers is in place in Bangalore in the form of a flower auction center. Such flower auction centers are in place in Noida and other metros.Floricultural exports from India comprise of fresh cut flowers (to Europe, Japan, Australia, Middle East and USA) loose flowers (for expatriate Indians in the Gulf) cut foliage (to Europe) Dry flowers (To USA, Europe, Japan, Australia, Far East and Russia) Potted Plants (Limited to Middle East) besides seeds and planting material. India also has a strong dry flower industry, with substantial contribution (>70%) to floricultural exports. Dry flowers alone contribute nearly Rs.320 crores (70%) of total exports valued at Rs.479crores (2016). India's position as an exporting country for cut flowers stands at 29 among the flower exporting countries with a value of 8227(000USD) which translates to a percentage share of 0.31%. On the other hand India imports flowers worth Rs. 112crores from Thailand, the Netherlands and People's Republic of China.

The demand for the flowers in India is constantly increasing especially among the metros. This trend has encouraged the Indian traders to import some of the exotic flowers for decoration and floral arrangements. Major flowers that are being imported and sold in Indian markets include Proteas, orchids, Iris, Cala Lily, Heliconia etc., Thailand is the major exporter of tropical flowers especially orchids to

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India followed by the Netherlands. India has a sizeable nursery industry with major hubs located in Kadiyam (Andhra Pradesh), Kalimpong (West Bengal), Pune (Maharashtra), Gajrola and Shaharanpur (Uttar Pradesh), Bengaluru (Karnataka). India is a leading producer and exporter of dry flowers in the world (Rs.320 cr during 2016). The product mix comprises of forest produce, farm residue, seeds, pods and fruits besides specific flowers that are dried. The major production centers are in Tuticorin, Cochi and Kolkata. The demand for flowers picks up during the major festivals, cultural and religious events, across the country. However, many times the farmers have to face declining prices due to following reasons:

a. Planting of same crop and same variety by large numbers of farmers results in glut in market causing price crash.

b. Inadequate knowledge on using different varieties that could mature in different periods of time.

c. Prejudiced belief that only white and yellow coloured flowers are more preferred by the consumers and therefore over producing the same flowers and colors

d. Inadequate knowledge about staggered planting to minimize the threat of glut.

e. Lack of on farm storage facility for storing the flowers for a short period to overcome the glut.

f. Inadequate infrastructure for processing and value addition.

Owing to the above mentioned constraints very often the farmers tend to lose even minimum expected returns from the harvested flowers. The Research and Development network in the country responded to the clarion call by the Government of India to double the horticulture production from 150 million tons to 300 million tones, during 2007 – 2012. The horticulture production surpassed the food grain production during 2013-14 to cross 280 million tones. The country is equally prepared for a similar call by Honorable Prime Minster of India to double the farmer's income by 2020.

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Dynamics of Potato Production for Enhancing Farmers Income

SWARUP KUMAR CHAKRABARTI

Comparative Farm Profits from Cereal Crops and Potato

There have been several studies showing that horticultural crops like fruits and vegetables provide more profit to farmers as compared to traditional cereals like rice, wheat and maize. Diversification of farm activities towards high value crops and enterprises can be a major driver of income growth for farmers. A comparative study of operational cost of cultivation and net income from potato and cereals like rice and wheat for three major states *i.e* Uttar Pradesh, West Bengal and Bihar is given in Table 1. It can be seen that operational cost of cultivation of potato for all selected states is higher than rice and wheat with highest in West Bengal @ Rs 1,08,860.30/ha. Due to very high gross income in potato, net income/ha from potato is more than double of rice and wheat in Uttar Pradesh. In West Bengal, income from potato is Rs 36,519.70/ha which is nearly three times higher than rice and wheat. Potato provided higher return of Rs 32,787.00/ha in Bihar as compared to Wheat (Rs 26,835.70/ha). Paddy cultivation in Bihar is not as profitable to farmers as potato because it is giving a meagre return of only Rs 6,277.70/ha. Thus, it can be noted that cultivation of tuber crops like potato can fetch more income for farmers as compared to traditional cereal crops.

How to Further Improve Farm Profit from Potato

Farm profit in case of potato is higher but there is a need to further enhance the income of farmers by increasing its productivity, decreasing cost of cultivation and proper marketing. Use of high yielding variety alone can enhance the productivity to a large extent and, therefore, farmers need to adopt new varieties of potato suitable for their locality for increasing their farm yield. ICAR-CPRI has developed an ICT based decision support system that can help the farmers to select the best variety for a particular area. Quality planting material is a major input accounting for more than one third of

Table 1: Comparison of cost of cultivation and net income from major cereal and potato

States	Particulars	Paddy	Wheat	Potato
Uttar Pradesh	Operational Cost of cultivation (Rs/ha)	29915.4	27501.3	77307.3
	Gross Income (Rs/ha)	61692.4	59233.9	139786.4
	Net Income (Rs/ha)	31777.0	31732.6	62479.1
West Bengal	Operational Cost of cultivation (Rs/ha)	44645.8	34709.1	108860.3
	Gross Income (Rs/ha)	57316.5	44614.7	145380.0
	Net Income (Rs/ha)	12670.7	9905.6	36519.7
Bihar	Operational Cost of cultivation (Rs/ha)	25236.5	23055.8	39952.7
	Gross Income (Rs/ha)	31514.2	49891.5	72739.7
	Net Income (Rs/ha)	6277.7	26835.7	32787.0

Source: Directorate of Economics and Statistics, Ministry of Agriculture, Govt. of India (2013-14)
*Net income = Gross income-operational cost of cultivation

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total cost of cultivation in potato. Therefore, availability of quality seed at affordable price is necessary for increasing productivity. Moreover, there is shortage of water which can be taken care by adoption of drip and sprinkler irrigation. Several studies have proved that these methods of irrigation not only save water to the extent of 30-50 % but also increase the quality of produce as well as productivity of the crop. Diseases and pest also causes loss in yield to a great extent. So, plant protection technologies should be adopted by farmers to control diseases and pests of tuber crops. This will enhance the farm productivity significantly thereby, help in increasing farmers' income. Following technological interventions are advocated here for increasing the productivity of potato.

High yielding improved varieties: In case of potato, ICAR-CPRI, Shimla has developed 53 varieties suitable for different agro-climatic conditions since its inception. Out of these, 25 varieties are still under cultivation in different states of India. Farmers need to grow late blight resistant high yielding potato cultivars for higher income. There are several short duration varieties like Kufri Pukhraj, Kufri Khyati and Kufri Surya which gives high yield even by 70-80 days only. Kufri Gaurav is a nutrient efficient variety which gives yield equivalent to any other variety even with low fertilizer dose in Punjab area. Some processing varieties like Kufri Chipsona-1, Kufri Chipsona-3 and Kufri Chipsona-4 can give more profit to farmers due to higher price in the market.

Quality planting materials: Most of the tuber crops are propagated vegetatively using either stem pieces or tubers. Therefore, maintaining the quality of seed particularly its freedom from viruses and other pathogens is very necessary. Availability of quality potato seed is still a major constraint for potato growers in India. Therefore, it is necessary to supply good quality seed to farmers at affordable rate. Farmers themselves can also grow potato seed by using "Seed Plot Technique" developed by ICAR-CPRI, Shimla. This technology was primarily responsible for the phenomenal increase in area, production and productivity of potato in India during last 50 years. Integration of seed plot technique with the advanced virus diagnostic techniques, plant protection measures and agronomic practices has laid the sound foundation of the Breeder Seed Production programme in India. However, there is still a gap because of high demand and limited supply of quality potato seed in the country. As per FAOSTAT, India used 2.96 million t potato tubers (8.5% of national potato production) as seed during triennium ending year 2010. The absolute quantity of potatoes used as seed is estimated to increase to 6.1 million t during 2050 (ICAR-CPRI Vision, 2050). Recently, high tech seed production technologies like tissue culture raised mini-tubers as well as mini-tubers raised by aeroponics technology have been developed and are being promoted for production of quality potato seed. Under tissue culture based technology, virus free stock of a cultivar is raised by meristem culture. The mericlones are tested by ELISA and ISEM and healthy plants are sub-cultured 8-10 times to get desired number of microplants/microtubers. These are free from the risk of spreading bacteria, fungi and viruses. These microtubers/microplants are then used for minituber production under net house.

Under aeroponic technology, potato plants are grown in a closed environment by periodically spraying roots with a nutrient rich solution without the use of soil or any other aggregate medium. There is fast multiplication of high quality planting material producing 35-60 minitubers per tissue culture plantlet. It also minimizes the contact of potato tubers with many soil borne pathogens. Moreover, it is easy to operate and can be installed even in non-arable and water scarce areas. This technology has high cost effectiveness as with an investment of Rs 100 lakhs for production of 10 lakh tubers, an entrepreneur can earn up to Rs. 52 lakhs per year. Thus, tissue culture and aeroponic technology has the potential to revolutionize the traditional seed production system in India.

Improved production technologies: Irrigation water constitutes the major constraint for cultivation of any crop including potato. Modern potato varieties are sensitive to soil water deficits and need frequent, shallow irrigation. In general, water deficits in the middle to late part of the growing period – during stolon formation and tuber initiation and bulking – tend to reduce yield, while the crop is less sensitive during early vegetative growth. Water savings can also be achieved by allowing higher depletion toward the ripening period so that the crop uses all available water stored in the root zone, a practice that may also hasten maturity and increase dry matter content. Some varieties respond better to irrigation in the earlier part of tuber bulking, while others show a better response in the latter part. Varieties with few tubers are usually less sensitive to water deficit than those with many tubers. Water requirement of potato can be economized by tailoring the timing and depth of water applications to specific stages of the plant's growth cycle. Technologies are now available for precise irrigation through drip and sprinkler methods rather than flood irrigation that will not only save water but also enhance productivity. Large scale adoption of micro-irrigation system in Gujarat has led to highest productivity of potato in the state.

Soil health is a global concern now. Indiscriminate use of chemical fertilizers has already done a considerable damage to quality of soil and ground water. A huge quantity of NPK is applied each year in cultivated land much of that either percolates to ground water or accumulates in surface water reservoirs through run off. For instance, fertilizer use efficiency ranges from 30-50% for N, 15-20% for P, 8-10% for S, 2-5% for Zn, 1-2% in case of Fe and Cu. To avoid nutrient loss and to improve soil health, ICAR-CPRI has developed several GSS and ICT based decision support systems that will calculate amount of fertilizers to be used for obtaining desired level of productivity at a particular location. Similarly, ICAR-CPRI has developed disease forecasting models to precisely determine the time of pesticide application so that unnecessary spray of chemicals can be avoided. Balanced and efficient fertilizer and pesticide use has to be supplemented with increasing soil organic matter contents through soil carbon sequestration supported by incorporation of crop residues, green manuring, application of FYM, compost, vermi-compost, bio-fertilizers and other bio-digested products.

Plant protection technologies: Plant protection is a major step towards increasing farm productivity. In case of potato, late blight and bacterial wilt are major diseases affecting the crop. Prophylactic spray (just at the time of canopy closure) with mancozeb @ 0.2% (2gm /lit of water) followed by cymoxanil + mancozeb @0.3% (3gm/lit of water) and one more spray with mancozeb @ 0.2% is effective for late blight management. Bacterial wilt requires integrated practices for its management which includes (i) soil solarization by covering the plot with linear low density polyethylene sheet of 25 mm thickness (LLDPE) during summer for at least 15 days, (ii) use healthy seed tubers obtained from bacterial wilt-free regions, (iii) dipping well-chatted tubers in 0.25% (10^6 CFU/ml) suspension of *Bacillus subtilis* (B5) and drying under shade before planting, (iv) crop rotation with finger millet or ragi.

Virus vectors like aphids and white flies also need to be managed as they spread several potato viruses in seed crop. Following strategies should be adopted for proper management of these sucking pests in potato – (i) place yellow sticky traps (15x30 cm^2 size) just above the canopy height @ 60 traps per hectare at equidistance from each other for mass trapping of white flies/aphids, (ii) seed treatment with Imidacloprid (200 SL) @ 0.04% (4 ml/10 L) for 10 minutes before planting, (iii) first spray with Imidacloprid (200 SL) @ 0.03% (3 ml/10 L of water) at the time of emergence of crop, if needed, and (iv) second spray with Thiamethoxam (25 WG) @ 0.05% (5 gm/10 L of water) after 15 days of crop emergence.

Improved post-harvest management: After harvest, tubers should be kept in heaps for 10-15 days in shade for curing of skin. It is necessary to remove all damaged and rotten tubers. To get the good returns, the produce should be graded and packed in gunny bags. Farmers can earn more profit if they can store potato in cold storage and wait for price rise. Potato for table purpose and processing purpose can be stored with the help of elevated temperature storage technology at 10-12 ^oC by treating them with CIPC @ 40 ml/tonne. The potatoes stored using this technology will not be sweet in taste and thus can fetch higher price. It should be noted that seed potato should be stored at 0-2 ^oC only. Value addition in potato by preparation of dehydrated potato products as well as chips, French fries, lachha etc. can also give handsome returns to farmers. Technologies for value addition at home scale is available with ICAR-CPRI, Shimla.

Conclusion

Horticulture *per se* has a great potential to enhance farm income. Therefore, shifting from traditional grain crops to high value horticultural crops would contribute in a big way towards doubling farmers' income in India. Among the horticultural crops, tuber crops are particularly important for achieving the goal because of their exceptionally high per unit productivity. However, to achieve the target of doubling farmers' income in an inclusive manner, the production clusters are to be well connected with the input as well as consumer markets. It is beyond any doubt that establishment of micro- mini-, small-, and medium-scale enterprises dealing with agricultural inputs and produces can effectively improve livelihood security of rural India. Tuber crops offer tremendous opportunity for establishment of such enterprises at village level. Besides, they also offer opportunity for greening rural development through healthy ecosystems support and sustainable agriculture which is the major mandate of the National Rural Livelihood Mission (NRLM/Aajeevika) launched by the Ministry of Rural Development, Government of India. The effective dissemination of the technological advancements can help in a big way to further improve productivity and to unravel the utilization prospects of potato for the benefit rural population.

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Orchids: An Option in Hills and Coastal Areas for Enhancing the Farmer's Income

D.R. SINGH* AND RAJ KUMAR

The Orchidaceae, the largest family of the plant kingdom, comprises more than 30,000 species in approximately 750 genera, and one of the most widespread of all plant families. Due to recent increase in the world floriculture trade, orchids became the second most popular cut flowers as well as potted floriculture crop rising at the rate of 10–20%. In India 1350 orchid species belonging to 186 generas, which is representing 5.98 % orchid flora of the world and 6.83 % of the flowering plants of India.The Himalayas, North East India, Western Ghats and Andaman & Nicobar Islands are the regions of orchid rich biodiversity.Majority of Orchids of India are Epiphytic, they predominate in the regions having cool temperature and moist climate. Arunachal Pradesh sustains the highest number of orchid species which is about 544 species alone, of which about 349 species are common with Sikkim hills. Sikkim Himalaya, comprising the hills of Sikkim and Darjeeling is the centre of origin for important species like Cymbidium.The tropical warm and humid climate of Andaman & Nicobar Islands favours the richness of orchid diversity in this region. 132 orchid species from 59 genera have been reported from Andaman & Nicobar Islands. 60 species are found in the Great Nicobar island alone and 32 species are found endemic to the region.

Genetic resources of orchids in North Eastern India and Andaman & Nicobar Islands

Habitat	State	Genera	Species
North Eastern Zone	Arunachal Pradesh	133	614
	Sikkim	122	520
	Mizoram	104	374
	Meghalaya	73	230
	Nagaland	74	249
	Manipur	66	207
	Assam	75	195
	Tripura	34	52
Andaman & Nicobar Islands	Andaman & Nicobar Islands	59	132

The orchid has taken a significant position in the cut flower industry due to its attractiveness,long shelf life, high productivity, right season of bloom, ease of packing andtransportation. Orchids account for a large share of global floriculture trade both ascut flowers and as potted plants and are estimated to comprise around 10% of theinternational fresh cut flower trade. The average trade value of fresh cut orchids and buds trade during 2007-2012 was US$ 483 million. In 2012, there were more than 40and 60 exporting and importing orchid countries, respectively around the world, andthe total size of the global trade was US$ 504 million.

The Netherlands is the top orchid exporting country in the world (39.67% of worldorchid market) followed by Thailand (28.41%), Taiwan

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(10%), Singapore (10%) andNew Zealand (6%). Importing countries are mainly Japan (30%), UK (12%), Italy (10%), France (7%) and the USA (6%). The total orchid cut flower trade of the world mostly consistsof 85% Dendrobium species and 15% Phalaenopsis and Cymbidium species, andAsia is the main source of orchid to enter the world market. Major markets for orchids in Asia are occupied by Japan and Singapore. The total imports of orchids by Japan accounted for US$ 57.4 mn in 2008 making it the largest importer of orchids in the world. The main sources for these imports include Thailand, Taiwan, New Zealand and Malayasia which together account for as much as 96.5% of the total orchids imports by Japan in 2008. Imports by Singapore of fresh orchids amounted to US$ 6.5 mn in 2007 with Malayasia, Thailand and Taiwan being the main sources of imports for the country. In contrast, imports of fresh orchids by Singapore from India were only US$ 1379.3 representing a share of 0.02% of the country's total imports of the product in 2007 This clearly indicates that there are vast possibilities for increasing India's exports to Singapore particularly considering the proximity of the country and India's East Policy.

Trends in Growth of Global Orchid Industry

Cymbidiums are among the most popular winter and spring blooming semi-terrestrialorchids originating from tropical and subtropical Asia; covering North Eastern India,China, Japan, Malayasia, the Philippines, the Borneo islands and North Australia,usually grown in cooler climates at high elevations. Cymbidiums are highly valued forgenetic resources, cut flowers, hanging baskets, potted plants and herbal medicines.Cymbidium has been considered the top commercial orchid in Europe for many years.They fetch the highest price in the international markets of which major destinationinclude Asian markets of Singapore and Japan or the Dutch market. Cymbidiumsimported from the Netherlands fetched as much as US$ 11.18 per stem in Singaporeand those imported by Japan from New Zealand fetched US$ 3.33 per stem. As far asthe Dutch Auction market is concerned, the cymbidiums fetched the highest value,averaging Euro cents 331 per stem.

Dendrobiums are popular flowering potted plants and cut flowers around the worlddue to their floriferousness, wide range in flower color, size and shape, year roundavailability and lengthy vase life. Hawaii, California and Florida are major potted Dendrobium growing regions in the United States. The wholesale value of salesfor this commodity in Hawaii has been established for several decades and salesincreased from US $ 2.4 million in 1991 to US$ 5.6 million in 2000. In the Netherlands, production of potted orchids is now 40 to 50 million unitswith Dendrobium increasing in popularity. Imports from Thailand, the worlds largestexporter of tropical cut orchids and second largest supplier to the EU, accounted for22% of supplies to the EU. Thailand holds a particularly strong position in Dendrobiumorchids.

Phalaenopsis is the second most valuable and popular flowering potted plant and cut flower around the world due to their easy cultural practices, diversity in flower colour, size and shape, year round availability, delicacy and longer vase life. It is commercially grown in Germany, Japan, The Netherlands, Taiwan and United States. In the United States, 75% of all orchids purchased are phalaenopsis and about 13,500,000 phalaenopsis were sold in 2005 in United States. The export value of Phalaenopsis from Taiwan to the United States increased from $8 million in 2005 to $13 million in 2006. Worldwide turnover of Taiwanese phalaenopsis increased from $27.5 million to $35.4 million from 2005 to 2006.

Vanda is widely distributed throughout Australasia from China through the Philippines, Indonesia, Malaysia, New Guinea and Australia, Myanmar, Thailand, India and Sri Lanka. In the world tropical orchid trade, Dendrobium is the most dominant crop in addition to Mokara, Oncidium, Aranthera, Aranda, Vanda, Arachnis, Renanthera, Ascocenda, Phalaenopsis, Cattleya and Paphiopedilum which are being grown as cut flowers and potted plants. Thailand is the largest world exporter of tropical orchids. China is the largest consumer of orchid cut flowers (7,493 tons from Thailand) followed by Japan, USA, Italy, India, Taiwan, Vietnam and the Netherlands at 4,407, 2892, 2395, 1830, 983, 793 and 689 metric tons, respectively. Other significant orchid genera being exported from Thailand were Mokara, Aranthes, Aranda, Oncidium, Vanda, Arachnis and Ascocenda with market shares of 3.69, 0.52, 0.48, 0.44, 0.13, 0.01 and 0.01% of total export value respectively.

Considering the import value of orchid plants, Japan was also the largest importerof Thai orchid plants at US$ 2.4 million worth followed by the Netherlands, USA,Germany, Rep. of Korea and Vietnam with values of 1.6, 1.4, 1.0, 0.9 and US$ 0.9 millionrespectively. In 2009, Thailand exported 211 genera of orchid plants. Dendrobiumand Phalaenopsis plants were the most important orchid genera for exports with marketshares of 51.4 and 25.5%, respective. Other important orchid genera exported fromThailand were Vanda, Mokara, Oncidium, Cattleya and Ascocenda with market sharesof 8.9, 3.7, 3.1, 2.7 and 1.2% of total export value, respectively.

Trends in Growth of Indian Orchid Industry

In the present senerio today in India, there is a tremendous scope for orchid improvement and development of industry based on these wonderful plants. Possibilities of producing new and novel varieties through successful wide matings have added new dimensions to the significance of these plants in the trade. Many orchids native to this country have already proved to be important parent plants and contributed to the production of several outstanding hybrids in the world. Hybrids of certain Indian orchids, like species of Aerides, Ascocentrum, Arachnis, Cymbidium, Dendrobium ,Paphiopedilum, Phalaenopsis, Renenthera, Rhynchostylis and Vanda are considered the monarchs in the orchid world. Due to the diversity of environmental condition in India, it is possible to grow all types of orchids in suitable places without controlling the environment and hence can be grown with minimum expenditure.

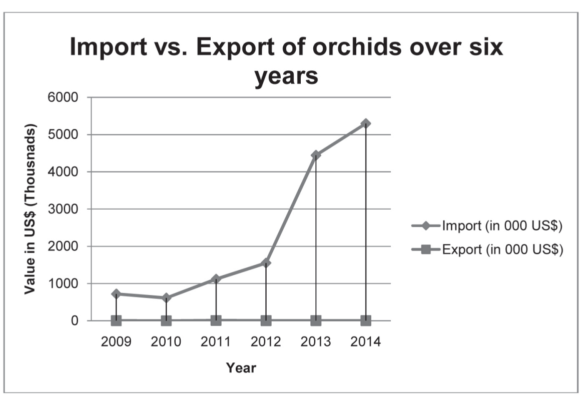

Fig. Change in pattern of Import and export from 2009-2014 of fresh cut orchids and buds, of a kind suitable for bouquets or for ornaments

In the last few years, "orchid mania" has invaded Kerela and quiet a few nurseries are growing Dendrobium and Vandaceous hybrids on a commercial scale.

The North Eastern Himalayan states, which are considered as orchid rich states, are best for commercial cultivation of different groups of orchids. Most of the present day cultivated hybrids are originated from the species native to this region, which have a very high demand in international cut flower, potted plant and indoor decoration and botanically important generas. Of late, there is a considerable awareness for developing the orchid Industry in this region. Cymbidium and Paphiopedilum species is considered to be grown potentially here.

There is a vast possibility that orchid industry might rule the floriculture trade in the future years to come but there are several constraints which hamper the development of a meaningful orchid based floriculture in the country. These include the lack of proper planting material and protocols for commercial cultivation, appropriate policies and incentives. Moreover as the trends in floriculture are ever changing, R&D activity has to be a continuous affair so as to develop suitable planting material from among the available germplasm. Therefore there is a strong need to have a concrete knowledge on the orchid flora, gather information on habitat ecology, identify the threatened and endangered species and conserve them to improve the quality of planting material through desired crossing. There is also a need to understand the value and importance of this precious plant nationally and internationally and aim at the proper utilization of the orchid material.

In India, the Arunachal hills, Sikkim and Darjeeling hills with cool summer nights and monsoonal summer rain are ideal for cymbidium cultivation. The growth of orchid exports from the north eastern hill region, especially Sikkim, would provide opportunities for employment as well as the development of supporting industries like packaging, cold storage and transportation. East Sikkim has been declared an Agri Export Zone exclusively for production of cymbidium orchids. In Sikkim, more than 250 hybrids of cymbidium orchids are commercially cultivated in and around 25 ha of land and about 5 lakhs spikes are produced annually.

The tropical type of orchids *i.e.* Dendrobium, Phalaenopsis and other vandaceous orchids are commercially grown in Kerala, Karnataka, Tamil Nadu, Pune area of Maharashtra and some parts of West Bengal.

The trend clearly shows that there is a rapid increase (more than five times in four years) in import of orchids due to increased demand in domestic market and this is expected to increase at least twice than current status in next five years if status-co is maintained. However, for the same commodity, our earning from export is only 3.24 lakhs during 2014 - 2015. Nearly 97% of orchid import in this country is for Dendrobium orchids and almost all of which is imported from Thailand. The Cymbidium orchid has very limited share in import of orchid.

Important countries of import over years and value of import in US$ (Thousands)of fresh cut orchids and buds, of a kind suitable for bouquets or for ornaments.

Countries of Import	Years of import					
	2009	2010	2011	2012	2013	2014
Thailand	717	589	910	1342	4345	5200
Netherlands	0	1	15	31	74	73
China	0	3	48	56	2	0
Germany	0	0	23	20	0	0
Japan	0	0	13	12	0	0
United States of America	0	4	23	23	3	0
Taipei, Chinese	0	0	4	9	0	13
Rest of the world	1	15	80	54	14	5
Total import value	718	612	1117	1550	4446	5298
Percentage contribution of Thailand in total import	99.86	96.24	81.47	86.58	97.73	98.15

Countries of Import	Years of import					
	2009	2010	2011	2012	2013	2014
Maldives	0	0	1	1	4	2
Jordan	0	0	0	0	0	1
Kuwait	0	0	0	0	0	1
United Arab Emirates	4	0	0	1	0	0
Bahrain	1	0	0	3	0	0
Mauritius	0	0	0	0	0	0
Singapore	0	0	7	0	0	0

Use of Orchids for Doubling the Income of Farmers

Orchids as Cut Flowers

Orchids are most important as cut flowers. The flowers having wonderful beauty and very good keeping qualities are of highest value. Some orchid flowers last for one to three months if remain attached to the plant, and as cut-flowers they remain fresh and perfect for two to six weeks. In recent times orchid cut flowers industries getting popular in our country. The present day orchid hybrids of Cymbidium, Dendrobium, Vanda, and Mokara remain perfect for 7 days to 35 days and even more days if provided suitable room temperature.

Commercial importance of orchids

S.No	Importance	Name of Orchids
1	Cut flowers	Cymbidium hybrids, Dendrobium hybrids, Phalaenopsis, Vanda, Mokara and Aranda
2	Potted plants	*Phalaenopsis, Paphiopedilum, Aerides, Dendrobium*sp, *Ryncostylis*sp, *Anoectochilus, Goodyera, Vanda* sp, *Coelogynecristata, Calanthemasuca, Phaiusflavus, Spathoglotisplicata.*
3	Suitable for Breeding	*Cymbidium devonianum, Cymbidium hookerianum, Dendrobiumnobile, Dendrobiumformosum, Dendrobiumdensiflorum, Phalaenopsis lobii, Vanda coerulea, Vanda tessellate, Thunia alba*

Orchid as Food

Orchids are used as flavouring agent in food, salad, main courses as deserts and to prepare teas. Vanilla is the most famous orchid for its flavour and has been used to flavour food & beverages and tobacco (in Cuba). Recently has been discovered by the Europeans that orchids have been used in Africa as food for hundreds of years.A recent expedition of botanists revealed that over 77 species of orchids are used as food in Africa. Not only are orchids edible, but also it is a source of fibre and vitamin C. Its taste is reported to be somewhat sweet; others say it tastes like tannin or raw chives.

Orchid Ice Cream: Food product made from salep is called Dondurma which is also known as Turkish orchid ice cream. This particular ice cream is not like normal ice cream instead it is very chewy and resistance to melting. The ice cream is made with milk, sugar, salep, and mastic (provides the chewy texture) and is kneaded either by hand or in a mixer. The ice cream is very commonly seen in Turkey and also in Greece, where it's referred to as Dudurmas or Kaimaki.

Orchid as Flavouring Agent

The pods of the climbing orchid *Vanilla planifolia* is used for the commercial production of the prized vanilla flavour, consisting of vanillin and other numerous flavouring compounds, with the use of a curing process. Other few species of Vanilla as *V. pompona*, and *V. tahitensis* also contain vanillin, but it is of low quality. It is the second most expensive flavouring spice after saffron. Vanilla was introduced to Europe by the Spanish Conquistadores in 1520, but commercial production of vanilla started about 300 hundred years later. Vanillin was first isolated from Vanilla beans in 1858 by Gobley and its structure was established by Carles in 1870. Goris was the first to show that vanillin is formed from glucovanillin, during the curing process of Vanilla beans. Other glycosyl and phenolics conjugates to mannose, galactose and rhamnose are also found in trace amounts in the developing pods. Studies on the botany of Vanilla beans revealed that flavour precursors, glucovanillin are found in the bean interior, where they are secreted onto the placental region around the seeds. The hydrolytic or other degradative enzymes (viz. â-glucosidase and glycosyl hydrolases), which catalyze the flavour precursors to flavour compounds, are localized mostly in the outer fruit wall region. Now a day, due to scarcity of Vanilla pods and high production cost vanillin is largely produced synthetically by the chemical route using lignin from wood or other petro-products. Natural vanillin, extracted from Vanilla beans cost between US$ 2000 and US$ 3000 per kg compared to synthetic vanillin costing between US$ 5 and US$ 15 per kg. In 2004 the world vanilla production was 5400 million tons which increase on an average 4% in the recent years.

Orchid as Herbal Tea

The genus *Dendrobium* is famous in the US as food-orchid. *Dendrobium* hybrid (bigibbum type) flowers are sold inthe US as edible decorations for food. Mature canes of many "soft-cane" *Dendrobiums* are being stir fried in many Asian countries, also being used for making sauces in Japan and Singapore. In Thailand, *Dendrobium* flowers are served by dipped in butter and deep fried, while many Europeans garnish desserts and cakes by using Dendrobium flowers. The pseudo-stems of *Dendrobiumkingianum* have been used as food by the aborigines in Australia since long time.

Dendrobium chrysotoxum

Dried flowers used as herbal tea

Dendrobium chrysotoxum flowers and *Dendrobium cathenatum* canes are dried and consumed as tea. *Dendrobiumlongicornu* flowers are pickled by the "Tamang" community people of Nepal. In Hawaii, locals use orchids to prepare salad dishes, sugar coated candies, and main dishes orchids cooked with scallops.The fragrant leaves of *Dendrobium salaccense* are used as a condiment for rice in Malaysia.In China many *Dendrobium* species are used to prepare healing teas. *Dendrobium cathenatum* canes are boiled for tea to regain strength after sex or illness.

Orchid Products used as Nutraceuticals/ Herbal drugs

Nutraceutical is a food that provides health benefits in addition to basic nutritional value. This term was coined by Stephen L. De Felice in 1989 by combining two words, nutrition and pharmaceutical. A Nutraceutical is any substance that may be food or part of food, which provides medical or health benefits, including the prevention and treatment of disease. Such products may range from isolated nutrients, dietary supplements, herbal products and processed foods such as cereals, soups and beverages. Although the concept of nutraceuticals is gaining more popularity more recently, its roots can be traced to the ancient Indian system of medicine, 'Ayurveda'.

a.*Chyawanprash*

Chyawanprash is a polyherbal formulation comprising of more than 50 medicinal plants ingredients. Among these, four (4) of them are orchids namely **Jivak (*Malaxismuscifrea*), Rishbhaka (*Malaxis acuminata*), Riddhi (*Habenaria intermedia*) and Vriddhi (*Habernaria edgeworthii*)**. All these ingredients have been well scientifically validated individually for their health care benefits. It contains high per cent of Vitamin C, many essential fatty acids, high bioflavonoids, carotenoids and a large amount of bioactive phytochemicals that acts as an immune modulator. It is the main source for the treatment of the respiratory tract system such as bronchial spasm, cough, asthmatic breathing, and tuberculosis and is also useful as immunomodulator and memory enhancer.

b. *Shi-Hu*

Shi-Hu is a commonly used preparation in Chinese medicine (Chinese pharmacopoeia), which is derived from different species of *Dendrobium* but the widely used specie is *Dendrobiumnobile*. It is commonly used for the treatment for kidney disorders, lung diseases, stomach diseases, low grade fever, red tongue, dry mouth, swelling, hyperglycaemia, atrophic gastritis and diabetes. It is also supposed to impart longevity, promote the secretion of acid in the stomach, and serve as an aphrodisiac. The extract prepared from stems is used to alleviate thirst, calm restlessness, accelerate convalescence, and reduce dryness of the mouth. Other properties are; stomachic, pectoral, antiphlogistic, analgesic, and antipyretic medication. It is also used to treat rheumatism, excessive perspiration, weakness brought about by thirst, impotence, entropion, leucorrhea, and menstrual pain.

c. *Tian-Ma*

As per Chinese Materia Medica, Tian- Ma herbal preparation prepared from the tubers of *Gastrodiaelata,*Which is used for curing headaches, dizziness, blackouts, numbness of the limbs, hemiplegia, epilepsy, limb cramps, spasms, migraine, expulsion of poisonous effluvia, rheumatism, vertigo, neuralgia, facial paralysis, dysphrasia, infantile convulsions, lumbago, fever, hypertension and other nervous afflictions. Gastrodin is the main effective compound of this preparationand has anti-delirium and anti-convulsive effects. It may lower blood pressure and protect the central nervous system by modulating the expression of excitatory amino acids and the nitric oxide system.

d. *Bai-Ji*

Tubers of *Bletillastriata* are most commonly used for the preparation of this Chinese traditional medicine. It is used for the treatment of tuberculosis, hemoptysis, gastric, duodenal ulcers, as well as bleeding and cracked skin of feet & hands. In other countries like China, Mongolia and Japan, used for purification of blood,strengthening & consolidation of lungs, treatment of pus, boils, abscesses, malignant swellings, ulcers and breast cancer.

Orchids as Cosmetics

Orchids are widely used as cosmetics in European and South-Asian countries for different purposes due to its antioxidants, moisturizing and emollient constituents.

a. *Moisturizing activity*

Orchid use in medicine was widely described a long time ago in the *Chinese MateriaMedica*. Mucilaginous content of orchid makes it ideal as a moisturizing and emollient agent, due to the large number of links formed by hydrogen bonding, thus maintaining optimal water levels of the stratum corneum. Orchids are now being touted for moisturizing, fighting free radicals, increasing skin immunity and reducing the appearance of fine lines.

b. *Anti-oxidant activity*

The flowers of orchids are used as antioxidants and soothing agents, due to the presence of anthocyanin pigment. Scavenging activity of free radicals also leads to its inclusion in hair products, to protect hair from hair fall.Therefore the Orchid is useful in the formulation of antioxidant and soothing cosmetic products.The recommended dose ranges from 0.5-5%. They are also used in frequent-use shampoos, after-sun screen products and in treatment products for sensitive skin.

Orchid Used in Perfumery

Many orchids are known for their wonderful sfragrance and it is believed that more than 75% orchids are fragrant species. The orchid fragrance is due to the presence of volatile aromatic oils produced in minor quantities in floral parts like sepals, petals, calluses, basal spurs to petioles. Floral scent emission shows diurnal rhythm and is controlled by internal biological clock. Some scent species emitfragrance at morning while others develop fragrance at late noon, evening or night. Orchid fragrance is a chemical messenger between the plant and its pollinator. Night pollinated flowers have peak emissions at night while the situation is reversed in day pollinated flowers.

Orchids flowers have specialized scent glands called osmophores that ooze liquid scent, which evaporates on contact with the air. Orchid fragrance ranges from warm, sweet & highly diffusive notes to stinky and offensive odour. The pleasant scented orchid flowers are often compared to fragrance of other flowers like rose, hyacinth, jasmine, freesia, lily, narcissus, sweet pea or easily identified scents like lemon, chocolate, vanilla, orange, coconut, cardamom, musk, honey, mint etc. Now-a-days fragrance in orchids is achieving a new importance as this characteristic adds to the aesthetic appeal of flower spikes besides determining the consumer choice as well as market price.

Orchids as Ornaments

Women use Orchids for their hair adornment and also as jewellery. Orchid flowers like *Rhyncostylis retusa* (Kopouphool) is used in the North Eastern region, symbolizing their purity, sanctity, love and peace. Yellow pseudostem of *Dendrobium utile* is used as bracelets in New Guinea. Pendants, earrings, brooches or pins made from orchid flower by casting a metal mould on it and then by gold or silver planting the same is common in Singapore and U.S.A.

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Technological Advances for Sustainable Production of Pomegranate in India

K.B. PATIL* AND ANIL B. PATIL

Horticulture is a fast growing sector and requires comparatively lower water and easy adaptability to adverse soil and waste land situations. The productivity of fruit is of vital importance as it provides higher cash income than cereals per unit of land. Pomegranate is one among the important fruit crops being cultivated on large area. India is one of the leading countries in pomegranate production and more than 1.32 lakh hectare area is under cultivation presently. Out of this nearly 0.94 lakh hectare area is covered in Maharashtra. The pomegranate plant enjoy hot and dry climate. The tree is considered as a tolerant to soil water deficit (Holland *et al*. 2009). It gives an advantage for picking up pomegranate in many states including Rajasthan and Andrha Prades very fast. Use of quality planting material, higher productivity, orchard management, training and pruning techniques, production of quality fruits, disease and pests management, methods of irrigation and fertigation are the major areas where farmers have to adopt advance technologies to make this crop profitable.

Quality Planting Material

Pomegranates are prone to various pests and plant diseases that include insects, fungi and bacteria. Disease and pest are the major cause in declining agricultural productivity all over the world. It has created attention not only of the grower but also the plant pathologists because of the huge reduction in yield. The losses occurred due to diseases in general vary from 10-90% in many crops, hence there is a big scope in improving agricultural productivity by controlling and or managing plant diseases. However, it find difficult to manage certain diseases since the chemical control is not feasible for some diseases that includes bacterial blight disease which is one of the major threats for pomegranate resulted in yield losses to the extent of 60-80% in Karnataka (Chand and Kishun 1991). Bacterial Blight Disease has emerged as a serious threat to pomegranate cultivation in major pomegranate growing areas includes Maharshtra, Karnataka, Andrha Pradesh and Tamil Nadu. In Maharashtra, the disease is prevalent in 52.25% of orchards, Karnataka 58.33%, Anantpur district of Andrha Pradesh has 43.47% blight prevalence. Bacterial blight affects all plant parts and as such symptoms are observed on leaves, stems, flowers and fruits. The bacterium survives in the infected plant stems, buds and plant debris in the soil (Kishun 1993) and survive in the infected leaves lying over the ground for more than 7-8 months (Rani and Verma 2002). The bacterium transfer from the source of the inoculums to healthy plants and new orchards through rain water, irrigation water, pruning tools, infected planting material, insect vectors and man (Sharma *et al*. 2010). Studies on transmission of bacterium revealed that planting material (stem cuttings, air-layered cutting) obtained from diseased plants carried the blight pathogen in latent form probably in buds (Anonymous 2009).

Apart from this, there are few diseases and pests that may carry along with the planting material and cause either huge crop loss or increase cost of cultivation for protecting the crop (Table 1&2). High incidence of pomegranate wilt caused by the fungus *Ceratocystis fimbriata* was reported in Karnataka and Maharashtra (Somasekhara and Wali 2000). The

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initial disease symptoms were yellowing and wilting of the leaves on a single branch. Severely infected plants show brown discoloration of roots and stems (Somasekhara and Wali 2000). Fruit and leaf spot associated disease caused by *Alternaria alternate* (Raghuwashi *et al*. 2005), *Cercospora spp.* (Morton 1987; Reddy *et al*. 2005) or *Colletotrichum gloeosporioides* (Jamadar *et al*. 2000; Reddy *et al*. 2005).

Table 1: List of diseases associated with pomegranate

Common Name	Scientific Name	Typeof organism
Bacterial Blight Disease	*Xanthomonas axonopodis pv.punicae*	Bacteria
Wilt	*Ceratocystis fimbriata*	Fungus
Leaf spot	*Pseudocercosporella granati*	Fungus
Leaf spot	*Discosia punicae*	Fungus
Leaf spot	*Cercospora sp.*	Fungus
Leaf spot	*Alternaria alternate*	Fungus
Leaf spot	*Aspergillus niger*	Fungus
Fruit spot	*Alternaria alternate*	Fungus
Fruit spot	*Colletotrichum gloeosporioides*	Fungus

The bark eating caterpillar known to be major pests in India (Shevale, 1991) causes severe damage to the trunk of the tree. Similarly Aphids are widespread pests in pomegranate orchards. Young pomegranate leaves are highly susceptible to aphid attacks. Aphids *Aphis punicae* (Blumenfeld *et al*. 2000) and *Aphis gossypii* (Juan *et al*. 2000; Caroll *et al*. 2006) tend to attack leaves in early spring and secrete honeydew, which attracts sooty mold. The fungus is not pathogenic but causes major damages particularly to the young trees. Thrips is another pest that damages fruits and trees (Bagle 1993; Shevale and Kaulgud 1998). Mites can attack pomegranate leaves, severe damage might result in defoliation of the plant (Khosroshahi 1984; Blumenfeld *et al*., 2000; Juan *et al*., 2000). The red mite heavily infests pomegranate orchards in Rajasthan (Kumawat and Singh, 2002).

Table 2: List of pests associated with pomegranate

Common Name	Scientific Name	Typeof organism
Shothole borer	*Xyleborus perforans*	Branches and trunk
Bark-eating caterpillar	*Inderbela quadrinotata*	Branches and trunk
Mealy bug	*Drosicha quadricaudata*	Fruit
Mite	*Tenuipalpus granati*	Leaves
Red Mite	*Tenuipalpus*	Leaves

The diseased plant material may transfer the disease from one generation to other and also from one region to other region. In this case planting/seed material becomes the carrier to transfer the bacterial, fungal pathogens and other pest from diseased area to disease free area. It hence become necessary that bacterial blight, wilt and pest free healthy planting material be produced for planting new orchards to ensure that infections do not occur in the orchard from the procured material.

Conventional Propagation: Conventionally, pomegranate is propagated by stem cuttings both by hard and soft wood cuttings, grafting and air layering where 8-15 mm diameter and 15-20 cms long stick is used. Un-availability of mother plants is a major hurdle in large scale propagation of pomegranate plants through conventional methods. Air layering is the most popular method being practiced in all pomegranate growing areas. Establishing hard wood cuttings are highly difficult (Srikandrajah *et al*. 1994; Naik *et al*. 1999; Naik and Chand 2003; Singh *et al*. 2007), the success rate is totally depends on climatic conditions where humid condition favor the successful propagation (Singh *et al*. 2013). Looking to the limitations of climatic conditions, success rate and un-availability of sufficient mother plants there is always a gap between demand and supply of planting material. Area under pomegranate cultivation is increasing day by day and the conventional method of propagation is unable to fulfill the demand of quality and disease free planting material (Singh *et al*; 2013).

Tissue Culture: Mass Propagation of uniform, disease free and healthy plants production through tissue culture is the only viable technique for production of large number of identical plants in a short time. *In vitro* propagation of pomegranate has been reported through axillary shoot proliferation from nodal segment (Zhang and Stolz 1991; Naik *et al.* 1999, 2000; Kanwar et ail. 2004; Murkute *et al*. 2004), shoot tips (Murkute *et al*. 2004). Regeneration of pomegranate plantlets *in vitro* can occur through organogenesis from callus derived from leaf segments (Omura *et al*. 1987a; Murkute *et al*. 2002; Deepika and Kanwar 2008).

The technique requires small amount of tissues/ explants for propagation hence maintenance of mother plants becomes easy and available for large

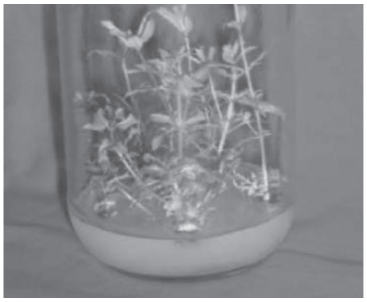

Fig 1: *I n vitro* plant

Fig 3: Secondary hardened plants

Fig2: Primary hardened plant

scale propagation. The mother plants can be grown under controlled conditions due to the limited number of plants required for propagation. Tissues used for micro-propagation can be tested for diseases and pests prior to use it for the propagation hence the only disease free tissues are used that guarantees production of healthy and disease free plants. *In vitro* plants are passed through stages of acclimatization where plants are exposed gradually to the natural environment that allows plant to produce healthy and vigorous shoot and root growth. These plants are uniform in their growth hence its survival and further growth can be assured (Fig 4-6).

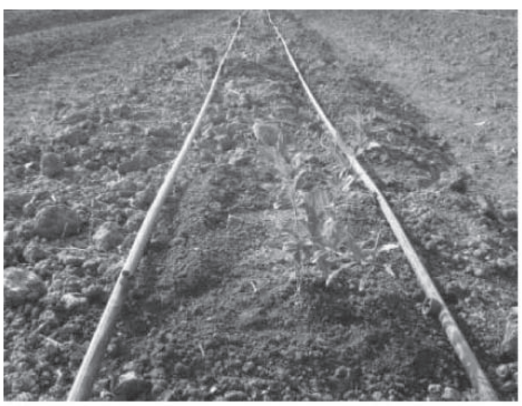

Fig 4: Newly planted tissue

Fig 5: Overview of tissue culture culture plant pomegranate orchard

Fig: 6 Two years old fruting stage tissue culture plant

Plant Density

In earlier days, the expected productive life span of pomegranate orchard was around 25 years with an average plant population per hectares was 375 plants. In recent past farmers have adopted high density plantation ranges from 772 plants per hectare to 1120 plants per hectare to obtain higher yield in early years with removal of alternate trees in later years. In this planting system, the height of the tree is typically maintained below two meters. This has definitely changed the investment patters in pomegranate cultivation in terms of maintenance cost, pattern of labor use for regular pruning, training and insecticidal spray. However, increase in crop population per hectare has changed the yield and return structure of pomegranate in qualitative as well as quantitative forms by reducing fruit load per tree.

Training and Pruning

It has been observed that the profitability of the pomegranate orchard is directly proportional to the fruit bearing where as fruit bearing depends on size of the canopy of the tree. Less the number of branches to the tree, less are the chances for bearing fruits to the tree. The mature tree should have more than 150 branches of refill, pencil and above thickness size. To produce more and more branches tree should under gone through regular pruning. Duration and frequency of pruning plays an important role in bearing more fruits. Insecticidal and fungicidal sprays are the prerequisite after every pruning since there are high risk of insect attack on the younger leaves produced as a result of pruning and fungal attack may occurred through the cut portions particularly under humid conditions. There are two common approaches for training the pomegranate tree, single or multi-trunk. The single trunk approach has the advantages of easier orchard floor maintenances and reduced costs associated with pruning but have a risk of whole tree loss because of disease and pest attack associated with stem. The multi trunk plant has 3-6 branches developed directly from the ground. This method helps to maintain productive branches through many years and helps to cope with pathogens inflicted by stem borers. When the branch is lost, a shoot is trained as a replacement branch (Fig 7&8).

Fig 7: Multi trunk method

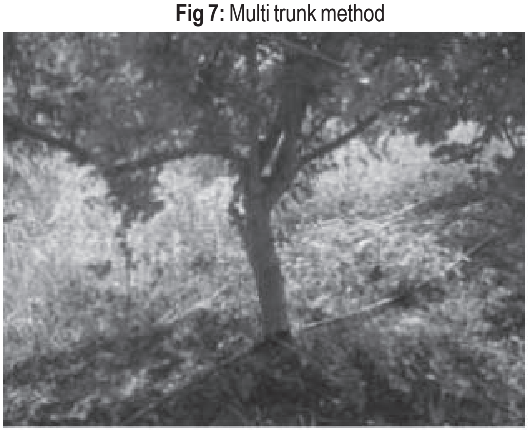

Fig 8: Mono trunk method

One of the main problems in pomegranate production is the tendency for young branches to bend from fruit weight disrupting tree structure and causing ground-contact of fruit. Tie up heavy loaded branches is a common practice however it is labor intensive. Frequent pruning by keeping length of the branch short is an effective way to strengthen the branch.

Irrigation: Although, pomegranate plant is considered to be tolerant to soil water deficit, however plant need regular irrigation throughout the dry season to reach optimal yield and fruit quality (Sulochanamma *et al*. 2005; Levin 2006; Holland *et al*. 2009). Irrigation plays important role in leaf area development, fruit number, fruit set, fruit retention (Khattab *et al*. 2012; Prasad *et al*. 2003; Shailendra and Narendra 2005; Sulochanamma *et al*. 2005). Drip irrigation method had been found positive effects on pomegranate growth such as tree height, stem diameter, and plant canopy (Sulochanamma *et al*. 2005). Drip irrigation saved 66% water compared to surface irrigation (Behnia 1999; Chopade *et al*. 2001).Double lateral drip irrigation systems with 6-8 dripers per tree having 4 lph discharges are found to be the best irrigation system for pomegranate. Daily irrigation is preferred and beneficial for maintaining quality of pomegranate orchard. Computerized irrigation yields better results and allows for better control of water qualities and time intervals between successive water applications. Computerized irrigation is of special importance when fertigation and other treatments are applied through the water (Fig 9&10). Age wise water requirement of pomegranate plants is depicted in table 3.

Control of irrigation timing and seasonal application are important not only for better growth and yield of the pomegranate tree but also are used to control time of fruit maturity. Schedule of irrigation are used to control and optimize the yielding season (Sonawane and Desai 1989).

Fertigation

Application of fertilizers along with irrigations is found to be more effective for pomegranate orchards (Firke and Kumbhar 2002). Frequent application of fertilizer found more beneficial than long span application. Excessive or late application of nitrogen may delay fruit maturity and color development (LaRue 1980).

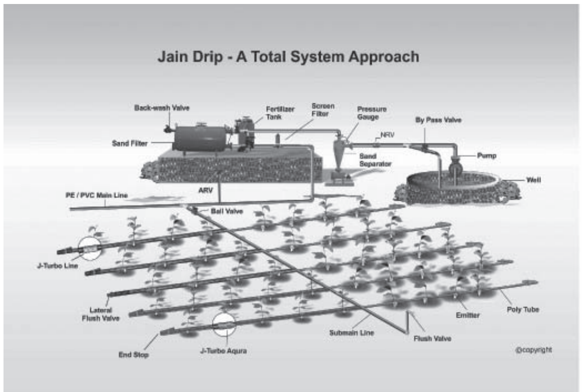

Fig 9: Schematic diagram of drip irrigation system

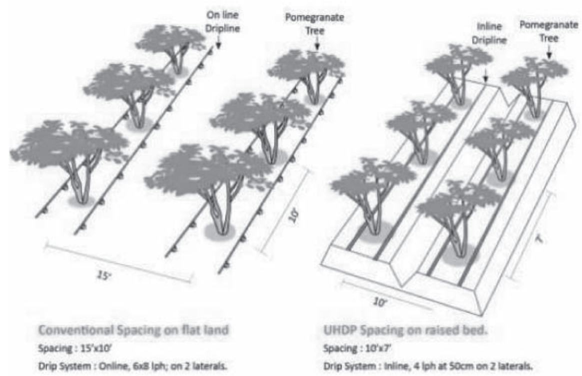

Fig 10: Schematic diagram of drip irrigation system for pomegranate

Note: Water requirement may vary according to planting method, soil type and weather conditions

With reference to many researchers across the world and farmers experience following schedule found to be useful for quality production of pomegranate.

1. At the beginning of natural stress and before pruning:20:20:0- 250 g/plant + Murate of Potash- 250 g/plant + Ammonium Sulfate- 150 g/plant
2. After leaf shading and when start fertigation as per below schedule:20:20:0- 250 gms/plant + Potash-250 gms/plant + Ammonium, Sulfate- 250 gms/plant
3. After first fertigation follow below schedule given in Table 3 (Total fertilizer -61.8 Kg N: 47 Kg P: 85.5 Kg/Acre)

Table 4: Fertigation schedule during reproductive stage for mature pomegranate orchard

Period of fertigation	Fertilizer grade	Total quantity of fertilizer	Fertilizer Kg/Acre
From first fetrtigation1-30 days	12:61:0	16.5	1.1
	13:0:46	11.0	0.750
	Urea	5.65	0.375
31 days to 60 days	13:40:13	30 Kg	2.0
	13:0:45	13.55	0.903
	Urea	9.65	0.643
61-104 days	19:19:19	52.63	3.5
	Urea	39.13	2.6
	0:0:50	6.00	0.2
105-135 days	0:52:3	30	2.0
	413:0:45	10	0.66
	Ammonium Sulfate	43.5	2.9
136-195 days	13:0:45	60	4.0
	0:0:50	16	1.1
196-210 days	0:0:50	15	2.0

Note: Above fertigation schedule is based on research and farmers experience. To follow it you need to have soil analysis report and vary as per soil type, season and farmers practice.

Foliar application of potassium chloride and potassium sulfate for maintaining optimal level of potassium were reported by Muthumanickam and Balakrishnamoorthy (1999). Microelements, such as zinc, iron, and manganese applied on leaves have resulted in increased yield and juice content (Balkrishnanan *et al*. 1996). Prasad and Mali (2003) have shown that the ratio of aril weight to total fruit weight is linearly correlated with the rate of supplied nitrogen while total soluble solid (TSS) were not affected. Panahi and Amiri (2006) have reported dependence of yield, fruit weight, aril number, aril volume, pH , acidity and TSS on nitrogen, manganese and potassium. It was shown that potassium application increased fruit weight that significantly increases the yield.

Conclusions

Area under pomegranate in India has been picking up very fast. However, there is very little knowledge available to the farmers in this crop as far as advancements in production technology is concerned. Traditional ways of cultivating pomegranate is unable to make this crop sustainable and profitable. In recent past, technological advancements have been occurred and newer technologies have been made available to the farmers. Production of superior planting material through tissue culture is one of the major developments occurred in recent past in this crop that help to stop spread of diseases from one region to other due to infected planting material. Conventional method of propagation found to be ineffective for fulfilling the demand of quality planting material. Jain Irrigation Systems Limited is the world first laboratory that has been propagating healthy, disease free quality planting material of pomegranate plants through tissue culture on commercial scale. In last eight years Jain Irrigation has produced and supplied around 30.0 million plants of variety Bhagwa and Mrudula in India. There has been technological advancement also occurred in the areas of plant density, methods of training and pruning, Irrigation and fertigation that farmer has to be adopted to improve benefit to cost ratio of the crop. Due to technological advancement includes tissue culture, drip irrigation and fertigation farmers are producing export quality fruit. How ever, production of disease free planting material the migration and spread of many diseases has comes under control. It will help for sustainable growth and production of pomegranate in our country in coming years together.

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Effective Use of Plant Genetic Resources for Enhancing Farmers' Income

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The history of agriculture begins with the first record of plant and animal domestication. However, the history of plant genetic resources (PGRs) forms the original prelude to this human effort. Agriculture *per se* owes its origin and sustenance to the immense wealth of PGRs that co-evolved on this planet. The importance of PGRs has further increased with the advent of scientific agriculture, wherein advanced technologies facilitate its utilization across genetic barriers. Hence, as of today, the PGRs are an inseparable component of all crop improvement efforts.

India has a rich heritage of biodiversity and the Indian gene centre is one of the 12 mega diversity centres of the world (Myers *et al.,* 2000). Out of the 34 'biodiversity hotspots' spread around the world, four are in India, viz., Eastern Himalayas, Western Ghats, Indo-Burma and Sundaland (Nicobar Islands) regions (Khanna, 1989). Our nation is home to more than 11% of the world's known flora which comprises of 46,042 species of flowering and non-flowering plants (Zeven *et al.,* 1982). However, very few amongst these species are utilized as plant genetic resources for food and agriculture (PGRFA). Globally, we depend on less than a dozen flowering plants for 80% of our caloric intake (Mc Couch, 2013). This extreme dependency on few species has led to marginalization of crop diversity and further, with the adverse impact of climatic and human interventions, up to 75% of the genetic diversity of crops has already disappeared (FAO, 2010). Therefore, the germplasm accessions that are currently conserved in around 1750 genebanks across the globe are the genetic treasure troves that ought to be mined for future crop breeding, because many of the accessions that are conserved in these genebanks are currently non-existent in their natural habitats.

The hundreds of landraces, primitive varieties, modern varieties and wild relatives of crop species that are held in such germplasm collections are the result of cumulative efforts made by stakeholders such as breeders, researchers and farmers, over a century, for gathering and saving the seeds. Some of these genotypes have made significant contribution to crop improvement and have helped in generating substantial profit for the farmers.

Utilization of Germplasm in Crop Improvement - Classic Examples

The GEB 24 Rice, which isderived from a local landrace of South India called Konamani (grown as early as 1920s) is used as a parent in rice breeding all over the world, for its high yield. It is often referred to as the mother of all rice varieties, because it is present in the genetic background of almost all high yielding rice genotypes. Three Indian origin wheat materials, *viz.*, Hard red Calcutta, Etawah and Indian G, have been used by CIMMYT for the development of their high yielding varieties, *Veery* and *Kauz.*C-306 another renowned tall Indian wheat variety of Central India, developed from several Indian local germplasm lines, is used in most of the international and national wheat improvement programmes, as a donor for drought tolerance. Even after the development of hundreds of high yielding wheat varieties, C-306 remains to be a highly

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preferred wheat variety for its unique chapatti quality. Dharwar dry, a land race from India, is another internationally recognized drought tolerant genotype, used in wheat improvement programmes.Kharchia Local is a landrace of wheat from Southern Rajasthan, developed by farmers over the years, by selecting for strains that are tolerant to salt and drought. This is globally used as a donor parent for developing salt tolerant varieties. The Indian wheat landrace 'Naphal' is also globally sought after, due to its double null trait, which makes it ideal for biscuit purpose, due to weak gluten protein. Bhaliya wheat from Gujarat is another unique genotype that has earned Geographical Indicator (GI) tag due to its high protein and carotene.The Kala Bhat soybean, a unique black seeded landrace from Uttarakhand, is being used in Soybean breeding due to its high iron and protein content.

Germplasm accessions have also served as life-saving sources of resistance for several disease epidemics of historical significance, which had threatened to wipe out phenomenal acreage of several crops in different continents. Such instances also highlight the importance of germplasm conservation, with the perspective of its utilization for posterity. The Southern Corn Leaf Blight epidemic which ravaged the maize production of USA in 1970s was controlled through inheritance of new source of resistance from a Nigerian maize germplasm accession having a single recessive gene *rhm*. During the same period, a severe and widespread downy mildew epidemic occurred on Pearl millet hybrids in India. ICRISAT took the lead in identifying resistant sources from its germplasm collection and a landrace from Chad was used for deriving the resistant line ICML 22, which is being used extensively in breeding programmes.

Similarly, a single wild species of rice, *Oryza nivara* originating from the fields of northern plains of India was, until recently, the only source of resistance against grassy stunt virus. The management of bacterial leaf blight in rice has also been achieved by IRRI through incorporation of host resistance using more than 2000 lines, several of which has been collected from Southern and North-eastern parts of India.

Direct Utilization of PGRs for Enhancing Farmer's Income

The rich biodiversity of our country is widely interspersed among its 15 prevalent agro-climatic zones and within each agro-ecological domain, there exists such unique germplasm material, which in itself is highly valued for specific unique traits. Recent interventions and awareness has led to a revival in their cultivation in these regions and farmers are benefitting significantly from this venture, especially due to huge export demands.

The Njavara rice from Kerala is extensively used in Ayurveda for curing arthritis, paralysis, neurological disorders. It has a GI tag and is being widely exported for a premium price (www. ipindia. nic.in).The Mushk Budghia Rice from Jammu and Kashmir is one of the most highly priced rice varieties (up to Rs 20,000 per quintal, in comparison to normal rice which sells at an average value of Rs 4000 to Rs 6000/quintal), due to its small/ bold grained, aromatic qualities. Attempts are also being made to create a *niche* export market for the black grained Chakhao rice of Manipur, which has very high anti-oxidant content and several therapeutic properties.

India is blessed with an unrivalled diversity in the millet resources, which are nutritionally superior to cereals. They are also drought tolerant crops, having resistance to pests and diseases, thereby minimizing the hazards of crop failure for the farmer. Due to their high dietary fibre and protein, they are considered as ideal food for diabetics. Till recently, it was grown only for subsistence consumption and feeding the live-stock. The consumers in non-traditional areas were totally unaware of its culinary uses. However, globally, there is a renewed interest in the health benefits of millet products, especially due to its gluten-free character. Hence, within the country, it has assumed the status of a value-added export product and several schemes are being put forward for promotion and commercialization of millet products. Finger millet/*Ragi*, which is a traditional crop in India from pre-historic times, is considered to be one of the most nutritious foods for infants and elderly, due to its high calcium (370mg/100g) and protein content (7.6g/ 100g).Similarly, foxtail millet (high protein and fat), proso millet (highest amount of protein-12.5%), kodo millet (high magnesium content-1.1 g/kg dry matter) and barn yard millet (richest source of crude fibre-13.5%) are all potential crops that are gaining importance in global markets (Vinoth *et al.,* 2017).

Among horticultural crops, the Gir Kesar Mango from Gujarat, Malihabadi Dusseheri from Lucknow and Fazli Mango from West Bengal are exported all over the world for their unique taste and aroma. The Darjeeling Tea and Kashmir Kesar are already recognized as elite export commodities and the farmers have also benefitted from their GI tags. The Indian Supari, Alleppey Green Cardamom and Malabar Black Pepper are the other major preferred products in global markets (www.ipindia.nic.in). India is also home to the world's hottest chilli-Bhut jolokia / Naga jolokia, which is found in Arunachal Pradesh, Assam, Nagaland and Manipur.

Another biodiversity domain that is significant to India is that of medicinal herbs. According to a WHO report, about 80% of the world population relies on the plant-based systems of medicine for their primary healthcare needs (WHO e-link).Our traditional, folk and herbal medicines utilize around 6000 indigenous plant species and are recorded to meet about 75% of medical requirement in the third world countries (Rajashekharan *et al.,* 2002). Even in developed countries, there is a renewed interest in alternative treatments having minimum side-effects, as in the case of our indigenous medicine systems like Ayurveda, Sidha and Unani. Some prominent herbs that have significant scope in global market are Giloe, Kalmegh and Ashwagandha**.** They are known to enhance immunity against viral infections. Similarly, Vasak(*Adathoda vesica*)**,** which is used in Indian traditional medicines from ancient times, is an important ingredient of almost all cough syrups. The preparations from *Allium sativum*, *Aloe barbedensis* and *Panax* sp. are listed among the top ten most widely selling herbal medicines in the developed countries and India has a rich diversity of these species. However, India has still not captured the global market of these herbs, to its full potential, whereas China has been capitalizing on its traditional herbal wealth since long. The major short coming is the lack of standardization, authentication and scientific product identification. There is an imminent requirement of policy interventions for a comprehensive development of the medicinal plant sector, whereby we can expand India's share in world herbal drug market and thereby ensure enhanced benefit to our farmers.

In addition to these routine components of our endemic flora, we have certain exceptional species, which are rare and highly valued. The Kappaphycus sea weed found in thecoastal regions of Gujarat is rich in minerals and vitamins and is also used in anti-cancer and anti-AIDS drugs. It is an ingredient in several commercial products like lotions, gels, biofertilizers and soft drinks and has a huge export market. Another such unique species is the Morchella Mushroom (Guchhi), which is found in higher altitudes of North-West Himalayas. It is globally sought after due to its exceptional taste, nutritional and medicinal properties (206 units of vitamin D_2/ 100 gm fresh wt) and is highly priced.

All these genetic resources are currently being produced in specific agro-ecological areas and are isolated from mainstream agriculture, due to poor marketing network and lack of enterprise amongst the producers. There is a dire need for policy interventions in this sector, to promote the production of such unique resources, whereby, in addition to enhancement of farmers' income, the genetic wealth of our nation can also be sustained. A few case studies, wherein successful attempts have been made for PGR production and utilization, are listed below.

Practical Approaches for Enhancing Farmers' Income through Use of PGRs - Some Case Studies

The indigenous biodiversity and its utilization, in most instances, are restricted to theoretical assumptions and predictions. Ground level analysis and data generation for an impact assessment of PGR utilization is scarce in scientific literature. However, attempts have been made by organizations, working especially amongst marginal farmers and tribal populations, for introducing this concept of harvesting the benefits of indigenous plant genetic resources.

Underutilized fruit trees for sustainable livelihood of tribal families: The BAIF Development Research Foundation (formerly the Bharatiya Agro Industries Foundation) of Maharashtra has studied the impact of introduction of agri-horti-forestry species like Indian goose berry, tamarind and jatropha amongst tribal families, who were otherwise cultivating mango and cashew nut, exclusively. These species thrived on the barren tracts and farmers could gain additional income, through certain market interventions made by the organization (BAIF website).

Landraces for adaptation to progressive climate change: Genotypes with resistance to drought, heat, pests and diseases are essential for combating the adversities of climate change. Several research efforts, over the last decade have created climate smart technologies and varieties; however, most of these have not been adopted by the small scale farmers. Our crop improvement programmes have, in many instances, overlooked the importance of landraces, which are known to be a unique source of genes and alleles for "climate change tolerance". A study by CIMMYT, Mexico (Jon Hellin *et al.,* 2014) has reiterated that efforts need to be directed at facilitating the development of prebreeding germplasm using landraces that already possess traits that enable adaptation to predicted climates. In India, we have local landraces that are internationally recognized as ideal genotypes for specific biotic and abiotic stress tolerance traits. Our crop improvement programmes should prioritize the utilization of such germplasm, which would subsequently, ensure development of farmer-appropriate, climate resilient varieties.

Role of Market interventions for effective PGR utilization: M.S. Swaminathan Research Foundation, Chennai, organizeda collective market development initiative for minor millets, amongst the tribal families of Kolli hills in Tamil Nadu, where diverse minor millet varieties were being grown since several years by the tribal communities, for their own consumption (Gruere *et al.,* 2009).The objective of this intervention was to convert this subsistence farming to a conservation-cum-commercialization venture, by ensuring an effective supply chain where the producers can take advantage of niche market opportunities. The study revealed that for such crops, expansion of consumer demand and acceptability is very important. Crops, in which utilization is restricted to local rural communities, require a robust marketing channel involving collective action of all stake holders, for making it a successful commercial venture for the farmers.

Conclusions

Our plant genetic resources form an integral part of the socio-cultural and agro-ecological foundation of our nation. The sustenance of these resources is an outcome of collective efforts made over centuries by our traditional farmers and subsequently by crop breeders. However, generally, we under-value the worth of these assets and fail to capture the advantages offered by these resources. If we quantify the genetic increments that have consolidated within each of these genotypes, over the course of time, it would surpass human capabilities, beyond any measure. Hence, on one hand, we concentrate our efforts on developing multiple-trait genotypes with compounded benefits, and on the other, we are ignoring the immense wealth of resources that nature has offered us for free. The effective utilization of these PGRs should be ensured for nutritional security and enhanced income of farmers, particularly the small and marginal farmers. However, it is required to be implemented without compromising on conservation for posterity.

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Biotechnology of Spices - Challenges and Opportunities

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Introduction

Spices are mainly used to flavor our food, confectionery, medicine and perfumery.Spices cultivated in an area of 3.3 million ha with a production of 6.1 m. tones that occupies around 13.0% area and 2.0% production of horticultural crops of India. Black pepper, cardamom, ginger, turmeric, vanilla, cinnamon, clove, nutmeg, tamarind, etc., constitutes the major spices. The productivity of many of these crops is low due to the lack of high yielding, pest and disease resistant varieties. The past few years have witnessed a quantum jump in utilization of biotechnological tools to achieve the above through commercial propagation, development of novel varieties and marker assisted breeding.. Biotechnological approaches like micropropagation, somaclonal variation, *in vitro* conservation, synseed technology, protoplast fusion, production of flavor and coloring components, and development of novel transgenics, have great potential in conservation, utilization, increasing the production and productivity of spices.

Black pepper

Black pepper is the most important spice in the world. Conserving the genetic diversity and development of *Phytophthora* Foot rot' resistance are the immediate priorities for breeding programmes.

Micropropagation and plant regeneration: Micropropagation is an effective tool for large scale production of disease free planting materials and germplasm conservation. High rate of multiplication coupled with the additional advantage of obtaining disease free planting material makes micro-propagation a viable alternative to conventional propagation (Nirmal Babu *et al.* 1997a 2003a, 2012b). Endogenous contamination severely hampers establishment of black pepper cultures. A commercially viable protocol for large scale *in vitro* multiplication of black pepper overcoming these problems were reported by Nazeem *et al*. (2004). Protocols were standardized for micropropagation of other endangered, and medicinally important species of *Piper* like *P. longum* and *P.chaba*, *P. betle*, *P.barberi* and *P. colubrinum* (Nirmal Babu *et al*. 1997a, 2012b, 2016). Joseph *et al*. (1996) and Yamuna (2007) reported somatic embryogenesis from zygotic embryos, while Nair and Gupta (2003, 2006) reported cyclic somatic embryogenesis from the maternal tissues, which has tremendous potential for automated micropropagtion. Nirmal Babu *et al*. (2005) reported somatic embryogenesis from mature leaf tissues Such systems are useful in transgenic experiments. Attempts on induction of variability on somaclones for tolerance to *Phytophthora* foot rot resistance by Shylaja *et al*. (1996) resulted in identification of tolerant somaclones through *in vitro* selection of calli as well as somaclones using crude culture filtrate and toxic metabolite isolated from *Phytophthora capsici.*

Molecular characterization: Recent advances in molecular biology led to more emphasis on molecular markers for characterization of the genotypes, genetic fingerprinting, identification and cloning of important genes, marker assisted selection and in understanding interrelationships at the molecular level. Genetic diversity of *Piper* species using RAPD,

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ISSR were also reported recently by many workers (Sen *et al.* 2010; Nirmal Babu *et al*. 2012b). Nirmal Babu *et al* (2011a) reported molecular interrelationships between 24 *Piper* species using RAPD profiles. Joy *et al*. (2011) characterized and studied genetic diversity of 40 popular varieties and four different species of black pepper using microsatellite markers.Molecular markers like RAPD, AFLP, ISSR SSR and ITS polymorphism was used for assessment of genetic variability in black pepper and to characterize important cultivars, varieties and related species of black pepper to develop fingerprints and to study the interrelationships (Pradeep Kumar *et al.* 2003; Nazeem *et al*. 2005; Sreedevi *et al*. 2005; Nirmal Babu *et al*. 2011a). DNA markers were also used to study the genetic fidelity among micropropagated black pepper and long pepper plants (Nirmal Babu *et al.* 2011a). Johnson *et al*. (2005) used male parent specific RAPD markers for the identification of hybrids in black pepper (*Piper nigrum* L.).Sheji Chandran *et al*. (2006) developed a SCAR marker for identifying *Phytophthora* resistant lines of black pepper. RAPD technique was also employed for the authentication of dried black pepper from its adulterant *Carica papaya* L. (Dhanya *et al.* 2009). A mapping population was developed for preparation of genetic map of black pepper (Nirmal Babu *et al*. 2011a) and

Protoplast culture: The 'protoplast' is devoid of cell wall and this makes the protoplast technology suitable introduction of trans-gene DNA and somatic hybridization by protoplast fusion. Successful isolation and culture of protoplasts were reported in leaf tissues in black pepper (Shaji *et al*. 1998) and these protoplasts could be successfully developed up to microcalli stage.

Genetic transformation: Reports are available on *Agrobacterium* mediated gene transfer system in *P. nigrum* (Nirmal Babu *et al*. 2005, 2011d, 2013). Maju and Soniya (2012) reported an efficient protocol for genetic transformation using *Agrobacterium tumefaciens* strain EHA 105 and multiple shoot production in *Piper nigrum* var. Panniyur 1to understand the mechanisms that control the regeneration process in the species. Mani and Manjula (2011) reported the *Agrobacterium* mediated transformation and endogenous silencing in *Piper colubrinum* by vacuum infiltration. The *inplanta* transformation *via* pollen tube pathway was done by Asha and Rajendran (2010) using the total exogenous DNA of *Piper colubrinum*, a species resistant to *Phytophthora capsici*.

Cloning and Isolation of Candidate Genes: Spices are sources of many important genes with anti biotic and pharmaceutical properties. Efforts are being made to identify and isolate genes of interest both for crop improvement and of industrial value. Molecular cloning of a cDNA fragment encoding the defense related protein β-1,3-glucanase in black pepper (*P. nigrum* L.) and methyl glutaryl CoA reductase in *Piper colubrinum* was reported (Girija *et al*. 2005a,b). PCR based SSH technique was used to generate a leaf specific subtracted cDNA library for *Piper nigrum* L. for the identification of more number of tissue specific genes (Alex *et al*., 2008). Bhat *et al*. (2005) reported isolation and sequencing of CMV coat protein gene infecting black pepper and its possible deployment in black pepper to induce virus resistance. Dicto and Manjusha (2005) used PCR based SSH to identify *P. colubrinum* resistance genes which is differentially expressed in response to salicylic acid. Mani and Manjula (2011) reported the cloning and characterization of two isoforms of osmotin, from cDNA library in *P. colubrinum*. Bioprospecting of novel genes from black pepper was attempted by Sujatha *et al*. (2005).

Cardamom

Cardamom, considered the 'Queen of Spices' is also native to India. The productivity of cardamom is hampered by various diseases of viral etiology. Utilization of virus-free planting material is an important input into disease management strategy.

Micropropagation and plant regeneration: Cardamom is one of the first crops where commercialization of micropropagation has been achieved (Nadgauda *et al.* 1983; Nirmal Babu *et al.* 1997b, 2003a, 2011b). Successful regeneration of plantlets from callus of seedling explants and anthers of cardamom was reported (Nirmal Babu 1997, 2011b). Manohari *et al*. (2008) also reported an efficient protocol for the induction of somatic embryogenesis and plant regeneration in small cardamom. Identification of a few Katte tolerant somaclones was reported.

Molecular characterization: Molecular profiling of 11 species representing 5 major tribes viz., *Amomum, Aframomum, Alpinia, Hedychium* and *Elettaria* and 96 collections of cardamom germplasm using

RAPD, PCR RFLP and ISSR markers to elucidate their interrelationships, identification of duplicates and geographical origins of Indian cardamom was reported by Nirmal Babu *et al.* (2011a). Molecular profiling of Indian, Sri Lankan and Guatemalan exported cardamoms using RAPD/ISSR primers indicated that though there is a lack of genetic polymorphism among them, they show the variation in quality parameters (Thomas *et al.* 2006).

Protoplast culture: Successful isolation and culture of protoplasts were reported from cell suspensions and leaf tissues in cardamom (Geetha *et al*. 2000) and these protoplasts could be successfully developed up to microcalli stage.

Ginger

Ginger is the third most important spice that originated in South Asia. There is no seed set in ginger leading to limited variability and this hampers crop improvement program. Rhizome rot caused by *Pythium aphanidermatum* and bacterial wilt caused by *Ralstonia solanacearum* are the major diseases affecting ginger. Diseases of ginger are often spread through infected seed rhizomes. The tissue culture will help in the production of pathogen-free planting material.

Micropropagation and plant regeneration: Clonal multiplication of ginger from vegetative buds (Nadgauda *et al.* 1980; Nirmal Babu *et al*.1997b, 1998; Sharma and Singh 1997), regeneration of plantlets *via* callus phase from leaf, vegetative bud ovary and anther explants (Kacker *et al*. 1993; Nirmal Babu 1997a, 2011c; Nirmal Babu *et al*. 2005, 2016) and plant regeneration from ginger anther has been reported (Samsudeen *et al*. 2000). This system was used for inducing somaclonal variability in ginger where lack of seed set hampers conventional breeding. A few promising high yielding rhizome rot tolerant somaclones also have been identified (Nirmal Babu *et al*. 1996; Sumathi 2007).

In nature, ginger fails to set fruit. However, by supplying required nutrients to young flowers and by *in vitro* pollination 'fruit'development and subsequently plants could be recovered (Nirmal Babu *et al*. 1992d). *In vitro* pollination was successfully attempted by Nazeem *et al*. (1996) to overcome the pre-fertilization barriers like spiny stigma, long style and coiling of pollen tube etc. that interfered with natural seed set in ginger successful seed set was obtained. Induction of tetraploids ginger through *in vitro* colchicines treatment and tetraploid somaclone with extra bold rhizomes was also reported (Nirmal Babu *et al*. 1996d, 2005)

Molecular characterization: RAPD profiling of ninety accessions of ginger indicated moderate to low level of polymorphism (Sasikumar and Zachariah 2003; Nirmal Babu *et al*.2005; Parthasarathy and Nirmal Babu 2011). Various markers like AFLP (Sajeev *et al.* 2011) ISSR (Kizhakkayil 2010) were used to study the genetic diversity in ginger. Chavan *et al*. (2008) developed SCAR markers as complementary tools for distinguishing *Z. ofûcinale* from the other *Zingiber* species.

Protoplast culture: Successful isolation and culture of protoplasts were reported from cell suspensions and leaf tissues in ginger (Nirmal Babu 1997a; Geetha *et al*. 2000) and these protoplasts could be successfully developed up to microcalli stage. Somatic hybridization of ginger through chemical fusion (PEG mediated) and its regeneration was reported by Guan *et al*. (2010) RAPD technique was used for the identification of hybrids and flow cytometry analysis revealed the diploid nature of all regenerated progenies.

Genetic transformation: Transient expression of GUS was successfully induced in ginger embryogenic callus bombarded with plasmid vector pAHC 25 and promoter Ubi-1 (maize ubiquitin) callus tissue (Nirmal Babu 1997). *Agrobacterium tumefaciens* strain EHA105/p35SGUSInt, effective in expressing â-glucuronidase activity, was used to transform ginger by Suma *et al*. (2008).

Cloning and Isolation of Candidate Genes: Nair and Thomas (2007. 2010) identified the three primer pairs designed from the conserved motifs of NBS domain of NBS-LRR gene class as most successful in isolating RGCs in ginger and these provides a base for isolation of RGCs mining in ginger. They also reported the efficiency and sensitivity of SSCP (Single-strand conformation polymorphism) analysis in discriminating *Pythium* susceptible and resistant *Zingiber* accessions (Nair and Thomas 2013) and the isolation of resistant gene designated ZzR1 from *Z. zerumbet* and its correlation between ZzR1 expression and resistance of the wild taxa to *Pythium aphanidermatum* infection. Swetha Priya and Subramanian (2008) reported the presence of R gene of CC-NBS—LRR class of plant resistant gene in ginger varieties against *Fusarium oxysporum* f.sp.*zingiberi.* Prasath *et al*. (2011, 2013) reported the isolation of PR5 protein gene CaPR5 and ZoPR5 which code for the precursor proteins of 227 and 224 amino acids. They used a PCR-based suppression subtractive hybridization (SSH) method to identify *C. amada* (a potential donor for bacterial wilt resistance to *Zingiber officinale*) genes that are differentially and early expressed in response to the *R. solanacearum* infection compared to *Z. officinale*. The study highlighted the expression of LRR, GST and XTG much higher in resistant species (*C. amada*) than in susceptible species (*Z. officinale*).

Turmeric

Turmeric of commerce is the dried rhizomes of *Curcuma longa* L. which belongs to the family Zingiberaceae. India is the major producer and exporter of this spice. Curcumin is the important coloring material from turmeric and development of varieties with high recovery of curcumin is the need of the hour.

Micropropagation and plant regeneration: Successful micropropagation of turmeric has been reported (Nadgauda *et al.* 1978; Nirmal Babu *et al.,* 1997b; Salvi *et al*. 2002; Panda *et al.,* 2007; Ghosh 2013). This technique is used for production of disease-free planting material. Organogenesis and plantlet formation was achieved *via* callus cultures of turmeric (Nirmal Babu *et al*., 1997; Salvi *et al*. 2000; *Nirmal Babu et al., 2016*). Variants with high curcumin content were isolated from tissue cultured plantlets (Nadgauda *et al.,* 1982). Root rot disease tolerant clones of turmeric cv. Suguna were isolated using continuous *in vitro* selection technique against pure culture filtrate of *Pythium graminicolum* (Gayatri *et al*., 2005). : Renjith *et al*. (2001) reported *in vitro* pollination and hybridization between two short duration types VK-70 and VK-76 and reported seed set and seed development. This reduces the breeding time and helps in recombination breeding which was so far not attempted in turmeric. Protocols for micropropagation of many economically and medicinally important zingiberaceous species like *Amomum subulatum* (large cardamom), *Curcuma aromatica* (kasturi turmeric), *C. amada* (mango ginger), *C. zedoaria, Kaempferia galanga, K. rotunda, Alpinia* spp. were developed (Vincent *et al.,* 1992; Ravindran *et al.* 1996; Geetha *et al.* 1997; Chithra *et al.* 2005; Raju *et al.,* 2005. Rahman *et al.* (2004) reported efficient plant regeneration through somatic embryogenesis from leaf base-derived callus of *Kaempferia galanga* L.

Molecular characterization: Genetic diversity evaluation among *C. longa* and other 14 *Curcuma* species done using ISSR and RAPD markers (Syamkumar and Sasikumar 2007) placing them into seven groups which is somewhat congruent with classification based on morphological characters proposed by the earlier workers. Genetic diversity in turmeric was assessed by using molecular markers like RAPD and ISSR (Singh *et al.,* 2012) and PCR based markers *viz* RAPD, ISSR, AFLP (Das *et al.,* 2011, Nirmal Babu *et al*., 2007, 2011). Development and characterization of EST derived and genomic microsatellites in *Curcuma longa* were reported by Joshi *et al*. (2010), Siju *et al*. (2010) and Senan *et al.* (2013) which could be used for diversity analysis. Nayak *et al*. (2006) carried out 4 C nuclear DNA content and RAPD analysis of seventeen promising cultivars of turmeric from India.

Salvi *et al*. (2003) and Praveen (2005) using RAPD analyzed turmeric somaclones and concluded that plants regenerated using shoot tips showed genetic stability while the callus derived and inflorescence derived plants showed variations. Tyagi *et al*. (2007) confirmed the genetic stability of 12 month old *in vitro* conserved turmeric by RAPD profiling.

Protoplast culture : Successful isolation and culture of protoplasts were reported from cell suspensions and leaf tissues in turmeric (Geetha *et al*. 2000) and these protoplasts could be successfully developed up to microcalli stage.

Genetic transformation:An efficient method for stable transformation was developed in turmeric using particle bombardment on callus cultures (Shirgurkar 2006). Transgenic shoots regenerated were multiplied and stably transformed plantlets were produced. Polymerase chain reaction (PCR) and histochemical GUS assay confirmed the stable transformation.

Cloning and Isolation of Candidate Genes:Joshi *et al*. (2010) used degenerate primers designed based on known R gene in combinations to elucidate resistance gene analogs from *Curcuma longa* cultivar suvarna.

Vanilla

Vanilla planifolia, native to Mexico and Central America, now cultivated in other parts of the tropics, is the source of natural vanillin.

Micropropagation and plant regeneration: Micropropagation of vanilla using apical meristem was standardized for large scale multiplication of disease free and genetically stable plants (Minoo 2002, Minoo *et al*. 2006, 2009). Successful plant regeneration from shoot and seed derived callus was reported in vanilla (Nirmal Babu *et al.* 1997; Minoo 2002, Minoo *et al* 2016).

Molecular characterization: Markers like RAPD and AFLP coupled with morphological characters were utilized to assess the variability and hybrid nature of genotypes and of successful interspeciûc hybridization and production of hybrids between *V. planifolia* and *V. aphylla* (Minoo *et al*. 2006, 2016). RAPD marker was used to estimate the level of genetic diversity and interrelationships among different clones of *V. planifolia* and related species. The data showed very limited variation within accessions of *V. planifolia* indicative of its narrow genetic base and its close relationship with *V. tahitensis* (Minoo *et al* 2008, 2009, 2010). A comparative study of RAPD and ISSR were reported to analyze the interrelationships among nine cultivated, wild and hybrid *Vanilla* species (Verma *et al.* 2009). 14 microsatellite loci developed from *V. planifolia* shown to be monomorphic within the cultivated accessions and 11 markers out of 14 were polymorphic when transferable to *V. tahitensis* (Bory *et al.* 2008).

Protoplast culture: Minoo *et al* (2008, 2016) reported the isolation of viable protoplasts in *Vanilla* species, *i.e*. in *V. andamanica* and that of PEG mediated protoplast fusion between *V. planifolia* and *V. andamanica.* The protoplast fusion technology can be useful in gene transfer of useful traits to *V. planifolia* especially the natural seed set and disease tolerance observed in *V. andamanica.*

Genetic transformation: Protocols are available for genetic transformation of *Vanilla planifolia* using indirect procedure *viz., Agrobacterium tumefaciens* using shoot tip sections (Malabadi and Nataraj 2007) and protocorm like bodies from shoot tips as explants (Ratheesh *et al*. 2011), providing a very useful basis for further genetic improvement of the orchid.

Tree spices

Cinnamon, Clove, Nutmeg, Curry leaf, Pomogranate, Tamarind, Allspice and Garcinia *etc* are some of the important tree spices. In these perennial tree crops, identification and clonal multiplication of high-yielding 'elite' genotypes becomes a priority due to long pre bearing period.

Micropropagation and plant regeneration: Micropropagation of cinnamon, Chinese cassia, and camphor was reported from seedlings and mature tree explants (Mini *et al*., 1997; Nirmal Babu *et al*. 1997). Multiple shoots were induced from shoot tips and nodal segments of *Cinnamomum camphora* from a cotyledonary node on MS medium. Successful micropropagation of *C. camphora* were developed by and Nirmal Babu *et al*. 2003b.*In vitro* multiple shoot induction was worked out in *G. indica* (Kulkarni and Deodhar 2002). Murashige and Skoog's medium supplemented with BAP gave optimal response in different genotypes investigated. Micro propagation of three species of Garcinia was reported by Malik *et al.* (2005) and Mohan *et al.* (2012). *In vitro* shoot initiation from explants of field grown trees of nutmeg was reported by Mallika *et al*. (1997). Micropropagation of clove from seedling explants have been reported (Mathew and Hariharan 1990;). MS medium supplemented with IBA or activated charcoal induced root formation. However, there are no reports on successful micropropagation of clove from mature shoot explants.

Reports on micropropagation of curry leaf, camboge and tamarind are also available (Mascarenhas *et al*., 1987; Hazarika *et al.,* 1995; Rao *et al*. 1997; Bhuyan *et al.* 1997; Mathew *et al* 1999; Nirmal Babu *et al.,* 2000; Mehta *et al.*, 2000). High-frequency direct shoot proliferation was induced in intact seedlings of *M. koenigii* (Bhuyan,*et al.,* 1997). Shoot proliferation also reported from different explants like nodal cuttings (Nirmal Babu *et al.,* 2000), leaves (Mathew and Prasad 2007) and immature seeds (Rani *et al.,* 2012). *In vitro* regeneration and high frequency regeneration of Tamarind was achieved in different media compositions (Hussain *et al.,* 2004). Reports on successful callus induction and plant regeneration in Nutmeg, Cinnamon, Camphor, and Curry leaf *etc* are available. (Bhansali 1990; Iyer *et al.,* 2000).

Molecular characterization: Sheeja *et al*. (2013) reported the diversity analysis of nutmeg (Myristica) and related genera using both RAPD and ISSR markers. Species specific bands could be identified from all the accessions, which can be converted into SCAR markers for genotype identification and authentication.Thatte and Deodhar (2012) identified male and female specific molecular markers in *Garcinia indica*. Genetic variability and relationship studies of Curry leaf was done using RAPD, DAMD and ISSR by Verma *et al.* (2013)

Development of Synthetic Seeds

Synthetic seeds or artificial seeds are defined as artificially encapsulated somatic embryos, shoot buds, cell aggregates, or any other tissue which can be used for sowing as a seed and those posses the ability to convert into a plant under *in vitro* or *ex vitro* conditions and that retain its potential also after storage. Artificial or synthetic seeds can be an ideal system for low cost plant movement, propagation, conservation and exchange of germplasm. Synthetic seeds were developed by encapsulation *in vitro* developed small shoot buds in 3-5% calcium alginate in black pepper, shoot buds in cardamom, somatic embryos and *in vitro* regenerated shoot buds in ginger and turmeric, *In vitro* regenerated shoot buds, protocorms in vanilla (Sharma *et al.* 1994; Sajina *et al.* 1997) somatic embryos in cinnamon and curry leaf etc (Sundararaj *et al*. 2010; Minoo 2002; Gayatri *et al.* 2005; Naik *et al.,* 2006).

Microrhizomes

Microrhizome technology is useful for developing disease free planting material, and hence is an ideal source of planting material suitable for germplasm exchange, transportation and conservation. *In vitro* induction of microrhizomes in ginger was reported by many workers (Bhat *et al.* 1994; Sharma and Singh 1995; Nirmal Babu 1997a; Nirmal Babu *et al*. 2003, 2005; Tyagi *et al.* 2007; Sumathi 2007). The microrhizome derived plants have more tillers but were shorter. They gave fresh rhizome yield ranging from 100- 800 g per plant with an estimated yield of 10 kg per 3 m^2 bed. Many reports are available on *in vitro* micro-rhizome formation in turmeric (Nirmal Babu *et al*. 2003). Low sucrose is reported to decrease the size of microrhizome but optimium micrirhizome production at 6-9% sucrose was also reported. Sucrose (6-9%) was most effective in rhizome formation.

Conservation of Genetic Resources

The genetic resources of spices are conserved either in seed gene banks and or in field repositories. Conservation of the germplasm in *in vitro* and cryo bank is a viable and a safe augment to conventional conservation strategies (Nirmal Babu 2012 c).

In vitro conservation of germplasm: Conservation of pepper, cardamom, herbal spices, vanilla and ginger germplasm in *in vitro* gene bank by slow growth was reported (Nirmal Babu *et al.,* 1999; Tyagi *et al*. 2009). Protocols for *in vitro* conservation by slow growth of black pepper and its related species *viz*., *P.barberi*, *P.colubrinum, P.betle* and *P.longum* were standardized by maintaining cultures at reduced temperatures, in the presence of osmotic inhibitors, at reduced nutrient levels, or by minimizing evaporation loss by using closed containers. Technology for *in vitro* conservation of Zingiberaceous crops like ginger, turmeric, kaempferia, cardamom and their related species was standardized by Geetha (2002) and vanilla by Minoo (2002, 2009). Slow growth techniques are being used for medium term conservation of spices in *in vitro* repository at NBPGR (Mandal *et al*. 2000).

Cryopreservation: Cryopreservation of black pepper and cardamom seeds in liquid nitrogen (LN_2) was reported by Choudhary and Chandel 1994, 1995. Technology for cryopreservation of black pepper, cardamom, ginger, turmeric and vanilla germplasm using vitrification, encapsulation and encapsulation-vitrification methods, are available (Minoo 2002; Yamuna *et al*., 2007; Minoo *et al*., 2011; Nirmal Babu *et al*., 2012,). Cryopreservation of encapsulated shoot buds of endangered *Piper barberi* was reported by Peter *et al.* (2002). Efficient cryopreservation technique for *in vitro* gown shoots of ginger based on encapsulation dehydration, encapsulation vitrification and vitrification procedures was reported by Yamuna (2007). Minoo (2002) reported cryopreservation of vanilla pollen for conservation of haploid genome as well as assisted pollination between species that flower at different seasons and successful fertilization using cryopreserved pollen.

Production of Secondary Metabolites

Biotechnology can be utilized to exploit the potential of spices for bio production of useful plant metabolites. The use of tissue culture for the biosynthesis of secondary metabolites particularly in plants of pharmaceutical significance holds an interesting alternative to control production of plant constituents. This technique is all the more relevant in recent years due to the ruthless exploitation of plants in the field leading to reduced availability. *In vitro* proliferation of nutmeg mace is the source of anti carcinogenic compound myristicin, this technique with improvement can be used for production of myristicin. Most of the reports in saffron were on the *in vitro* proliferation of stigma and *in vitro* synthesis of colour components and metabolites.

Plant cells cultured *in vitro* produce wide range of primary and secondary metabolites of economic value. Production of flavour components and secondary metabolites *in vitro* using immobilized cells is an ideal system for spices crops. Ahmad *et al*. (2013) concluded that regenerated tissues of *P. nigrum* are a good source of biologically active metabolites for antimicrobial activities and callus culture presented itself as a good source for such activities. Callus and cell cultures were established in nutmeg, clove, camphor, ginger, lavender, mint, thyme, celery etc. Cell immobilization techniques have been standardized in ginger (Ilahi and Jabeen 1992). Once standardized this technology has tremendous potential in industrial production of important compounds like vanillin, myristicin and curcumin.

Conclusions

Biotechnology has the potential to be a key tool to achieve sustainable agriculture and agri based industry, through improvement of food production in terms of quantity, quality and safety, while preserving the environment. Significant progress has been made in the field of biotechnology for micropropagation, conservation and management of genetic resources, disease and pest mangement and molecular characterization. Identifying markers linked to important agronomic characters will help in marker assisted selection to shorten breeding time. Application of recombinant DNA technology for production of resistant types to biotic and abiotic stress has to go a long way before they can be effectively used in spices improvement. Though programmes have been initiated in many laboratories for *in vitro* secondary metabolite production these techniques are to be refined and scaled up for possible industrial production of the products. Owing to their commercial potential, intensification and application of biotechnology in spices is important and indispensable in the coming decade.

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Dynamics of Canopy Plant Architecture and Management for Doubling Farmers' Income

VISHAL NATH AND E.S. MARBOH

Canopy development in perennial trees has a seasonal and lifetime developmental pattern. The sum of development over individual seasons results in the final canopy dimensions and form. In fruit trees, there is a natural progression from a single-shoot tree towards a complex tree forms. Under natural condition, trees attain unmanageable height with dense canopy, posing problems in spraying, pruning and harvesting. In addition to shading effect, it has poor distribution of light throughout the canopy leading to a low light interception, leaf area index, creation of congenial microclimate for pests and diseases and delayed cropping. An ongoing concern has beenthat shading causes yield decline.Yields in orchards with tree volumes corresponding to light interception levels in excess of 85% (McFadyen *et al.*, 2004) declined by between 2%-3% per year for up to 10 years. Owing to burgeoning population, the pressure to produce more from a given area of land also increases. Land being a shrinking resource, therefore more efforts has to be diverted towards raising the production per unit area of land. This calls for a holistic management approach that can integrate the available resources into plant performance in favour of higher yield of quality fruits. It has been noticed that lack of focus upon regulating growth of tree, and appropriate canopy architecture right from the establishment stage are the main reasons for such problems. Due to casual approach and negligence by orchardists, the trees acquire their natural shape marked with criss-cross branches leading to highly dense vegetative mass with very poor penetration of photosynthetically active radiation (PAR). Such conditions not only affect the photosynthetic rate but also facilitate proliferation of pests and diseases. Consequently, such trees turn senile, unproductive and uneconomical.

Canopy architecture management can plays a vital role in harnessing solar energy and utilizing available space, soil nutrients and moisture in new as well as existing productive and old senile fruit orchards. The role of light and photosynthesis in tree fruit production, has been well documented (Lakso, 1994). Much of the research has focused on altering tree size, shape, and planting systems to increase light (photosynthetic active radiation, PAR) interception and thereby maximize carbon assimilation with an ultimate goal of increased yields and enhanced fruit quality. While recognizing the importance of these methods for increased light interception, it was realized that a major portion of the fruit trees canopy is subjected to shade during most daylight hours each day. For instance, in apple, shading to 40% of full sunlight reduced flower and fruit numbers, total yields, and fruit dry weight (Chen *et al.*, 1997) and several days of continuous shade soon after bloom can reduce fruit set (Byers *et al.*, 1990). Having realized the importance of canopy in quality fruit production, an attempt has been made to deliver on the most crucial aspects of tree forms, light availability, air flow, space to plant, multiple sourcing to common sink, ease of operation and natural resource harnessing with the following objectives.

- Provide the basic tree form and to aid the development of a strong tree framework by encouraging strong wide crotch angles.
- To encourage tree for longer living and precocious bearing.

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- To make maximize utilization of light as light has key role in flower induction as well as in fruit development through carbohydrate synthesis.
- To accommodate more number of trees per unit area to increase the yield and reduce the juvenility period of the fruit
- Permit proper light and air distribution to the tree interiorto expose maximum leaf surface area to sun.
- Managing tree growth to ease various cultural operations and orchard uniformity.
- Induce and sustain proper amount of well distributed fruiting terminals.
- Minimize tendencies toward biennial bearing.

Basic Principles of Canopy Management

Uniform exposure to sunlight throughout the volume of the canopy is necessary for abundant formation of flower buds, growth, size, and color development of fruits. Fruit yield relies largely on the light use efficiency of canopies, whereas fruit quality is primarily related to the light distribution among the canopies. Reducing leaf area and increasing the proportion of canopy gaps decrease shading effect. However, excess proportion of canopy gaps allows sunlight to be 'lost', falling on the orchard floor. A balance between excessive gaps that minimize wastage of sunlight energy and insufficient gaps to avoid shading effect is an integral role of canopy management. A large canopy surface area well exposed to sunlight is desirable, that increase light interception and trapping of solar energy. Well-formed canopies permits better aeration and sunlight exposure to foliage, fruits, improve the photosynthetic efficiency, fruit bud differentiation, fruit set, growth and quality vis-a-vis reduced microclimate buildup for pests and disease. Closed canopies impairs the penetration of both direct and diffused sunlight into the enclosure formed by canopy walls and the ground surface. Thus canopy shade should be avoided to maintain a uniform light microclimate that have an overall influence on flower initiation, bud break, fruit set, fruit size and quality. This will ensure an appropriate photosynthate partitioning between shoot and fruit growth. Maintenance of fruiting organs within the restricted zones in space facilitates mechanization in shoot pruning and fruit harvesting. While designing the canopy architecture, basic management considerations like development of strong structural framework, maximizing light penetration in and outside the canopy, natural control of diseases and pest, number of fruiting terminals and croploads to improve productivity and quality of fruits, ease in mechanization, cultural operations and crop regulation should be the central point.

Practical origin of the concept

The relevance of the work on canopy management was evident in an early study by Kliewer and Lider (1968) showing the significant effects of sun exposure and of shade cast by the canopy and within clusters on the temperature and composition

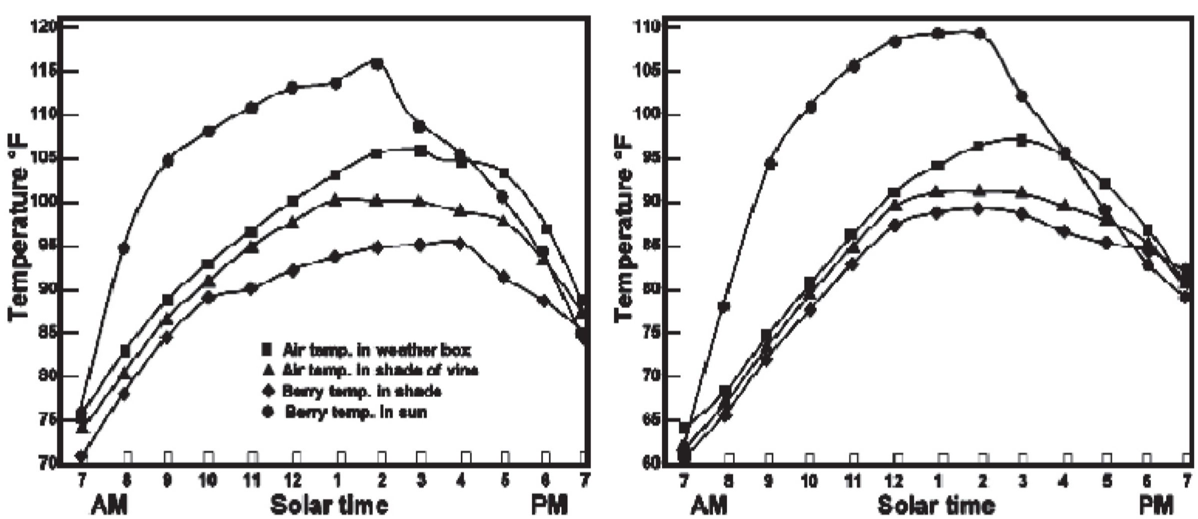

Fig. 1. Temperature of Thompson Seedless berries in the sun and shade, and air temperature in a weather box and in canopy shade, measured hourly on hot (left) and moderate-temperature (right) days. Redrawn from Kliewer and Lider (1968).

of grape berries, including the synthesis and catabolism of organic and amino acids, sugars and anthocyanin in vines and berries (Table 1, Figure 1). Later, Lakso and Kliewer (1978) provide key insights into the temperature dependence of malic acid accumulation and degradation in grape berries by determining the relative activities of phosphoenolpyruvate carboxylase and malic enzyme in response to temperature which favour malic acid accumulation at moderate temperatures (20-25°C) and degradation at above 38°C. Several studies of light and temperature effects on berry colour and phenolics were conducted under controlled environments. Accumulation of anthocyanin in berries was found to be repressed by exposure to high temperatures (30-35°C) (Kliewer and Torres 1972).

Su exposed clusters were borne on cane trained for maximum exposure. Shaded clusters developed in the canopy interior and received little direct radiation. Berries were selected randomly from each cluster (Kliewer and Lider, 1968)

By the late 1980s the evidence was clear that the development, physiology, fruit yield and fruit quality of a grapevine are all governed principally by the canopy light environment. Given the light filtering effects of leaves on both the intensity and quality of light within the canopy, Kliewer and Smart (1989) studied the possible role of phytochrome in light effects on fruit composition. Under low-light conditions they found the activities of PAL, nitrate reductase, and invertase in berries were stimulated with supplemental red light.

The role of nitrogen in canopy performance and the light dependence of its utilization within the vine have also been described. Analyses of amino acids in berries and vines over growing cycles revealed the prominent role of arginine and proline in the seasonal storage and mobilization of N to support the growth of shoots and young berries (Kliewer 1969, 1970). A dependence of berry amino acid levels on leaf area relative to fruit mass per vine was found by Kliewer and Ough (1970). Later studies focused on the extent to which nitrogen limits the growth and functional performance of canopies in supporting fruit development (Kliewer *et al*. 1991). Canopy light interactions with N distribution and utilization were also explored. Perez and Kliewer (1982) showed that nitrate reductase activity in leaves is enhanced by light exposure and the distribution of N among leaves was correlated with light intensity as affected by canopy leaf layers, and the N content of basal leaves in particular was correlated with bud fruitfulness and fruit yield of individual shoots. Canopy division was demonstrated to improve the responses of fruit yield and canopy growth to N fertilizer (Kliewer *et al*. 1991). A critical finding by Krueger and Kliewer (1995) linking canopy light to arginine supply within the vine was that sunlight exposure enhances the synthesis of arginine in leaves.

Light and its Implication in Fruit Trees

In fruit trees, fruit yield and quality depend on the light microclimate. Because photosynthetic carbon fixation depends mainly on the sunlight captured by a tree or an orchard, fruit yield of healthy and well-watered trees is related to total light interception (Robinson and Lakso 1991). Within tree architectural position or uneven distribution of light within the crown havea direct bearing on fruit quality in temperate and subtropical fruits. Usually, shade reduces fruit mass and fruit quality attributes like color and soluble sugar and secondary metabolite concentrations (Lakso 1980). Shading decreases shoot photosynthesis and fruit temperature and may change the light spectrum (Awad *et al*. 2001). Local irradiance may also affect flower bud initiation and development and leaf attributes affecting photosynthetic capacity, namely specific leaf area (Palmer *et al*. 1992). At the orchard scale, light interception depends on planting pattern and tree spacing (Palmer *et al*. 1992).Light use efficiency in rectangular versus square plantation design, single versus multi-row system and row orientation have also been quantified (Palmer 1989). At the tree scale and for a given genotype, light interception is affected by pruning and training procedures (Johnson and Lakso 1986). Many studies on irradiance and light

Table 1: Influence of cluster exposure on the basic composition of Thompsom Seedless berries.
Berry juice components

Exposure	Berry mass (g)	TSS (^{0}Brix)	Glucose (g/L)	Fructose (g/L)	pH	Tartaric Acid (g/L)	Malic acid (g/L)
Sun	1.14	24.2	11.5	14.5	3.79	6.5	0.5
Shade	1.05	23.1	10.9	12.9	3.63	6.4	1.2

interception have compared training systems at the tree scale (e.g., Palmate-Leader versus Central Leader; V-trellis, Solen Y-trellis, Geneva Y-trellis versus Slender Spindle and also at the orchard scale (Tustin *et al*. 1998) which suggest that fruit growers can improve orchard light microclimate by manipulating canopy structure.. When attempting training and pruning of fruit trees, utmost attention must be paid to induce growth of fruiting shoots towards the outer canopy to make use of available light in the outer periphery. This can be further improved upon by providing duct space between two rows in rectangular system and between rows and plants in square systems (Nath, 2014).

Interception of Radiation

Plants intercept direct and diffuse sunlight. The upper leaves receive both types of radiation, while the lower leaves intercept a small portion of direct radiation. Diffuse radiation therefore, becomes more significant in the lower leaves due to radiation transmitted and reflected from the leaves and the soil surface. Solar radiation transmitted by the leaves is predominantly infrared. From a practical point of view, the solar radiation spectrum is divided into regions, each with its own characteristic properties. Visible radiation, between the wavelengths of 400 and 700 nm, is the most important type from an eco-physiological viewpoint, as it relates to photosynthetically active radiation (PAR). Only 50% of the incident radiation is employed by the plant to perform photosynthesis (Varlet-Gancher *et al*, 1993). The quantity of radiation intercepted by plant cover is influenced by a series of factors such as leaf angle, the properties of the leaf surface affecting light reflection, the thickness and chlorophyll concentration, which affect the light transmission, the size and shape of the leaf phyllotaxis and vertical stratification, and the elevation of the sun and distribution of direct and diffuse solar radiation. Of the 100% total energy received by the leaf only 5% is converted into carbohydrates for biomass production later. Of the global radiation incident on the plant canopy only a proportion is used to carry out photosynthesis: PAR (photosynthetic active radiation). The plant's response differs with different wavelengths. Chlorophyll is the main pigment that absorbs the light, other accessory pigments are the b-carotene, red isoprenoid compound which is the precursor of vitamin A in animals and the xanthophyll, a yellow carotenoid. Essentially the entire visible light is capable of promoting photosynthesis, but the regions from 400 to 500 and 600 to 700 nm are the most effective (Fig. 2).

- 620-700 nm (red): A greater absorption bands of chlorophyll.
- 510-620 nm (orange, yellow- green); Low photosynthetic activity.
- 380-510 nm (purple, blue and green): Is the most energetic. Strong absorption by chlorophyll.
- < 380 nm (ultraviolet). Germicides effects, even lethal < 260 nm.

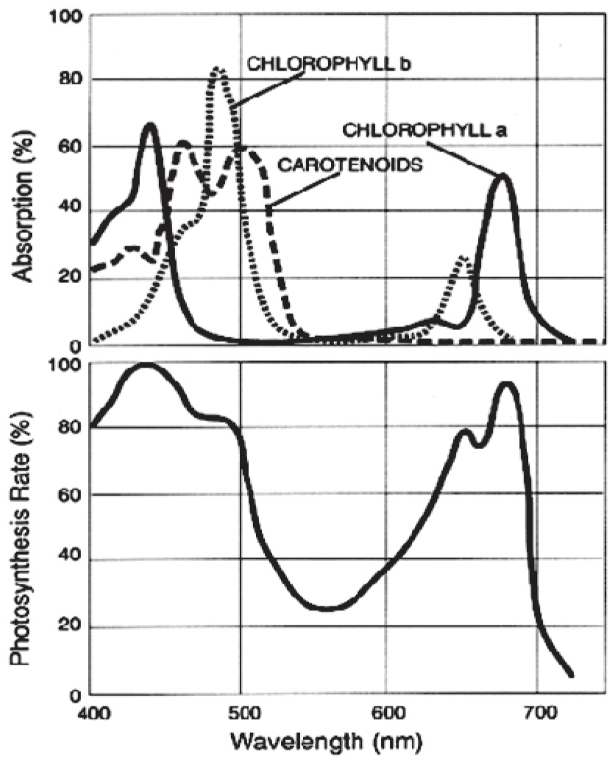

Fig. 2: Typical PAR action spectrum, shown beside absorption spectra for chlorophyll-A, chlorophyll-B, and carotenoids (Whitmarsh and Govindjee, 1999).

Light Harvesting

Light harvesting by plants is influenced by many factors such as, diurnal variation in solar elevation and variation in leaf angle, leaf position in the canopy, sky cloudiness, canopy density and amount of radiation penetrated through the canopy, and all the factors affecting gas flux properties of individual leaves. Photosynthesis occurs in leaves, the small-sized food factories constituting the majority of the canopy volume. Any disturbances in canopy microclimate such as variations occurred in ambient gas composition, light quantity and quality, temperature and humidity will lead to corresponding changes in C uptake by the leaves.

Foliage density distribution and leaves orientation highly impact sunlight attenuation through the canopy. The amount of photosynthetically active radiation intercepted by a leaf usually depends on its position in the canopy and the angle it faces incoming solar radiation. Leaves within the canopy are generally subject to three types of radiation: light beam, reflected and transmitted radiation. Direct beam light predominantly absorbed by the leaves at the top of the canopy, some portion transmitted down with altered spectral quality, due to action of the various leaf pigments. Leaves like any other biological surfaces not only transmit light but also reflect a portion which depends on morphological and physical properties of leaves such as, leaf shape, thickness and shininess of the cuticle. This reflected light may be absorbed or transmitted by the lower leaves similar to the radiation reaching the canopy surface. Rundel and Gibson (1996) found that leaf angle and orientation are the main factors which control daily integrated radiation, maximum irradiance and diurnal distribution of irradiance. Orientation of leaves at the top of the canopy is usually oblique (acute or obtuse) to incident light. Onto genetical change from sessile juvenile leaves to petiolate adult leaves is accompanied by a change in leaf orientation from horizontal to vertical (King, 1997).

Computation of Light Interception

In order to understand how to control the environment to make maximum use of available light, it is important to know about the properties of light and the manner it is measured. Light has both wave properties and properties of particles. Depending on how light is considered, the measurement of light can reflect either its wave or particle properties in terms of photons. Different types of light sensors are available for use with computerized environmental control systems. As long as the sensors measure the light available to plants, it is for growers to be able to relate these measurements to how the crop is performing. Light is a form of electromagnetic radiation produced by the sun. A narrow range of this electromagnetic radiation falling within the range of 400 to 700 nanometers (nm) of wavelength is referred to as the spectrum of visible light; this is essentially the range of the electromagnetic spectrum that can be seen. Plants respond to light in the visible spectrum and uses this light to drive photosynthesis. PAR is the general term which covers both photon and energy terms (LI-COR Inc.). The rate of flow of radiant (light) energy in the form of an electromagnetic wave is called the radiant flux, and the unit used to measure this is the Watt (W). The unit of Watts per square meter (W/m^2) is used by some light meters and is an example of an "instantaneous" measurement of PAR (LI-COR Inc.). Other meters commonly seen in greenhouses take "integrated" measurements reporting in units of joules per square centimeter (j/cm^2) (LI-COR Inc.). Photosynthetic Photon Flux Density (PPFD) is another term associated with PAR, but refers to the measurement of light in terms of photons or particles. It is also sometimes referred to as Quantum Flux Density (LI-COR Inc.). Photosynthetic Photon Flux Density is defined as the number of photons in the 400 - 700 nm wavebands reaching a unit surface per unit of time (LI-COR Inc.). The units of PPFD are micromoles per second per square meter ($micromol/m^2$).

Several methods have been proposed for studying light interception by orchard trees. On the one hand, empirical studies based on light measurements within and below the canopies have been attempted (Ferree *et al*. 1992). On the other hand, formalism relating canopy geometry to light interceptionhave been developed. Most models have been based on the turbid medium analogy, where trees are abstracted as simple geometric shapes with a uniform density of leaf area (Oyarzun *et al*. 2007). These models compute total light interception at the orchard scale and light distribution within tree crowns. Virtual experiments making 3D tree mock-ups with light computations based on projection methods to study canopy structure and light interception attributes, using structural parameters at the tree scale were computed from the databases where canopy geometry is described at the leaf scale. Only a few measurements based on 2D or 3D leaf clipping have been reported in fruit trees (Palmer *et al*. 1992) and vineyards. They are usually destructive and time-consuming. Varying approaches have been adopted to measure total light interception at the tree scale, e.g., arrays of sensors, fisheye photographs below the canopy and photographs of the shadow cast by the crown (Hemmerlein and Smith 1994). At the shoot scale, video projection and photography methods have been proposed for detached shoots. Field methods for estimating light interception at the shoot scale within crowns are time consuming. It requires construction of a virtual homogeneous tree canopy where leaves were randomly distributed in the crown volume. However, such computations could not be made in the field, mainly because homogeneous trees do not exist in nature. Unfortunately, virtual experiments also have limitations. The main one is related to the construction of 3D plants. Light micro-sensors can be attached to the leaf surface but this method needs many sensors to get unbiased values of mean irradiance (Sinoquet *et al*. 2001).

Considerations for Managing Tree Architecture

Intrinsic Factors

Plant architecture as well as overall canopy structure is an important factor influencing light absorption, being one of the driving forces behind plant photosynthesis, which determines crop yield(Niinemets, 2007). The intrinsic architectural pattern of fruit species and cultivars influence the architectural design of the individual fruit plantfrom upright highly branched scaffolds to low-branched tip-bearing fruit cultivars (Lespinasse and Delort 1986). For a given cultivar, the rootstock also plays a major role via the canopy volume that confers on the cultivar. Every plant has inbuilt inherent characteristics which governs the architectural behavior like tree forms, angling of branches and pattern of branching, flushing pattern, dormancy pattern and bearing behavior, level of endogenous growth hormones, etc. Based on these factors, the principles and action for canopy architectural design are planned and decided. Some plants have shoot growth with extension of flushes (mango) while others have continuous flushing during active growth phase (litchi). Few species have inherent dormancy for certain period (ber, guava, grapes, temperate fruits) and produce current shoots or fruiting terminals/spurs after pruning which finally bear fruits. Therefore, the architecture of each plant is decided according to their inherent growth characteristics.

Genotypes

Plant architectural characteristics (such as the number and geometry of organs, i.e. their shape and position within the plant and the canopy), are genotype specific, while at the same time highly dependent on the climatic conditions at the time of their initiation and development (Godin, 2000). Within a tree, differences in structural parameters and interception properties can be related to the typology of the genotype: for example in apple, Type II cultivars show more short shoots and fewer long shoots, as shown by Stephan *et al*. (2007) for 'Scarletspur'. This leads to smaller canopy volume, leaf area and total light interception. Small internode length, which is a characteristic of dwarf or compact scion cultivars has been shown to increase foliage clumping (Takenaka 1994).Partitioning leaf area between fruiting shoot and vegetative shoot revealed differences among cultivars, with much more vegetative shoot leaf area compared with fruiting shoot leaf area in 'Scarletspur'and 'Golden', and similar leaf area for the two shoot types in 'Granny'. Because fruit yield is related to light interception by spurs (Lakso *et al*. 1999), the greater sunlit leaf area in fruiting shoot of 'Granny' likely explains the higher regularity of bearing of this cultivar (Stephan *et al*. 2007).

Tree forms and light distribution

Several approaches have been used to improve the light distribution in fruit tree canopies. For example in apple, relatively natural tree forms are exploited that allow light penetration through the canopy by providing many small openings in the foliage such as in the multiple leader, central leader, vertical axis, or slender spindle forms (Heinicke, 1975). This approach can be successful, but generally requires a high degree of horticultural skill to manage the growth of the canopy. A second approach is to provide fewer large, permanent openings for light penetration into canopies restricted into geometric forms. Examples are thin restricted planes of foliage such as narrow hedgerows, tree walls, and A, V, or T forms (Palmer, 1989). This approach generally requires severe geoemtric restriction of the canopy, expensive support structures, and significant labor to place and maintain the branches in specific locations. The value of these different tree forms lies in their light distribution properties and the attendant improvements in fruit yields and/or quality.

Round crown trees

Heinicke (1963) and Looney (1968) showed that in large round crowned trees light intensity decreased rapidly with increasing depth of foliage and that lower and center positions of the tree received very low light intensities (6% to 30% of full sunlight). The exterior quarter of the tree had a small percentage of the total leaf area yet had a large shading effect on the rest of the tree where the major portion of the leaf surface was located. Heinicke (1963) proposed that 30% of full sun serve as a lower limit of desired light level in apple canopies. Jackson (1980) found a more rapid decline in light level with depth of canopy, with light levels reduced to 34% of full sun within 1 m of the canopy exterior. He found that the main cropping zone of the tree received a minimum of 35% full sun, while the more shaded areas produced relatively few fruits. This result has led to the rule of thumb that effective penetration depth of light into unrestricted apple canopies is approximately 1 m.

The central leader tree

The benefits of smaller trees led to the development of the "Central Leader" (C.L.) tree (Heinicke, 1975). The system has a pyramid-shaped tree with tiers of branches spaced along the trunk. The widest part of the tree is at the bottom tier. Years of experience have led growers to increase the distance between the bottom and second tier to a minimum of 1 m and to leave gaps in the canopy to increase the light penetration to the bottom tier. Barritt *et al*. (1991) have reported on the seasonal change in interior canopy light climate of 'Delicious' central leader trees. Their data show a rapid decline in light exposure to <20% full sun by early June for the interior parts of the canopy. The rapid seasonal decline in light exposure of the interior of central leader trees has led to summer pruning to improve fruit color. In mature central leader 'Empire'/M.7 and mini-central leader Empire/M.9/MM.111 trees (Interstems), the light exposure in the lower part of the canopy were categorize into three light zones: 1) well-exposed zone with light levels >50% of full sun; 2) marginally exposed zone with light levels between 30% and 50% of full sun; and 3) a poorly exposed zone with light levels <30% of full sun.

The palmate leader tree

In many cases as central leader trees age, the upper limbs outgrow the bottom of the tree, resulting in excessive shade in the bottom of the trees. There is a strong tendency for the upper scaffold limbs to grow more vigorously than the lower limbs due to better exposure. The shading that develops reduces flowering and fruiting in the center of the tree. Lakso *et al*. (1989) described a modification of the central leader tree form named the palmate leader (PL) designed to improve the light distribution of the tree canopy. This tree form is developed by removing upper east- and west-growingbranches, thus creating large gaps in the canopy on the east and west sides of the tree. This change results in a flat north-south oriented palmate top. The lower tier of limbs is left intact. The primary advantage of the PL form is that the large gaps in the upper east and west sides of the tree guarantee good light exposure to all parts of the tree. A more subtle benefit is that good light penetration into the tree center is maintained throughout the season. This is particularly important since many of the processes critical to fruit production, such as flower bud development and fruit cell division occur in the first 3 to 6 weeks after full bloom (Westwood, 1978).

The slender spindle tree

The slender spindle tree is a narrow, fully dwarf tree developed to allow planting of very high tree densities in either single, double, triple, or multiple-row beds to improve the early yields of apple orchards (Wertheim, 1968). It is designed for greater biological and management efficiency by allowing all management to be done from the ground. The width of the canopy is d" 2 m, which should ensure that most of the canopy is well exposed. However, in this case, the branches may be close together with only small gaps in the canopy, resulting in a high density of foliage in the tree. With moderate to vigorous growth, these gaps can be closed very quickly in the season, thus leading to poor fruit color and quality if the trees are not summer pruned (Corelli and Sansavini, 1989). Under vigorous growth conditions light levels in the lower part of the canopy of a bed system were lower than in a medium density palmate hedgerow(Sansavini *et al*. 1981). Slender spindle trees of 'Empire'/M.9 had very good light exposure in most of the canopy. All parts of the canopy had >30% full sun and only a small portion in the bottom was <50% full sun. However, as tree grows, light exposure levels had dropped considerably, indicating that the gaps between limbs had been closed.

Thin restricted plane canopy trees

Planar canopies have been developed to overcome the problems of light penetration into thick canopies. Examples are thin narrow hedgerows, tree walls, vertical low and high trellis, Ebro trellis, and A, V, and T trellises. Since the foliage and limbs are restricted to a single plane, these tree forms usually have a dense canopy that is essentially non-transmitting. The rule of thumb of 1 m of light penetration into canopies does not hold in this case. With the horizontal planar canopies, such as the T or Ebro trellis, there is a drastic reduction in light levels from the top to the bottom of the canopy. Ferree *et al*. (1989) reported that the Lincoln canopy (Ttrellis) had a high transmission of light through the canopy following severe dormant pruning, but, with moderate pruning, the canopy had very low transmission values. In the Ebro trellis, which is afour-tier horizontal canopy system, Tustin *et al*. (1989) found low light transmission through the top layer of the trellis resulting in excessive shade to the lower layers. These horizontal canopy systems were developed for mechanization of harvest but they suffer from the horticultural problems of excessive upright shoot growth from the top side of the trellis. This increases the amount of shading and, in the case of the Ebro trellis, can result in complete closure of the space between tiers. Fruit color of cultivar 'Empire' in horizontal trellises is poor and canopy development has been slow due to the flat limborientation.

Bearing Habit of Fruits Trees

In nature, plantspecies produce flowers, fruits and seeds and the primary objective is to reproduce them. Plant species those are unable to produce viable seeds, reproduce themselves by other means. With a common of these processes they vary in various aspects of flowering and fruiting. The variations may be due to their different growing habits, requirement of different environments, differences in their basic nature etc. An accurate knowledge of varying forms of fruit bearing habit is necessary to prune fruit plants to harvest the good of pruning (Usha *et al*., 2015).The bearing habit of a species can be described by the location and types of buds which produce flower and fruit (Gardner *et al*., 1952). As plants attains proper nutritive condition particularly accumulation of certain carbohydrates upto desired level, any bud can differentiate to flower bud and set fruit. Invarious plant species, different buds located at different locations (on a shoot) varies to attain thiscondition. The justification of formation of fruiting buds on particular locations in a particular species is that at those locations the nutritive and other conditions are more favourable for flowerbud formation. Since all the buds can be considered as potential flower buds. So, flowers, inflorescence and finally fruits will bear wherever buds are borne. Based on fruit bearing habit, fruit trees are categorized into different groups as below:

Group- I :Fruit buds borne terminally, containing flower parts only and giving rise to inflorescences without leaves (Examples: Mango and Loquat)

Bearing habit of this group can understand very clearly form mango. In mango, afterharvesting the shoots grows and matures and produces panicle terminally. Growth of lateralbranches situated below panicle is continued. In case of accident to terminal panicle, then someof axillary buds may differentiate flower parts.This bearing habit is not found with any of thecommon deciduous fruits.

Group- II: Fruit buds borne terminally, unfolding to produce leafy shoots that terminate in flower clusters(Apple, Pear, Quince, Walnut, Pecan)

This type of bearing habit is characteristic of most of the pome fruits. It can beunderstood very well with example of apple and pear. Majorly, apple and pear, bears on spurs(commercial crop of good quality and quantity). These spurs bear fruit buds terminally. Thesespurs bear for many years (varies according to varieties). New spurs originate from lateral budson the shoots of the preceding season and very occasionally from latent of adventitious buds onthe trunk or older limb. However, in some varieties of apple which is young and vigorous, manyof long shoots form terminal flower buds. But, they contribute very less to total commercial cropof that tree.

Group-III: Fruit buds borne terminally, unfolding to produce leafy shoots with flowers or flower clusters in the leaf axils (Guava, pomegranate, tropical almond, olive, Eugina).

This is an incomplete terminal bearing habit because the fruit itself is not borne terminally, but is present laterally on the growth. However, the flower buds are terminal. The terminal buds of the flowering shoots may differentiate flower parts for the following year s production or new buds may develop from lateral leaf buds. In guava, the fruit buds are formed on short shoots (current season growth) and flower and fruits produced in the leaf axils.

Group-IV: Fruit buds borne laterally, containing flower parts only and giving rise to inflorescences without leaves or if leaves are present they are much reduced in size.

[Peach, Plum, Apricot, cherry, Almond, Walnut (staminate flower), Pecan (staminate flower), Date, Coconut, Citrus fruit, Plumcot, Current, Gooseberry].

This type of bearing habit can easily understand by examples of peach and citrus fruit (Kinnow mandarin). In Kinnow mandarin, the fruit buds borne laterally on old season shoot and after emergence it produces flower bud (s) and few leaves. In case of peaches, the shoot of previous season produces flowers on laterally without leaves.

Group-V: Fruit buds borne laterally, unfolding to produce leafy shoots that terminate in flower clusters.[Litchi, Black berry, Rasp berry, Dew berry, Grape, Filbert, Blue berry, Cranberry(European), Cashew nut, Brazil nut, Pond apple (and various other annonaceous fruits), Apple(occasionally), Pear (occasionally)].

Bearing habit of litchi can best describe the type of fruiting habit of this group. Litchi produces fruit budslaterally which produces leafy shoots which ultimately produces panicles terminally. In case ofgrapes, the fruit buds borne laterally which produces shoot and this shoot actually bears berrycluster terminally (which makes fit for this group) but as shoot grows further, its growth pushesfruit cluster in one side and it gives appearance as it is situated laterally and opposite a leaf.

Group –VI: Fruit buds borne laterally (or pseudoterminally), unfolding to produce leafy shoots with flower cluster in the leaf axils. [Jujube (Ber), Persimmon, Mulberry, Fig, Cranberry (American), Chestnut, Pistachio nut, Star- apple, Avocado, Olive (Partly)].

Ber is very good example to understand this type of bearing habit. Ber produces various current season shoots from old pruned shoots laterally. These branches bear flower clusters in the leaf axils. After fruit ripening, the leaves and fruits fall and ultimately the branch falls. Buds for the next season crop will produced by strictly vegetative branches. It indicates dimorphism in branching of ber. First type of branches are permanent in mature and forms basic framework for a tree. Second types of branches are deciduous in nature and they dry out after producing flowers and fruits in a season.

Extrinsic Factors

Besides internal factor, several other factors like planting system, spacing, solar radiation, wind velocity, rainfall pattern and light distribution, etc. also play very crucial role in plant canopy development in fruit crops. Hedgerow planting system with a principle of single canopy and multiple root system is ideal for those fruit species which are responsive to pruning and bear on either current season shoots or spurs (guava, peach etc), whereas open centre system may be more useful for plants requiring more solar radiation for fruiting and colour development (litchi). Bearing area alignment in canopy, depth requirement in canopy, rootstocks, soil depth, etc. are also important external factors, which influence canopy architecture and management in a species.

Light distribution within tree canopies depends on various inter-related factors. The significance of planting system (Jackson 1980) in light harvesting efficicency which includes both tree arrangement in the orchard (planting distances, row orientation) and training of the tree canopy by pruning and bending procedures (tree shape and height) has been emphasized. Training partly defines the proportion and distribution in space of the various shoot categories, long versus short shoots and vegetative versus fruiting shoots. Since whole-tree photosynthesis is primarily light limited (Lakso 1980), manipulation of canopy architecture to enhance global light interception is a major objective of all planting systems. The contribution of the various shoot categories to tree productivity is now well documented and, as a general trend, whole-tree yield has been shown to strongly depend on light interception by the spur canopy (Lakso *et al*. 1999). This probably arises from both morphological features of short as compared to long shoots, the former having higher leaf to shoot ratios, and faster carbon exportation capacity early in the season (Sansavini and Grappadelli 1992). These results clearly illustrate the advantages of managing well-illuminated spur-rich canopies with high porosity to light (Sansavini and Corelli-Grappadelli 1992). Improvement of light distribution and interception in the orchard can take place at two levels: management of discontinuities between tree crowns which depends on tree shape and planting distances (Tustin *et al*. 1998), and development of training procedures which decrease within-tree shading. The latter factor has not been adequately studied and is more difficult to manage, and training systems which typically aim at increasing light interception by the canopy—e.g. Lincoln Canopy and, to a lesser extent, V-trellis and Y-trellis—often result in excessive annual, vertical growth on the exposed sides of scaffolds (Palmer and Warrington 2000). Unless these shoots are removed during the growing season, they increase shading on fruiting spurs located lower down. An improvement of training systems should therefore integrate not only the management of tree height and shape and discontinuities between trees, but also a better knowledge of the tree reactions to training methods, specifically shoot orientation and pruning.

Potentials of Plant Canopy Management in Increasing Fruit Production

Maintaining Tree Size

Certain principles of canopy architecture management have been in focus for most fruit trees. These are

- Facilitating aeration inside the canopy
- Maximizing light penetration in and out of canopy
- Facilitating conversion of sunlight into chemical energy by plant leaves
- Controlling plant structure including stature
- Improving fruit colour, quality and yield

Nature does not care how many good sized, high quality fruits are to be borne in a tree but is certainly affected by the capacity of plant to sustain these. For economical fruit growing, the natural form and shape of fruit trees has to be modified through the practices of pruning to achieve targeted yield with better quality fruits. Fruit growers desire to regulate the growth and development of their trees in a specific manner for production of maximum fruit, because it is not always wise to allow a plant to develop naturally, since unwanted portions may develop at the expense of those which are essential from the cultivator's point of view to increase production. Canopy architecture management is thus one of the most important production factors confronting the rapidly increasing fruit industry in India. In many fruit crops, 15-20% increase in production with enhanced fruit quality has been witnessed by managing appropriate and efficient canopies particularly in short-statured trees. Small trees capture and convert sunlight into fruit production in a better way than larger ones hence it has direct impact on orchard efficiency.

Improving Light Interception

Light is critical for plants as well as for fruit growth and development. The green leaves harvest sunlight to produce carbohydrates and sugars, which are transported to the sites/sinks where they are most needed like buds, flowers and fruits. Improving light penetration into the tree canopy improves tree growth, productivity, yield and fruit quality. High density planting and orientation of planting often pose a problem for light penetration in an orchard. Generally, in close planting, quicker shading becomes a problem. An East-West row orientation results in more shading compared to Western and Southern orientation of trees. Strong bearing branches tend to produce larger fruits. They also transport nutrients and water more efficiently throughout the trees. Pruning aims to encourage new and strong growth of all branches. Some of the basic principles of the canopy management are maximum utilization of light, avoidance of build-up of microclimate congenial for disease and pest infestation, convenience in carrying out cultural operations, maximizing the productivity with quality fruit production, economy in obtaining the required canopy architecture (Nath, 2014).

Fruit production involves capturing and conversion of sunlight into production of fruit biomass (dry-matter content). The main controlling factors in this context are the amount of incoming radiation and percentage of total radiation received by photosynthetically active leaves (PAL) for conversion of solar energy into fruits yield.

Improving Fruit Quality

The geometrical structure of a plant canopy determines its interaction with fluxes of energy. Canopy architecture and density are intimately related to crop productivity since the distribution of leaf and non-leaf surfaces influences light interception and subsequent carbon assimilation and water loss. This has been widely recognized for fruit and grape production (i.e. Dokoozlian and Kliewer 1995). Light transmittance influences growth and development of trees and their fruit. The effect from decreased light transmittance on yield due to dense leaf and shoot canopies and shaded fruiting zones affects the flower primordial development of the following year's crop. The development of these primordial is influenced heavily by light transmittance, as shaded canopies have been shown to lower the development of these primordial, thereby reducing the following year's yields (Smart and Robinson 1991). Improved sunlight transmittance to as many leaves as possible will provide for the most efficient use of photosynthetic processes, maximize flower primordial development and increase yields (Smart and Robinson 1991). Sunlight transmittance can also affect yield and grape quality by affecting the temperature in the microclimate (Crippen and Morrison 1986).

Improving Yield

Plant production depends on the conversion of sunlight into chemical energy, and, for the most part, this process takes place in the leaves. There has been a strong move to improve the productivity of temperate fruit trees in the past 30 years or so, based on an understanding of the relationship between yield and light interception. Modern apple and stone-fruit orchards are planted at high density and trees kept small through the use of dwarfing rootstocks and intensive pruning. These systems maximize the interception of light by the canopy. This philosophy is not well developed in litchi and most other tropical fruit trees, with few dwarfing rootstocks or validated pruning strategies. The tree architecture and canopy management, especially size control, has become a priority for reducing production cost and increasing yield and quality. Canopy design and shape influences light interception with assured higher monetary returns to fruit growers. Therefore, early height control and tree canopy management should be practiced in fruit crops for doubling orchard income. Some of these factors are being enumerated. In sapota, centre opening through mild pruning resulted in lesser height increment compared to unpruned trees. However, higher production of lateral branches resulted in increased fruit yield, though there was reduction in the height increment. In general, pruned plants perform well both under wider spacing and narrow spacing in terms of yield and quality traits. Since, yield maximization is the prime objectives, the plants under narrow spacing with pruning were found to be the best (Mathew, 2007). Besides training and pruning facilitates easy hand picking of fruits and easier intercultural practices.

Overall pruning were found to have rejuvenating impact on aged trees due to better light interception leading to better photosynthetic rate, better nutrient and water supply with reduced canopy and better quality yields. The earliest bud emergence, high number of buds per shoot, increase fruit yield, size and weight with improved fruit quality was reported in guava under different pruning intensities as compared to no pruning (Bhagawati *et al*., 2015). Fruit yield during the initial years of pruning, sharply declines with respect to the unpruned trees, but in the subsequent years, when all the trees remained unpruned, yields stabilized in both pruned and unpruned trees. It is a well-proven fact that yield decreases in the year in which pruning is performed, but if the effect of pruning is analyzed over several years, this adverse effect disappears because the tree compensates for the previous reduction in the non-pruning years, probably as a consequence of the accumulation of reserves and better lighting (Yildirim *et al*., 2010). Yield greater than 60 kg/tree were recorded in rejuvenation pruning done at 1.50 and 2.00 m height on mango cv. Amrapalli planted at 5.0 x 5.0 m spacing (Table 2). Initiation of fruiting began after third year of rejuvenation pruning. Pruning at 1.0 m, 60 cm length of primary shoot and no control on length of secondary shoots was found to be the best management practice for rejuvenation of unproductive mango orchards of cv. Amrapali planted at close spacing (Das and Jana, 2012).

Table 2: Effect of canopy management after rejuvenation pruning on plantgrowth and yield of mango cv. Amrapalli.

Treatments on Canopy architecture	Height (m)		Yield (kg/tree)	
	2007	2010	2007	2010
Rejuvenation pruning I m, primary shoot 60 cm, secondary shoot 60 cm	2.43	4.05	0.0	37.90
Rejuvenation pruning I m, primary shoot 120 cm, secondary shoot 60 cm	2.73	4.323	0.00	8.35
Rejuvenation pruning I m, No control on primary shoot, secondary shoot 60cm	2.75	4.38	10.95	8.35
Rejuvenation pruning I m, primary shoot 60 cm, No control on secondary shoot	2.37	4.08	1.67	51.68
Rejuvenation pruning I m, primary shoot 120 cm, No control on secondary shoot	2.81	4.30	5.80	8.64
Rejuvenation pruning I m, No control on primary shoot and secondary shoot	3.10	4.52	0.00	30.54
Rejuvenation pruning I.5 m, primary shoot 60 cm, secondary shoot 60 cm	2.97	4.60	4.73	51.44
Rejuvenation pruning I.5 m, primary shoot 120 cm, secondary shoot 60 cm	3.35	4.75	1.83	47.90
Rejuvenation pruning I.5 m, No control on primary shoot, secondary shoot 60cm	3.29	4.67	9.40	39.35
Rejuvenation pruning I.5 m, primary shoot 60 cm, No control on secondary shoot	2.98	4.33	2.30	57.74
Rejuvenation pruning I.5 m, primary shoot 120 cm, No control on secondary shot	3.12	4.57	0.00	31.63
Rejuvenation pruning I.5 m, No control on primary shoot and secondary shoot	3.60	4.58	0.00	61.43
Rejuvenation pruning 2 m, primary shoot 60 cm, secondary shoot 60 cm	3.45	5.07	6.12	51.95
Rejuvenation pruning 2 m, primary shoot 120 cm, secondary shoot 60 cm	3.72	4.90	5.67	43.02
Rejuvenation pruning 2 m, No control on primary shoot, secondary shoot 60 cm	3.63	4.83	2.97	57.03
Rejuvenation pruning 2 m, primary shoot 60 cm, No control on secondary shoot	3.48	5.22	1.17	38.40
Rejuvenation pruning 2 m, primary shoot 120 cm, No control on secondary shoot	3.60	5.08	0.00	51.30
Rejuvenation pruning 2 m, No control on primary shoot and secondary shoot	3.51	5.13	6.12	61.80
SEm	0.11	0.17	1.89	15.81
CD at 5%	0.31	0.48	NS	32.27

High Density Planting

The productivity of an orchard dependsin part on how well it collectssunlight. As such, "light interception" is a function of the density, heightand shape of the trees, which in turnincorporates the number, angle and orientation of their branches. These characteristics are the primary components of a planting system. The ideal orchard planting system can vary based on numerous factors, including geographic location, variety and species, soil type, rootstock, and local cultural and economic concerns. However, each system has inherent qualities that, if understood, can be used to help growers meet their goals for the orchard.

Tree form and height are two key factors in determining how efficiently fruit orchardsproduce fruit profitability. Increasing tree densities per unit area can improve production efficiencies because orchards reached full production more rapidly. In closer plantings, trees reach their ultimate "design size" more quickly, and consequently also reachfull production more quickly compared to wider spacings. During the early 1960's high-density orchard plantings were based onEuropean hedgerow systems in whichrow width was reduced to 12 to 15feet, and tree distance within each rowwas reduced to 6 to 12 feet, therebyincreasing tree densities from about240 to 605 trees per acre. In addition,smaller tree shapes were used, usuallyeither upright central-leader/spindleforms (without the cone), or veryupright palmate or parallel-V forms(with a much more narrow cone thanthe open vase). Day *et al*., (2005) confirmed that high-density central leader and parallel-V systems did indeedhave greater cumulative yields in peach and nectarines, than the standard open-vase system through the first 7 years of orchard life, when all the trees had matured.In guava, meadow orchard system coupled with regular topping and hedging can accommodate 5000 plants ha^{-1} at 2.0 x 1.0 m spacing. Such practices ensure better light interception within tree canopy by increasing the number of well illuminated leaves. It also promotes rate of photosynthesis which directly increase the yield per unit area (Singh, 2013).

Rejuvenation of Senile Orchards

The presence of old and senile orchards has been attributed as one of the major factors for decline in productivity. Old trees often produce fruits and difficult to harvestdue to their size. Moreover, old trees harbour pest and diseasesand it is difficult to reach the whole tree while spraying to controlthem. It is possible to cut these trees back to a more manageablesize, but depending on the severity of the pruning, one may losetwo to three crops.

Rejuvenation improves production, fruit sizeand quality once trees recover.

The importance of canopy management in improving the productivity of old orchards has been demonstrated in litchi at ICAR-NRC on Litchi. In general, litchi plant starts bearing after 5-6 years of planting and attains commercial bearing stage at least after 10 years and commercially viable life (period) lies between 11 to 40 years. At this commercial juncture of bearing stage, the plant needs skillful management by proper pruning and training for status and canopy management apart from proper nutrition, irrigation and disease-pest management for quality production. It has been observed in general that orchards after attaining the age of 30-40 years even spaced at 10m x 10m, turns dense with compact top canopy covering most of the branches at the bottom and bearing fruits only on the high-tops. The plants pose problems in proper management such as pest control and, harvesting etc. Under such circumstances, it is rather difficult to assess longevity of trees. On the other side, with rising cost of management, it may not be economical to maintain these old senile orchards of above 40 years of age. Such orchards need to be rejuvenated for further higher production of quality produce.

Space Utilization for Yield Compensation

Just after the completion of reiterative pruning for rejuvenation, the open interspaces between the plants / trees is created in the orchard like newly planted orchard. Intercrops during summer season like Black gram, Mung, Maize, Cucurbitaceous vegetable, fodder crops etc. and during rabi season, the crops like Cowpea, French bean, Pea, Potato, Mustard etc have been found most suitable. Flowering plants and annual fruit crops like papaya and banana have also been foundto give good income for 2-3 years. Apart from the significant income obtained by the intercrops in rejuvenated orchards, the added advantages like improvement in the soil tilth (health), almostcomplete check over weed growth as well as less incidence of pests diseases are also obtained

Fruit Yield and Quality

It has been found that the yield obtained from the old trees (non-rejuvenated) is high butfetching very less price in the market due to inferior quality particularly with respect to size andwastage due to attack of many physiological disorders and attack of pests-diseases. Fruit yield and physiochemical characters of mature fruits were found to be better in fruits obtained fromrejuvenated trees. Maturity period is found to be slightly delayed in rejuvenated plants. The yield, quality and economics of fruit production in rejuvenated litchi orchards are presented in Table 3 & 4.

Advances in Canopy Architecture Management in Fruit

Table 3: Quality of fruits obtained from rejuvenated trees

S.N.	Particulars	Fruit Yield (Kg/tree) Categorization of fruits under different quality class			
		Extra Class	Class I	Class - II	Wastage
	Old litchi tree	85	19 (22.35%)	24 (28.23%)	16 (18.82%)
	Rejuvenated litchi (3rd year)	28	12 (42.85%)	10 (35.71%)	02 (7.14%)
	Rejuvenated litchi (4th year)	46	21 (45.65%)	14 (13.43%)	04 (8.69%)
	Rejuvenated litchi (5th year)	53	24 (45.28%)	16 (30.17%)	04 (7.57%)

Table 4: Economics of rejuvenation

S.N.	Particulars of operation/items	2003	2004	2005	2006
	Sale of fruits before rejuvenation	6500.00	-	-	-
	Cost of rejuvenation	(-) 12250.00	-	-	-
	Sale of woods	8000.00	-	-	-
	Cost of intercropping	(-) 2700.00	(-) 4500.00	(-) 6500.00	(-) 6000.00
	Profit from intercrops	10200.00	19000.00	24500.00	22000.00
	Sale of fruits from rejuvenated trees	-	-	-	9500.00
	Gross Income	9250.00	14500.00	18000.00	25500.00

Planting systems

The major advances in planting systems are square system with high density planting, rectangular system with high density planting, double hedge row planting and single hedge row planting. These systems (Table 5) are adopted in different fruit trees to obtain the maximum yield and quality fruits per unit area.

Table 5: Planting system adopted in different fruit crop with canopy architecture.

Crops	Planting system
Litchi	Square system with medium density planting (6x6 m, 6x4 m) for Shahi and China, Single hedge row system (9x4.5 m, 8x4 m)
Mango	Square system with medium density planting for Dashehari (6x6 m) and Amrapalli (5x5 m)
Guava	Single hedge row system with ultra-high density planting (2x1 m), Ultra density rectangular system (1x1 m)

Canopy Architecture Designing for Different Densities

Orchards are planted at different spacing in various planting system. Among the prevalent planting systems, square and rectangular systems are most commonly adopted whereas hexagonal and contour systems are need-based depending upon the availability of area, land topography and purpose thereof. The modern planting systems like single hedge row and double hedge row are the derived form of rectangular system where concept of single canopy with multiple root system is followed. These methods are adopted to harness maximum solar radiation and potential use of mechanization.

The designing of Canopy architecture in different density depends on the space provided to each plant in each direction. Under square system of planting the plants are designed in such way that the canopy grow uniformly in each direction where as in rectangular system the canopy is allowed to grow wider in two directions and shorter in two directions where space is less. While developing design for canopy, the frame of skeleton, the angle of branches, the axis of growing branches, the spacing between the growing branches, the orientation of branches etc are essentially kept in mind.As a matter of fact, 60% space in one direction should be allotted for skeleton, 25% for fruiting terminals and 15% for gallery space in square system. The situation is almost

Table 6: Canopy design concept for different densities

Plant spacing	Headback height (cm)	Iorder Branch (m)	II order Branch (m)	III order Branch (m)	Fruiting terminals (m)	Gallery space (m)
Square system						
8x8 m	60	1.0	0.8	0.7	1.0	0.5
6x6 m	50	0.8	0.6	0.5	0.7	0.4
5x5 m	40	0.7	0.5	0.4	0.6	0.3
4x4 m	30	0.6	0.4	0.3	0.5	0.2
3x3 m	30	0.4	0.3	0.2	0.4	0.2
2x2 m	20	0.3	0.2	0.2	0.2	0.2
8X4 m	50	1.0	0.8	0.7	1.0	0.5
6X3 m	40	0.6	0.4	0.3	0.7	0.0
		0.8	0.6	0.5	0.7	0.4
"Y" Shaped trellis (5x3m)	40	0.5	0.4	0.3	0.3	0.0
		0.6	Parallel training of I, II & III branches	0.8		
		-	Fruiting surface on II & III branches	0.0		
Rectangular system						
8x3	50	1.0	0.8	0.7	1.0	0.5
		0.4	0.3	0.2	0.4	0.2
7x3	40	0.8	0.7	0.6	0.8	0.6
		0.4	0.3	0.2	0.4	0.2
6x3	30	0.8	0.6	0.5	0.7	0.4
		0.4	0.3	0.2	0.4	0.2
5x3	30	0.7	0.5	0.4	0.6	0.3
		0.4	0.3	0.2	0.4	0.2
4x3	30	0.6	0.4	0.3	0.5	0.2
		0.4	0.3	0.2	0.4	0.2

similar in rectangular system except the side where distance between two plants is narrow. A concept of Canopy design in different densities has been given in Table 6.

Most of the perennial fruit plants especially the mango and litchi bears on 2/3rd lower and middle canopy and fruiting in top region is generally prone to biotic and abiotic stress (Table 7). Well-designed canopy facilitates many orchard operations like bunch / fruit bagging, spraying, netting etc. The result has been so far indicated that hedge row system in Shahi and Square system in China produces higher yield. However square system in Shahi (TSS: Acid ratio, 91.74) and single hedge row China (TSS:Acid ratio 89.04) produced best fruit quality in litchi. Therefore, it has been concluded that row planting is the most suitable planting system for cultivar Shahi and China at Ranchi, Pantnagar and Pusa.

Improving Light Interception by Orchard Canopies

Light interception in orchards can be raised by increasing the density of foliage in the canopy, increasing the height of the trees relative to the clear alley width, or by increasing the number of trees per hectare (Corelli and Sansavini, 1989). Because of the tractor alleys used for orchard management, light interception is more stronglyinfluenced by tree numbers per hectare and tree height : clear alley ratios than by canopy density.Light interception could also be considered over the lifetime of the orchard with a mean lifetime fraction of light intercepted. Several studies have examined light interception in mature and young orchards.

The realization that significant land and light resources are wasted in the early life of an orchard has encouraged the planting of higher and higher tree densities. This practice has resulted in greater early yield and greater lifetime light interception. Verheij and Verwer (1973) examinedlight interception in low- and high-density hedgerows of 'Golden Delicious'. The low-density plots (1100 trees/ha on M.9 and 660 trees/ha on M.2) intercepted roughly half of the incident light at maturity and yields peaked at 40 t·ha-1. The high-density plots (3300 trees/ha on M.9 and 2260 trees/ha on M.2 intercepted two-thirds and three-quarters of available light, respectively. Yields were >70 t·ha-1 in their 6th and 7th years, but thereafter yields declined due to inter-tree competition. The effect of the tree arrangement was less important than number of trees/ha for increasing total light interception and yield. The results of tree arrangement showed that single-row or full-field arrangements of trees gave better yields than the three-row system at equivalent tree densities. Increasing tree planting density has been the most important means of increasing the early yield and early light interception of young orchards. Barritt (1989) found that tree density was more important than training system or rootstock for improving light interception and yield of 'Granny Smith' in the 3rd year.

Thin vertical canopies receive light exposure from both sides of the canopy and so should have good light distribution within the canopy. Ferree (1980) reported that a palmette hedgerow had better light penetration into the canopy than did slender spindle, inter-stem, or pyramid hedgerow trees. The trellis also had greater crop density and greater efficiency than the other systems. Generally it was revealed that, if the trellis canopies are kept thin, they produce excellent fruit quality. However, as the width of these canopies increases, the center of the canopy produces poor quality fruit. With wide palmate trellis hedgerows, Ferree *et al*. (1989) found light transmission to be similar to the slender spindle. The vertical stacking of fruiting branches with palmette trellis hedgerows leads to more growth on the top branches than on the bottom branches due

Table 7: Canopy design for various planting system.

Spacing	Plants/ha	Max. Permitted Plant Height, (m)	Max. Permitted Plant Spread(m)	Canopy vol. (m^3/ha)	Effective canopy vol. (m^3/ha)*
4x4m	625	3.0	3.0x3.0	79,545	78,750
5x5m	400	3.5	4.0x4.0	1,87,712	1,83,958
6x6m	277	4.0	5.0x5.0	3,62,697	3,51,816
6x4m	415	3.0	5.0x4.0	2,60,828	2,55,612

Canopy volume m^3 has been calculated by the formula 4/3ð a^2b where a= half of spread and b= half of the height (Westwood *et al*., 1963).
* Reduction in canopy by 10, 20, 30, 10%, respectively from top non yielding areas.

to better light exposure. If not carefully managed, the top branches shade the lower ones, resulting in loss of vigor and fruit quality in the bottom of the tree.

Conclusion

Canopy architecture and its management is one of the important operations in fruit crops for harnessing natural resources through utilization of proper space, nutrients, moisture, solar energy and aeration in the new as well as existing productive and old senile fruit orchards. There are many factors that determine plant canopy architecture. Some of these factors are genetic and relate to the plant species while some are ecological and relate to the plant environment interactions. The tree architectural management, for strong frame and size control, has become a priority for reducing production cost and increasing input use efficiency, yield and quality in various perennial tree fruit species. The productivity of a crop depends on the ability of plant cover to intercept the incident radiation, which is a function of the leaf area available, the architecture of vegetation cover and conversion efficiency of the energy captured by the plant in biomass. The interactions of plant canopies with the environment are very complex. In an agricultural context, canopy management practices additionally interfere with and modify these relationships. Light utilization is the basis for the production of fruit. High light interception is needed for high yields and sufficient light exposure for flower-bud formation, fruit set, and characteristics of fruit quality. Light utilization is manipulated by planting density, arrangement, tree size and shape. Hence development of planar canopies such as Y-trellis improved light exposure on the sidesand overcome thehorticultural problems of the horizontal canopiesof the canopy. High yield and high fruit quality come from combining goodlight distribution in the canopy and high light interception. Hightree density combined with thin canopy depths provides high yields and high efficiency. Such training systems combining high light interception and good light distribution will result in high yields and high cropping efficiency.

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Tissue Culture Helps Doubling Farmer's Income

ANIL B. PATIL*

Cost to benefit ratio is the major factor that effects of crop profitability. Cost to benefit ratio is increasing in many crops because of low productivity occurred due to increase in land costs, farm inputs, inferior planting material, incidences of disease and pests and impact of climate change. High productivity and zero down losses is the key for higher profitability. Technological interventions in agriculture have made possible not only improve productivity of the farm but has also enhanced farmer's income reducing losses due to disease and pests. Tissue culture is one among the most successful technology introduced in Indian agriculture that has created great impact on production, productivity and quality of the produce.

Disease and pest are the major cause in declining agricultural productivity all over the world. It has created attention not only of the grower but also the plant pathologists because of the huge reduction in yield. The losses occurred due to diseases vary from 10-90% in many crops, hence there is a big scope in improving agricultural productivity by using disease free planting material. Plant diseases also increase cost of production of the crop due to more insecticide and pesticide applications. The vegetatively propagated plants are the main source of infection whether it is bacterial, fungal, and viral or other pest includes weevil, stem borer, nematode etc. Tuber, rhizome, corm, sucker, bulb etc. are generally used as the seed material in storage organ bearing plants while cutting, layering are some other methods used to propagate plants by vegetative means.

India is the world largest banana producer, contributing 19.71% to the global production with a total production of 23.20 million tones. Many pest and disease of banana reduces the productivity significantly. Losses occurred due to *Fussarium wilt*, *Erwinia* head rot, viral diseases and pests viz., Banana Bunchy Top Virus, Cucumber Mosaic Virus, Banana Bract Mosaic Virus, Banana Streak Viruses and *Weevils* and nematodes are major concern of the grower. The conventional planting material used for cultivation is presently a major source of pest and disease spread especially viruses and nematodes. Though the cultivation technologies and other environmental factors are also important in production, the quality of the planting material is the prime factor that decides the fate of the crop and its production.

Yield Losses Occurred Due to Bacterial and Fungal Disease

Bacterial and fungal disease creates severe losses in many crops. In potato, infected seed tubers are major source of disease development during the growing season and are also a source for soil infestation. Minimizing soil infestation is of major importance in countries where short crop rotation cycles are employed due to land shortage. The short rotation cycle leads to extensive use of soil fumigation and entails the risk of enhanced aggressiveness of seed borne pathogens due to a reduction of competition by other organisms eliminated by the fumigation.. Thus planting contaminated tubers in fumigated soil could cause severe outbreaks of disease. Use of disease free seed tubers can not only prevent yield losses but also improve quality of the produce.

Bacterial wilt of Potato is a destructive disease in tropical, sub-tropical and warm temperate regions of the world. It was first recorded in India from

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Pune, Maharashtra. Bacterial wilt causes premature wilting of standing crop and rotting of tubers both in fields and stores. Heavy yield losses may occur due to premature wilting before tuber setting. Up to 75% losses have been reported in some areas of Karnataka .Brown Rot Disease of potato is another serious problem in Potato. The most effective means of spread of brown rot worldwide is through distribution and planting of infected seed potatoes. The unharvested potatoes from the previous crop (groundkeeper) become the host for the organism.

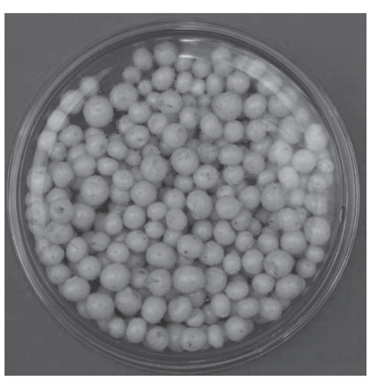
Ginger is also propagated vegetatively through underground rhizomes exclusively and farmers usually take planting material from their own product, a practice that tends to spread diseases. Heavy losses have been reported due to bacterial wilt (*Pseudomonas solanacearum*), soft rot (*Pythium aphanidermatum*) and nematodes (*Meloidogyne spp*). In India, rhizome rot and yellows caused by *Fusarium oxysporum* f.sp. *zingiberi* is a serious threat to this crop during storage and under field conditions.More than 87% transmission rate of *Fusarium oxysporum* f.sp. *zingiberi* through rhizomes in Himachal Pradesh since the disease is mainly transmitted by rhizomes propagated every year. Similarly rhizome rot in ginger not confined only to the crop in the field but also cause 80-90% loss of corms in storage. Under field condition if the plants are raised from infected rhizomes the young shoot arising from such rhizomes show damping-off. If infection occurs after emergence of shoots, the pseudostems withers and die, this results in poor stand of the crop. Anthracnose disease of Yam has a considerable impact on Yam production worldwide. Out of the world Yam production of over 30 million tons per annum, Nigeria alone produces 22 million tons . However, it has been estimated that an average of 25% of the yield is lost annually due to disease and pests.

Yield Losses Occurred Due to Viral Diseases

Commercial propagation of potato is normally done vegetatively using 'seed' tuber. Therefore, degeneration of seed stock due to viruses is common as vegetative propagation results in the continuity of several viral pathogens. The losses in potato yield due to one or more virus(s) infecting potatoes vary from low to very high. Generally severe mosaic caused by potato virus Y (PVY) and potato leaf roll virus (PLRV) alone can reduce the yield up to 70-80% while mild viruses like PVX, PVS, PVM also depress the yields by 10-30%. The extent of yield losses depend on the percentage of PLRV infected plants in the field caused 78% yield losses recorded 58.43% reduction of plant height over control due to 100% inoculums level of PLRV. It seems that yield loss as well as extent of degeneration due to PLRV infection in plants is correlated with the time of infection i.e., early infection causes severe damage. The loss in yield in the infected tubers was because of reduction in number as well as weight of the tubers.

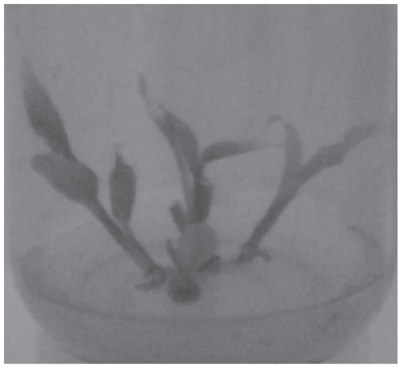
Yield Losses Occurred Due to Nematode

Nematode constitute one of the major limiting factors in many crops including banana production causing extensive root damage resulting in serious economical losses. Crop losses caused by nematodes to bananas are very high, with an average annual yield losses estimated at about 20 per cent world wide. A total of 132 species of nematodes belonging to 54 genera are reported to be associated with the rhizosphere of banana in the world. The most destructive and widely distributed nematode is the burrowing nematode, *Radopholus similis*, followed by root – lesion nematode, *Pratylenchus coffeae*.



Micropropagation of Potato

In vitro produced potato micro-tubers



Micropropagation of ginger

Micropropagation of Garlic

Applications of Tissue Culture Technology: *In vitro* propagation technology has been proved its advantages in producing disease free planting material. It requires small amount of tissues as a starting material for propagating large number of plantlets. The initial tissues are indexed for bacteria, fungus and viruses before starting the process. Apical merisatem, the undifferentiated tissue at the microscopic tip of a shoot, used for propagation, has an added advantage to produce virus-free plantlets. The apical meristem is generally virus-free even in the diseased plant, because the meristematic cells are not yet joined to the plant's vascular system and perhaps they grow faster than the viruses. The whole process of *in vitro* micro-propagation is done under controlled condition in the laboratory and subsequent to acclimatization hence minimizes the risk of infection. The *in vitro* propagation facility must be supported by pathology and virology laboratory to test the starting material. There are number of tools available to detect the micro-organism. Organism specific media are used to detect bacteria and fungus while ELISA, PCR and RT-PCR are used to detect viruses.

Yield losses due to genetic and age non-uniformity: Uniformity in age and genetic purity plays an important role in enhancing productivity in many crops. Because of non-uniform age of conventional planting material in banana the crop takes minimum 6-8 more months to harvest whole orchard and minimum 20% plant could not flower during the crops life cycle (Table 1). By inherent virtue of providing the same genotype and phenotype characteristics in growth and yield, *in vitro* propagation method has become the most preferred alternative method of multiplication of plants.*In vitro* grown plants exhibited vigorous growth as well as superior qualitative and quantitative yield at least two folds than the conventional planting material.

Flowering is staggered during 9-14 months in conventionally grown orchards against 7 months in the case of *in vitro* grown planting material. The bigger plants do not allow smaller plants to grow and will not complete its life cycle or if it flowered will produces inferior/low quality fruit in conventionally grown orchards. It takes 20-25 days for germinations and the growth rate is heterogeneous

Plant uniformity in the field

Uniform bunch

where as *in vitro* grown plantlets are already three months old hence grow almost homogenously and attain maximum growth.

Table 1: Planting material as a function of per cent flowering, period for maturity in banana

Method of propagation	No. of age groups	Period required for maturity (months)	Non-flowered plants (%)
Tissue culture	5	12	0
Suckers	17	22	20

Increased productivity: The genetic purity, age uniformity and disease free planting material produced by *in vitro* propagation technology has been proved to enhance the productivity minimum by 2 folds in banana. The fruits are of premium quality hence receiving maximum price. Comparative study (Table 2) of *in vitro* and conventionally grown orchard showed that *in vitro* grown plants gives two crops in maximum 21 months with an average yield of 60 kg per plant against one crop in conventionally grown orchard in 18 months with 15 kg fruit per plant.

Table 2: Planting material as a function of productivity in banana var. Grand nain

Method of propagation	No. of crops harvested	Period required for harvesting	Total yield obtained (kg/plant)
Tissue culture	2	18	60
Suckers	1	21	15

Reduced crop cycle: The homogenous growth of plants produced under *in vitro* conditions proved to reduce the crop cycle minimum by six months against conventionally grown planting material in banana. This helps to allow farmer to keep ratoon crop which is not practiced in conventionally grown planting material because of heterogeneous growth. The slow germination and heterogeneous growth of plants by conventionally grown planting material, the crop cycle gets prolonged.

Summary

Technological interventions in agriculture have made possible not only to improve the productivity of the farm but also enhanced farmers income. Tissue culture is one among the most successful technology introduced in Indian agriculture that has created great impact on production, productivity and quality of the produce. Banana is the most successful crop in this industry because (i) Genetic purity (ii) Age uniformity (iii) Disease free characteristics of the planting material.

Tissue culture plants are uniform in their age as against conventional planting material. Comparative study conducted with the planting material showed that around 20 % plants never flower when grown from conventional planting material i.e. rhizome against >98% flowering with tissue culture raised planting material in banana. The observations confirmed that the reason behind non-flowered plants was non-uniformity in the age. Because of the non-uniformity in the age the conventionally grown orchard takes 22 months for complete harvest of first crop against one main and one ratoon crops in 18 months with tissue culture raised plants. By this way farmer can earn double the income using tissue culture raised plants against conventional planting material. Tissue culture technology allows producing disease free planting material which is the added advantage for the farmer. Bacteria, fungi and virus are the major organism causes huge losses. Weevil, stem borer, nematode are other pest reduces the productivity. Plants that are propagated conventionally are the major source of carrying pathogens if it is initially infected. Tissue culture method proved to be the best to prevent the incidence of infection. The observations showed that the incidence of disease was 10 times more in conventionally grown orchards against tissue culture raised planting material.

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Vertical Gardens – An Option for Greening and Enhancing Income

T. JANAKIRAM

"Aside from brightening our horizons, delighting city-dwellers and chiming with the global trend for urban gardening, there are also environmental benefits for planting up"

Societies are in a need for making a conscious choice to switch to a more sustainable way of life. Design, construction, and maintenance of buildings have a tremendous impact on the environment and the natural resources. All around the world, a huge amount of buildings are being constructed with many more to be done. The challenge will be to build them smart with a minimal usage of non-renewable energy, minimal production of pollution, and minimal cost of energy dollars. Other important issues in building include increasing the comfort, health, and safety of people who live and work in them. Indeed, buildings consume many of the natural resources and are responsible for many problems. Now, in the 21st century, people are slowly beginning to realize the necessity of green architecture where new aspects and technologies started to emerge in terms of green buildings such as green walls which are considered a new prospect for the phenomenon of urban heat island and energy conservation aspects.

The living wall could also function for urban agriculture, urban gardening, or for its beauty as art. It is sometimes built indoors to help alleviate sick building syndrome. Living walls are particularly suitable for cities, as they allow good use of available vertical surface areas. They are also suitable in arid areas, as the circulating water on a vertical wall is less likely to evaporate than in horizontal gardens.

Urban Heat Island (UHI)

UHI is characterized by significantly higher air temperature in densely built environment as compared to rural temperatures. This is caused by the rapid urbanization and change of the land profile where more impervious surfaces such as asphalt, concrete and glass are found rather than grass or green area.

Causes of Urban Heat: Canyon Geometry, Building Materials, Greenhouse Effect\, Anthropogenic Heat Source, Evaporative Cooling Source, Wind Pattern

Bringing land to life and life to land is the need of the era. What we need is the transition from grey to green walls which is only possible by urban horticulture/ landscaping. It will not only support urban biodiversity but also increase carbon capture and better climate change adaptation. Vertical gardens are the urban gardening revolution that anyone with an aversion to brickwork and steel has been waiting for, promising some leafy relief from the concrete jungle.

Vertical Gardens

Vertical gardens not only look great but they are extremely good for the environment, especially when they are installed in built up urban areas. Vertical gardens are also referred as **Green wall**, **Living wall, Bio walls** more scientifically **VCW_V** (vertical vegetated complex walls).A green wall is a wall, either free-standing or part of a building that is partially or completely covered with vegetation and,

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in some cases, soil or an inorganic growing medium. The concept of the green wall dates back to 600 BC with the Hanging Gardens of Babylon. The modern green wall with integrated hydroponics was invented by Stanley Hart White at the University of Illinois Urbana-Champaign in 1931-38. White holds the first known patent for a green wall, or vertical garden, conceptualizing this new garden type as a solution to the problem of modern garden design. More recently, the larger green walls concept has been utilized with innovative hydroponics technology. The vegetation for a green façade is always attached on outside walls; with living walls this is also usually the case, although some living walls can also be green walls for interior use. For living walls there are many methods including attaching to the air return of the building to help with air filtration.

Patrick Blanc

Perhaps the world's most famous vertical garden designer is Paris-based botanist Patrick Blanc. He has been creating his stunning installations for the past 25 years and grows his gardens, which he calls "vegetal walls", on supporting structures attached to buildings so that the plants roots do not cause damage to the original walls. Although his creations can be seen in cities as diverse as São Paulo and Singapore, some of his best-loved work is on home turf. In 2001 his remarkable interior garden helped establish Paris's Pershing Hall hotel as an eminent address among the city's cognoscenti. Another notable work is the lush plant covering on the Musée du Quai Branly, in the shadow of the Eiffel Tower. Designed by the world-renowned French architect, Jean Nouvel, the exterior of this building is as much a draw as the collections housed within.

Types of Green Wall

There are two main categories of green walls: green façades and living walls. Green façades are made up of climbing plants either growing directly on a wall or, more recently, specially designed supporting structures. The plant shoot system grows up the side of the building while being rooted in the ground. With a living wall the modular panels are often made of stainless steel containers, geotextiles, irrigation systems, a growing medium and vegetation.

Benefits of green wall

i) In our hot and humid climate, the most important benefit of Green wall is that internal room temperature can be reduced by 5 to 10 degrees in summer by installing them from outside, thus reducing cooling costs considerably

ii) In growing wall system, plants are kept away from soil- borne diseases.

iii) More plants with limited space

iv) Keeping dust and noise away when installed outdoors

v) Helps in saving water

vi) Helps in hiding less attractive portions of your landscape

vii) Provides excellent air circulation for the plants

viii) Can be used as a shade

ix) Makes the environment cleaner and healthier

x) Can provide privacy and a disguise from unattractive views

Planning for the Vertical Garden

The initial work includes studies of the local climate and the future location to see what site specific factors there are to consider. This will give the limits for what plants that may be used and is important information in the following survey of nursery stock from those nurseries, foreign or local, that can deliver to the location.As the general conditions are defined, the design plan is developed in order to attain the desired character. It is during the design phase that the final selection of species is made, based on physical conditions, aesthetic preferences and availability. At the construction site, the first step is to set up the supporting structure and make necessary preparations for the irrigation. When the technical system is completed with the mounting of the felt and the integrated drip-tube - the surface is ready for plantation. During the whole process a dialogue is kept with the architect and client in order to achieve the desired result.

Construction of Green Wall

Each vertical garden is given a unique design and selection of species. The composition of plants takes in consideration the specific environment where it will be built, such as the local- and micro climate, sun exposure and the surrounding context. The aim is to create a one of a kind and site-specific garden that stands beautiful through all the seasons of the year. A well executed design is also a way to minimize the future maintenance demand of the garden. A plant's growth habit, size and behavior on a vertical surface is important knowledge for making the right combination of species, in order to keep the competition between plants at a healthy level. Choosing the right plant for the right place makes sense for any garden, but maybe even more so in a vertical garden.

Selection of plants

Selection

Apart from aesthetic preferences and the plants ability to grow on a vertical location; the selection of plants is based on several factors, for example: What is the local climate like (minimum temperature especially important to know)? How much sun exposure is each area of the surface receiving and how does it change during the year? Is there any particular micro climate- such as high buildings creating strong winds along a wall? Understanding the prevailing growing conditions is essential to make the right decision when choosing plants. Studying plants that occur in the surrounding natural areas is also a great guidance. Although wild growing species are rarely available in nurseries, it still gives a good indication of what related species or plants with similar hardiness that might be used. Along of list of plants is available which are suitable for planting on green walls, such as; *Actinidia*, *Akebiaquinata/ trifoliate, Aristochia*, *Campsis*, *Celastrus*, *Clematis*, *Cotoneaster*, *Euonymus fortune*, *Hedera*, *Heuchera, Humuluslupulus, Hydrangea petiolaris, Lonicera, Nephrolepis, Parthenocissus, Polygonum, Pyracantha, Selaginella, Wisteria, Rose, Petunia, Nasturtiums,* Daisies, Ferns and Bromeliads etc. Even some vegetables can also be planted like tomato, chillies, cucumber, peas and lettuce etc.

Supply

To find the right species and quality of plants there are different possibilities. Sometimes local nurseries can be a great source. There, plants that have been grown successfully for years in the region may be found. Vertical Garden Design collaborates with growers that can provide a great selection of anything from tropical to mediterranean plants or plants suited for colder temperate climates. Rare and hard-to-find species are ordered from specialist growers to add unique character to the garden. The combination of local nurseries, large-scale commercial nurseries and specialist nurseries offers a satisfying solution for most kind of projects.

Plants for Exterior wall

As growing conditions change widely in exterior locations, so do the plants that may be used for such a garden. With more variation in plant material it also allows for more variation of the design. For example a sun exposed surface in a mediterranean climate can be made of many typical aromatic mediterranean plants, such as *Lavandula, Thymus, Rosmarinus* or *Salvia*. On the other hand, a shadowed surface in the same climate can have an almost tropical touch with species from genera like *Begonia, Arum, Davallia, Asplenium,* and *Fuchsia*. A vertical garden can be built in virtually any location. The key is to choose the right species for the right location.

Plants for Interior Wall

Indoor climate is naturally very similar all over the world. It is characterized by a temperature of around 20-25° C, low light intensity and many times — low humidity. Many plants adapted to shady environments grow large leaves in order to assimilate the small amount of light that reaches them. Also they have quite modest flowering, although there are exceptions that can make a great contribution to an interior garden. Typical genera used for interior gardens are aroids like *Philodendron* and *Epipremnum*or gesneriads such as *Aeschynanthus*, *Columnea*and *Saintpaulia*, many species of *Peperomia* and *Begonia* or different ferns like *Nephrolepis* and *Pteris*.

Supporting Structure

The supporting structure consists of a 10 mm PVC-board mounted on a stud work. The solid PVC-board is sealed at joints, and an air gap between the board and the wall behind assure a double protection against moisture. On top of the board, a multi-layered, synthetic and highly absorbent felt surface is attached. It gives an even distribution of water over the surface and provides mechanical support for the plants as they grow attached to the felt. A cut is made in the outer felt layer and the plants inserted in between. As a soilless surface, the construction is very light – less than 25 kg/m^2. Including plants, but depending of what species that are used, the average surface depth is increased with 200-500 mm.

Planting on a Vertical Plane

It stands to reason that you focus more on things that are not down low but right in front of your eyes. When you plant flowers on the ground they get noticed some but not as much as flowers that are higher, like on a stair stepped slope. Flowers and plants at eye level get admired more than the ones planted in the ground. Hanging baskets have been the most common way of bringing flowers into eye level vision. They're pretty but they dry out quickly, are awkward to water and usually need frequent watering. Vertical gardening is an innovative way of bringing flowers and plants into the forefront of your consciousness. When that happens, your mood is lifted, stress is relieved. When neatly manicured, thriving, lush vegetation is in your space, it increases positive energy around you.

Vertical gardening and living walls are igniting the imagination of designers everywhere. What's not to like about splashes of greenery and other colors that generate a calming and peaceful environ. There are a variety of ways to plant flowers, herbs and vegetables on a vertical plane. Also a variety of benefits, but we're focusing here on beauty. Flower towers are a great way to get your gorgeous blooms noticed and send shock waves of admiration through all who view them. Vertical gardening can really dial up the drama and evoke feelings of awe and serenity. Flower Towers, Polanters, and Vertigardens (which all originate from England), are a few of the inexpensive ways to plant up some gorgeousness, plus they have an effective watering system that keeps you dry and the flower's roots wet.

Irrigation

The irrigation system is designed to minimize water consumption. It consists of an automation-unit with equipment for control of nutrient injection and irrigation cycles. When a surface has a variation of sun exposures, the irrigation is divided into segments in order to program it specifically for each part. Within the multi-layered felt surface a drip-tube is integrated. Water consumption varies with heat and sun exposure, but compared to normal green spaces or a lawn, the consumption is normally lower. It averages between 2-5 l/m^2/day.

Light

Direct sunlight can deliver over 100 lux whereas the average light level in an office is around 300-500 lux. Even if the least light demanding species are used, artificial light is normally necessary indoor. A few species will stay fine at 900 lux, but a slightly increased level at some parts of the surface will broaden the variation of species that can be used. An artificially illuminated surface has shifting light levels, due to the fact that light reduces with the square of the distance from the light source. The plant design is made with this in mind, taking advantage of the higher levels for more demanding and interesting species.

Not only is artificial light necessary for the plants survival and growth, but it also makes the garden more beautiful as it brings out colors and textures of flowers and leaves. A suitable light source is the metal halide. It produces the essential wave-lengths that plants need and is an energy-saving and cost-efficient alternative. Through an initial computer simulation, a study is made to calculate the required number and model of armatures. Finally, the levels are measured on location to fine-tune the setup.

Maintenance

As the supply of the basic needs of plants (light, water and nutrients) are automated, not only does this make for unusually healthy plants - it highly reduces maintenance demand and makes the vertical garden possible to use on high buildings or other places where accessibility is limited.

The garden is designed so that the plants´ natural growth habit is given space, and for different species to have a dynamic co-habitat with adjacent species. During a year, the garden will profit from pruning approximately 1-2 times per year. All plants that are used are perennial, but as the years go by, a few will have to be replaced. These maintenance measures will ensure a long term lush and attractive garden.

As ornamental objects, not only can the beauty of plants be fascinating, but also the fact that they are alive and always changing. Much work is put into the aesthetic result of the gardens, and part of that is to develop this attracting sensation of life and unpredictability that plants bring within them. For the overall design a lot of inspiration is taken from natural shapes and environments where these type of plants have their origin, and in the smaller scale each species is given a context where it can develop it's characteristics. All together creating an unique garden with much content, surprise and variation.

A vertical garden can be installed in almost any location and as a living material; the potential of integrating plants in our urban environments is interesting. Places never thought of as possible could be inhabited by plants, like subway stations or other intensely frequented places where horizontal space is difficult to spare.

Extending the plants or greenery onto the building façade has shown potential in improving air quality and reducing surface temperature in the built environment. Plants certainly help to promote thermal comfort as they cools down the building façade and cools down the surrounding by transpiration. The breathing wall with vegetated façade tends to focus to develop the building as an ecologically complex and stable plant, microbial and human community, that helps to improve the air quality in an interface between natural processes and the built's structure environmental system. The whole system works for the social, ecological and environmental benefits. If this system multiplies and implemented to all the skyscrapers in an urban area the beneficiary will be all the species including the humans. The results will be the noticeable decrease in urban heat island, rapid reduction of energy consumption and refreshing air for a healthy environment. The concept also provides opportunities for establishment of several allied activities like materials, media, irrigation equipment, nurseries etc which can provide employment opportunities and livelihood besides enhancing income.

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Quality Seed Production in Ginger and Turmeric: Present Status and Future Prospects

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Spices from India have carved a unique identity in commodity trade across the globe. Though India's role and relevance as the spice basket of the world has been subjected to challenges from new areas of spice cultivation, it still retains a place of prominence in global spice trade. India is the single largest producer and consumer of spices in the world accounting for more than 40 per cent of the global spice trade. The spice economy has played a decisive role in shaping economic destiny of stakeholders across the spice value chains. India exported 8.43 lakh tonnes of spices worth 162382 million INR during 2015-16 with a share of more than 10 per cent in the total agricultural exports from the country. The area and production under spices have shown robust growth during the last two decades. Since the turn of the millennium, the area and output of spices has increased by 33 and 102 per cent respectively. With more than 80 per cent of the primary spice cultivators operating small holdings, the growth of this sector is critical for equitable and inclusive growth of the agricultural sector. Apart from the foreign exchange potential of spices through export earnings, the latent potential for value addition, potential for employment generation and its role as an integral component in enhancing value of output per unit area makes spices an important component of the agricultural economy of the country.

Ginger and turmeric belonging to the family Zingiberaceae, are two annual spice crops contributing to the national economy of India. Ginger (*Zingiber officinale* Rosc.) is one of the oldest known spices, esteemed for its aroma, pungency and medicinal properties. It is a tropical spice crop adapted for cultivation even in regions of subtropical climate. Being a shade loving crop with shallow root system, it is suitable for intercropping in coconut and arecanut gardens and in homesteads. Ginger is grown mainly as a rainfed crop in Kerala. In North Central India, it is grown as an irrigated crop. India is the largest producer of ginger. The crop occupies the largest area in Karnataka, followed by Assam, Odhisa, West Bengal, Madhya Pradesh, Meghalaya, Mizoram and Nagaland (DASD, 2016).

Turmeric (*Curcuma longa* L.) is an ancient and sacred spice of India. The crop can be grown in diverse tropical condition from mean sea level to 1500m above MSL and is adapted to different soil types. India is the world's largest producer of turmeric. It is a major annual spice, grown as a rainfed crop in Kerala adapted to the coconut based cropping system. The crop occupies major share of area in Telengana, Tamil Nadu, Andhra Pradesh, Karnataka and West Bengal (DASD, 2016).

Over the years, India's share in world spices market has not appreciated much and its monopoly as a supplier of spices is threatened by countries like China, Brazil, Vietnam, Pakistan, Egypt, Turkey and other African and Caribbean countries. India also faces shortage of exportable surplus because of increasing domestic demand. Sharp fluctuations in the quantum and value of exports and in the unit value realization have characterized the spices trade in recent years.

Forecasted production level (Table 1) highlights the targeted task to be achieved for major spice

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crops. These estimates were made taking into account the present level of production, export, import, per capita consumption, expected level of increase in export and population growth etc. There is an urgent need to take stock of the present level of production and export and prospects of increasing the production with available technologies to meet the future demand.

Table 1. Estimated production target for spices in India (Qty. = tons)

Year/Spices	All Spices	Ginger[1]	Turmeric[2]
2011-12	4268221	500558	776905
2016-17	4810895	640934	897816
2021-22	5416858	819999	1037830
2026-27	6103366	1051128	1200210

Note: 1-With 60% import reduction; 2-With 80% import reduction;

Another factor that needs to be considered is that in spices like black pepper majority of the vines in households supply the requirement for the family and only the surplus reach the market. Besides, the consumption of spices within the country has raised due the changing food pattern and other alternate uses showing increased trend in per capita consumption of spices. The Fig 1 depicts the projections on the requirement of major spices and the targeted productivity levels for attaining the projected productions. For meeting the total demand, the productivity should be increased to 0.49, 1.45, 9.4 and 6.9 t/ha in black pepper, cardamom, ginger and turmeric, respectively by 2020 (Parthasarathy *et al*., 2007; 2011).

Seed rhizome requirement

Presently ginger is cultivated in an area of 1.41 lakh ha with a production of 7.60 lakh tonnes. Planting material required to cover this area is 2.32 lakh tonnes @ 2 t ha^{-1} seed rate. Area expansion may be a little scope. If we take nominal rate 2% expansion, the seed material required for the year 2025 is 3.1 lakh tonnes. Similarly, present turmeric area is 1.84 lakh ha with a production of 8.30 lakh tonnes. It is estimated that seed requirement at present is 3.3 lakh tonnes and for the year 2025 it is 4.4 lakh tonnes by considering 2 t ha^{-1} seed rate and assuming 2% area expansion. There Central Sector Schemes like NHM, Mini-Missions and ICAR Schemes like Seed Project are adequately support the planting material production. Seed village can be established by participatory seed production of these crops to meet the quality planting material.

Table 2. State wise planting material requirement at present and at year 2025

States	Ginger		Turmeric	
	Present	2025*	Present	2025*
Andaman & Nicobar	738	993	92	124
Andhra Pradesh	4144	5577	124044	166947
Arunachal Pradesh	9556	12861	1000	1346
Assam	36196	48715	23748	31962
Bihar	1020	1373	6095	8203
Chhattisgarh	3043	4096	1500	2018
Gujarat	4280	5760	2203	2965
Himachal Pradesh	3462	4660	839	1129
Jammu & Kashmir	54	72	8	11
Karnataka	31780	42771	17836	24005
Kerala	20332	27364	6436	8662
Madhya Pradesh	10908	14681	1288	1733
Maharashtra	2396	3225	13535	18217
Manipur	4612	6207	692	931
Meghalaya	18120	24387	3400	4576
Mizoram	8331	11213	1328	1788
Nagaland	2410	3243	786	1058
Orissa	31168	41948	47888	64451
Rajasthan	260	350	212	285
Sikkim	12520	16850	1048	1410
Tamil Nadu	1088	1464	44640	60080
Tripura	2532	3408	2468	3322
Uttar Pradesh	1580	2126	2552	3435
Uttaranchal	3512	4727	1184	1594
West Bengal	18172	24457	24900	33512
Total	232213	312528	329722	443763

*Planting material requirement estimated for the present area at seed rate of 2 t ha^{-1} and projection is by assuming 2.0% area expansion every year.

Conventional Methods of Seed Production

Ginger and turmeric is cultivated both under rainfed in high rainfall areas and under irrigation at low rainfall situation. There are different production systems followed in India that depends on soil type, slope, rainfall and management. Ridges and furrows, beds and channels, raised beds are some of the methods adopted for raising the crop. Seed rate varies between 1.0 to 3.0 t ha^{-1}. Seed size also vary from mini-sett or micro rhizome of less than 5 g to 150 g. But an ideal size would be 25 to 50g. Depth of planting is also varying and it is better to plant at 5cm depth. Being rhizomatous crops, earthing up (hilling) is very much essential for better development of rhizome. Normally two or three earthing up is done and it may coincide with weeding and fertilizer application. Mulching is yet another important operation practiced under rainfed production system. Mixed green leaf mulch @ 20 to 30 tonnes per ha found to give better yield. FYM is also applied as a mulch. Traditionally weeding is done by manually Each state in India has their own set of recommended packages to suit the local conditions. Crops are annual nature and inter or mixed cropping is an integral part of the production. Ginger and turmeric grown under shade of fruit and and plantation crops. Around 25% shade is ideal. High shade would reduce the yield. Mechanization is possible in leveled land. Drip and sprinkler system or fertigation techniques can be employed for enhancing yield and saving resources.

Rhizomes are seed material have to be stored during off-season for about 90 to 120 days between harvest and subsequent planting. Seed storage is very essential to maintain good seed health. The seed rhizomes should be stored appropriately so that rotting; shriveling, dehydration and sprouting are avoided until the next season. Farmers adopt different methods for storage. Storage losses can often be as high as 10-50 per cent. Recovery of seed rhizomes at planting was as high as 96 per cent by selecting fully matured rhizomes for storage, dipping in a solution of quinalphos 0.05% and Dithane M45 0.3% for 30 min and drying under shade and storing in pits (wherever bacterial wilt is a problem in ginger, the seeds should be treated with streptocycline 200 ppm).

Maintaining a storage temperature of 22-25^{o}C make the growing buds fat and strong and temperature higher than 28^{o}C in the long run make the buds thin and weak. If the storage humidity is too low, rhizome epidermis may also loose water and wrinkle and the sprouting speed and bud quality may be affected. Pre-storage steeping of rhizomes in *Trichoderma hamatum* or *T. viride* also showed inhibition against *Fusarium equiseti* infection. Treated rhizomes are placed in pits leaving 10-15 cm space on the top, covered with wooden plank to have space for aeration and plastered with cow dung. Covering the seed material with a layer of *Glycosmix pentaphylla* leaves is also beneficial. Zero energy cool chamber (ZECC), is found ideal for storing fresh ginger. The loss in weight of rhizomes was only 23% after storing for four months in this chamber, while the ginger stored in open conditions was shrunken in four months. The stored rhizomes are examined monthly intervals and rotten rhizomes removed to keep pathogen free.

Pest and diseases – Diagnostics

A number of insect and nematode pests have been recorded on ginger and turmeric. Among them shoot borer, rhizome scale and white grubs on ginger and turmeric are serious insect pests. The major nematode species include root knot nematode, burrowing nematode, lesion nematode and reniform nematode on ginger and turmeric. Excessive and indiscriminate use of pesticides for the management of these pests could result in pesticide residues in the produce affecting human health and also causing other ecological hazards. There has been a renewed interest in developing environment–friendly crop management schedules in these crops.

Being propagated through rhizomes, they are naturally susceptible to several devastating soil borne plant pathogens. Predominant among are the various kind of rot diseases caused by Oomycetes pathogens such as *Phytophthora,* and *Pythium*. Foliar diseases caused by broad host range fungal pathogens such as *Colletotrichum* and *Phyllosticta* are reported to cause yield reduction in these crops. Other globally significant diseases of economic important are bacterial wilt in ginger and leaf blotch in turmeric. Sporadic occurrence of diseases caused by Rhizoctonia/Fusarium/ is reported in ginger and turmeric. The pathogen that is rhizome borne in nature plays an important role in the transmission of the pathogen across the growing region. Among them, *Ralstonia solanacearum* assumes significance as the pathogen is reported to latently infect ginger rhizomes and the apparently healthy rhizome are responsible for the spread of the disease.

Transplanting

To overcome the disadvantages of conventional planting system of seed rhizomes and to produce good quality planting material with reduced cost, rapid multiplication of ginger and turmeric through single bud rhizome technology has been standardized at ICAR-Indian Institute of Spices Research, Kozhikode, Kerala and Horticulture College and Research Institute, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu.

*Ginger:*Though transplanting in ginger is not conventional, it is found profitable. A transplanting technique in ginger by using single bud sprouts (about 5 g) has been standardized to produce good quality planting material with reduced cost. The yield level of ginger transplants is on-par with conventional planting system. The technique involves raising transplants from single sprout seed rhizomes in the pro-tray and planted in the field after 30-40 days. The advantages of this technology are production of healthy planting materials and reduction in seed rhizome quantity and eventually reduced cost on seeds (Prasath *et al*., 2014).

Technology

- Select healthy ginger rhizomes for seed purpose
- Treat the selected rhizomes with mancozeb (0.3%) and quinalphos (0.075%) for 30 min and store in well ventilated place
- One month before planting, the seed rhizomes are cut into single buds with small piece of rhizomes weighing 4-6 g.
- Treat the single bud sprouts (mancozeb 0.3%) for 30 min before planting
- Fill the pro-trays (98 well) with nursery medium containing partially decomposed coir pith and vermicompost (75:25), enriched with PGPR/*Trichoderma* 10g/kg of mixture
- Plant the ginger bud sprouts in pro-trays
- Maintain the pro-trays under shade net house
- Adopt need based irrigation with rose cane or by using suitable sprinklers
- Seedlings will be ready within 30-40 days for transplanting

Turmeric

Single bud rhizome of turmeric has been used as planting material as an cost effective technology of turmeric planting. In this method, single bud rhizome is utilized to produce transplant in protray. This one month old transplant is used as planting material for turmeric cultivation (Shylaja *et al*. 2016).

Advantages in single bud rhizome method of planting

- Less requirement of planting material – 0.750 tonnes per ha.
- Reduces cost of production (less quantity of seed rhizome)
- Crop establishment is good (98-100 per cent)
- Early rhizome development (starts from three months after planting)
- Production of quality planting material
- The transplants may be planted in raised beds as well as ridges and furrows

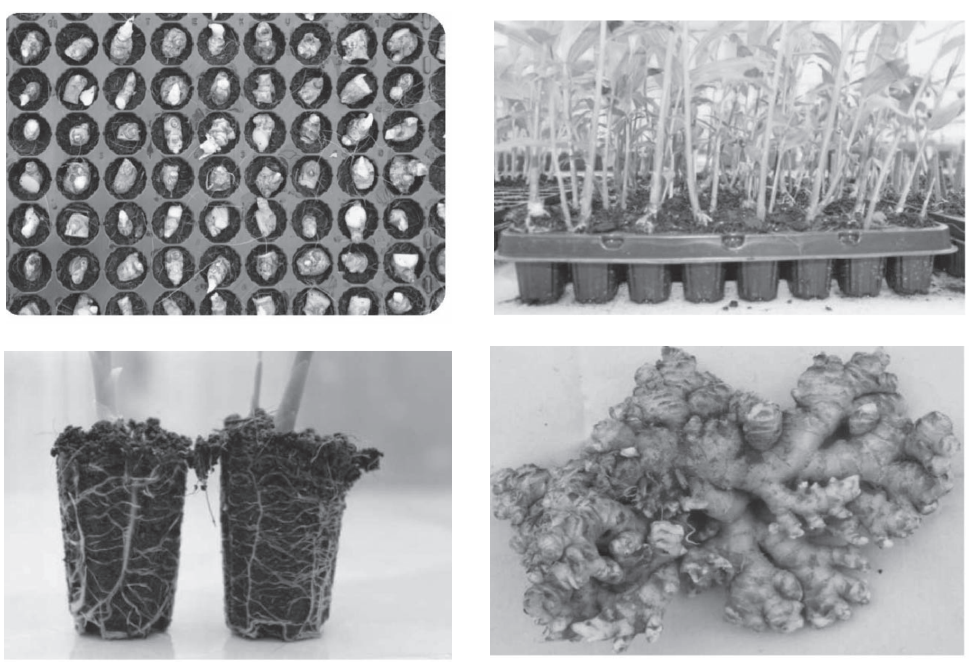

Fig. 1: Transplanting technology in ginger

- Extended period of planting is possible.
- The yield of fresh rhizome may be increased upto 25% compared to average yield.

Based on the advantages of single bud rhizome, it can be selected as planting material in turmeric cultivation. This technique can be explained as below.

Rapid multiplication of turmeric using single bud rhizome

Curing of seed rhizomes (1 – 1½ months after harvest)

↓

Seed rhizome treatment (Carbendazim @ 2 g/l + Quinolphos @ 2 ml/l)

↓

Rhizomes are cut into small pieces with single bud (5 to 7 grams)

↓

Curing of single bud rhizome pieces on palm mat (one inch)

↓

Covering the single bud rhizome with cocopeat (0.5% humic acid treated)

↓

Sprinkling of water on bed (four days)

↓

Sowing of sprouted single bud rhizome in protray (Cocopeat (100g) + *Pseudomonasfluorescens* (5g))

↓

Covering the protrays with polythene sheet (seven days)

↓

Observation of sprouting of buds

↓

Regular watering of protrays kept under 50% shade

↓

After emergence of a leaf, spraying of humic acid (0.5 %)

↓

Seedlings are ready for transplanting (30 - 35 days)

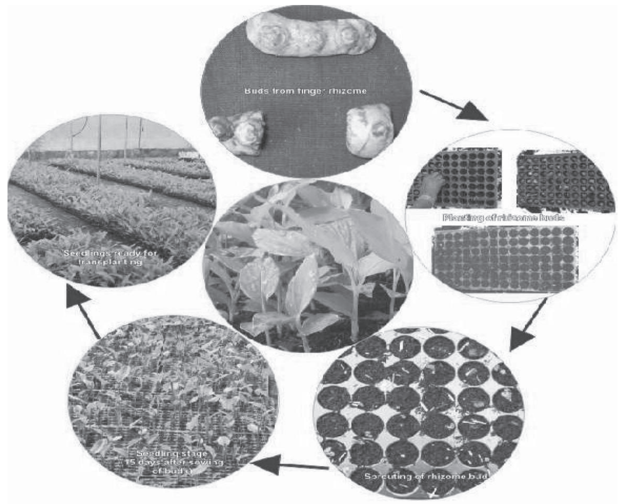

Fig. 2: Rapid multiplication of turmeric using single bud rhizome

Advanced methods of seed production

Hydroponics

The soil-borne disease and nematode problems are high in ginger production. Aeroponic cultivation of ginger can provide high-quality rhizomes that are free from pesticides and nematodes and produced in mild-winter greenhouses. The hydroponic system produced more yield and better quality rhizomes.

Hydroponics can be an alternative horticultural system for crops susceptible to soil-borne diseases. The uniform growing environment in a controlled greenhouse may produce crops with more consistent levels of secondary metabolites, which is of concern to the phytopharmaceutical industry. Unfortunately, there are few hydroponic or aeroponic production systems suitable for rhizome crops. Most hydroponic systems are designed for crops that produce fruit or leaf products and have fibrous root systems and a predictable crown size at the soil line. Rhizome-producing crops have special requirements, in that the horizontal growth habit of the rhizome needs room to expand and produce vertical shoots and secondary roots as needed, uninhibited by physical barriers.

Most commercial hydroponic systems utilize an aggregate growing medium, such as perlite or rockwool, contained in a plastic wrap or bag and are drip irrigated with a fertilizer solution. These systems provide sufficient aeration for the roots while physically supporting the plants. Non-aggregate systems, such as Nutrient Film Technique

(NFT), Deep Flow or Ebb-Flood systems, are also popular commercially, but tend to minimize root growth and are dependent on a rigid plastic structure to support the plant at the crown. Aeroponics is another type of non-aggregate hydroponics, where the roots of the plants are suspended in an enclosed chamber and sprayed periodically with a fertilizer solution by means of a timer and pumps. Aeroponics offers several advantages over other hydroponic systems, particularly for root crops. The roots are easily accessible for monitoring, sampling, and harvesting. Without the buffering capacity of a solid or aggregate growing medium, the air/liquid medium of aeroponics permits precise control of the nutrient solution mineral composition and temperature. Finally, the common use of A-frame growing structures in aeroponics permits twice the growing area surface in the same size greenhouse, potentially doubling the economic yield for a grower. However, all aeroponic systems previously described in the literature require a rigid structure at the crown of the plant to support the plants while their roots are suspended in the fertilizer spray. This rigid support would restrict the horizontal growth habit of the rhizome. A new aeroponic system was needed to accommodate the horizontal nature and growth habit of a rhizomatous crop.

Preliminary observations in South Florida showed that costs of production were lower under hydroponic system due to reduced maintance associated with diseases, insect and weed control. Hayden *et al*., (2004) in Arizona also tried soil less aeroponic cultivation of ginger to get high-quality rhizomes that are free from pesticides and nematodes in mild-winter greenhouses. The unique aeroponic growing units incorporated a "rhizome compartment" separated and elevated above an aeroponic spray chamber. Plants received bottom heat on perlite medium has showed accelerated growth and faster maturity. A noncirculating hydroponic Method was used at Hawaii to produce diseases free ginger seed production (Hepperly *et al*., 2003).

Advantages of greenhouse production

- A "clean start" is ensured by using clean seed rhizomes planted in a wilt-free greenhouse using a wiltfree commercial growing medium.
- Seed-pieces are of high quality because the rhizomes are selected from second-generation plants of tissue- culture origin, which allows for elimination of the offtype rhizomes that may be produced from first-generation tissue-cultured plants.
- Control over growing conditions is assured when the growing area is secured and protected from weather throughout the growing season, reducing the potential for accidental introduction of the disease.
- Production is "unitized," in that each grow-bag is a production unit, allowing for quick removal from the area of a plant suspected of being contaminated.
- Materials and supplies are readily available.
- Wilt-free seed-pieces can be regenerated year after year.
- The facility and production system can be cleaned and disinfected for each growing season, eliminating the need to search for and prepare new land yearly.
- The value of investment in a greenhouse and benches can be depreciated through years of operation, and the yearly costs for heavy equipment for field preparation are eliminated.
- Grow-bags are topped with light-weight medium as the plants grow to simulate the hilling cultivation done in the field, eliminating the potential for root injury as an entry point for the disease.
- Use of light-weight planting medium provides for easy hilling, harvest, and cleaning; the medium is also readily removed and washed off, which is laboursaving and results in an excellent, clean appearance of the marketable rhizomes.
- High yields
- The product is of high quality and free of bacterial wilt disease

The disadvantages of this systemare (i) initial capital investment can be high for greenhouse or shelter structures, plastic composite benches, an irrigation system, pots, and clean potting medium; (ii) A reliable source of clean water is needed, preferably a piped-in "county" water source, (iii) The availability of wilt-free starters is currently limited, and (iv) Strict sanitation practices are needed to maintain greenhouse sanitation to prevent introduction of diseases.

Tissue culture

The cell and tissue culture techniques have immense advantage in this vegetatively propagated crop, mainly since the conventional breeding programs are hampered due to poor flowering, lack of fertility and natural seed set. It is propagated vegetatively through rhizome. The germplasm collections in clonal repositories are also seriously affected by fungal diseases. Moreover since pathogenic fungi, bacteria or viruses are readily transmitted through traditional practices, it was deemed important to develop *in vitro* propagation techniques and to make available for commercial use the pathogen free germplasm. Protocols for micropropagation, callusing, plantlet regeneration, meristem cultureandmicrorhizome induction are optimized. The main advantage of *in vitro* methods are that it helps in isolating disease free plants from elite varieties and also helps in inducing variability leading to high yielding, high quality and disease resistant lines.

Microrhizomes

The low efficiency of vegetative propagation, susceptibility of rhizomes used for vegetative propagation to diseases and degeneration of rhizomes on long term storage coupled with poor flowering and seed set has affected ginger cultivation and breeding. These can all be easily overcome through the microrhizome technology. Microrhizomes resemble the normal rhizomes in all respect, except for their small size. The microrhizomes consist of 2 to 4 nodes and 1 to 6 buds. They also have the aromatic flavour of ginger and they resemble the normal rhizome in anatomical features in the presence of well-developed oil cells, fibres, and starch grains were observed. The microrhizome derived plants have more tillers but the plant height is smaller. *In vitro* formed rhizomes are genetically more stable compared to micropropagated plants. Seed rhizome weight was 2-8 g as against 20-30 g in case of conventionally propagated plants. Microrhizome gave very high recovery thogh lesser yield per bed. Microrhizome also was genetically stable. This coupled with its disease free nature will make microrhizomes an ideal source of planting material suitable for germplasm exchange, transportation and conservation (Nirmal Babu *et al.,* 2005). It is paradoxical that inspite of the best protocols available, the use of microrhizomes as a commercial method of seed production has not been reported. The perfected technique needs undergo commercialization to reduce cost of production.

Seed village

Quality seed rhizomes are the key input for realizing potential productivity in ginger and turmeric. There is vast scope to produce and distribute quality seed rhizomess in these corps for which seed village concept is a noval and highly practical approach and needs to be promoted to facilitate production and timely distribution of quality seeds of desired varieties at village level. In this context, the concept of seed village which advocates village self-sufficiency in production and distribution of quality seeds is getting momentum.

Concept

- Organizing seed production in cluster (or) compact area
- Replacing existing local varieties with new high yielding varieties.
- Increasing the seed production
- To meet the local demand, timely supply and reasonable cost
- Self sufficiency and self reliance of the village
- Increasing the seed replacement rate

Features

- Seed is available at the door steps of farmers at an appropriate time
- Seed availability at affordable cost even lesser than market price
- Increased confidence among the farmers about the quality because of known source of production
- Producer and consumer are mutually benefited
- Facilitates fast spread of new cultivars of different kinds

Conclusion

The productivity of ginger and turmeric is around 20-40 t/ha which depends on several factors predominantly the cultivar in use, prevailing biotic and abiotic stress, and geographical location. However, much higher productivity has been realized in a few countries and can be achieved world wide. Conventional propagation methods of rhizomes being slow due to a dormancy period, a rapid method of multiplication is needed especially for newly developed high yielding varieties, which are available in small quantities. Production of pathogen free seed rhizome by microrhizome technology can be capitalized to ensure healthy crop. These sporadic research attempts on hydrophonics and green house disease free seed production systems need to be consolidated and focused to produce healthy seeds of ginger and turmeric. The conventional seed rhizome production system can be strengthened further through seed village concept for quality seed production.

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Strategies Approaches for Water Conservation and Management for Doubling Farmers' Income

R.C. SRIVASTAVA

Eastern Region is bestowed with huge natural resources but poorest among all regions. It can be termed "*Resource Rich Region with Resource Poor people"*. In Bihar 68% population derives its livelihood from agriculture but contribute just 22% of SGDP. Bihar agriculture can be termed as *"Low investment high risk low productive low profit enterprise"***,** as it suffers from frequent drought / flood. As per one study of IFPRI study, a low intensity drought reduces farmers' income by 9%, medium by 25% and severe by 60% and throws a significant percentage of farmers in transient poverty. Thus drought proofing by proper management of water resources is essential for doubling farmers' income. However the landholding pattern is worrisome from doubling income point of view. About 94% farmers small and marginal, while 60% farmers hold less than 1ha land and 38% farmers hold less than 0.5 ha land. The low level of mechanization and local level processing increases the cost of production and reduces price realization. Further only 60% area is irrigated and majority of irrigation comes from ground water with almost 100% diesel engine powered extraction. This extraction is done through use of inefficient centrifugal pumpswith efficiency around 30-40%.

The income of any enterprise can be increased by three routes: (i) Increasing price of end products through government intervention, i.e. Minimum Support Price. Although easiest to adopt and implement but this option is fraught with consequences for overall economy as it will be inflationary. Further poor penetration of Public Procurement System will make it ineffective. In addition it is not applicable to many crops; (ii) Reducing cost of inputs. The foremost is proper mechanization which will reduce cost of labor whose share in cost of cultivation is presently 34% for wheat, 33% for maize, and 44% for rice. Another component can be reducing cost of irrigation by electrification of extraction system either by solar or traditional source of electricity. Further the cost of fertilizer can be reduced by optimizing application and local level manufacturing ofbio fertilizers. (iii) Increasing the system efficiency of enterprise by enhancing productivity, reducing post harvest losses and value addition at village level. Thus best route is to adopt 2nd and 3rd options. Proper management of water will play an important role in both of these options either by reducing the cost of irrigation in existing irrigated areas and/or increasing productivity of hitherto rainfed areas by providing irrigation.

The major issued faced by farmers who have irrigation is high cost of irrigation as most of the ground water is extracted by diesel pumps. Due to diesel engine being prime mover, the pumps are inefficient centrifugal pumps. In case of water level going below 8 m , the farmers to dig well to lower the pumps. During rains, the pit gets flooded and pump has to be removed. This increases the cost of irrigation significantly. This high cost of irrigation forces farmers to reduce quantity of water in one irrigation as well as number of irrigations leading to loss of productivity. This problem is further compounded with poor design of irrigation methods. Very little work on design of method of irrigation as well as adoption of suitable design for surface irrigation has been undertaken in whole country in

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general and Bihar in particular. Further there is miniscule penetration of pressurized irrigation which is also limited only to horticultural crops.

The problem of excess water will also have to be handled which has received scant attention. Productivity of sugarcane as well as sugar recovery is poor due to waterlogging during monsoon but no research effort on drainage. The problem needs to be quantified and suitable measures have to be developed to suit the region. Further no concerted effort for management of municipal waste water which is drained to rivers without treatment polluting the life line of region.

A Road map for Sustainable Water Resource Development of Bihar should contain following:

- Electrification of Pumping system for whole state
- Use of Solar energy for pumping especially solar tree
- Out of box solution for use of solar powered pumping systems for Diara, Dhab, and Tal areas
- Emphasis on 10 ha block basis pumping system with underground pipeline and flexible pipe for higher conveyance efficiency
- Laser levelling for rice fields
- Subsidy pattern to be changed from one time to payment of EMI basis- will deter fly by night operator
- Increase exploitation of GW alongwith recharge system

To meet the requirement of this roadmap, Dr RPCAU Pusa has initiated few steps. This include (i) Design of block system for efficient use of ground water; (ii) Evaluation of solar tree for solar powered pumping system; (iii) Development of Floating Boat based Solar powered Pumping System for Diara, Dhab and riverine areas (iv) Development of Mobile Tractor Trailer based Solar Powered Pumping System for Tal areas (v) Development of water filter for water supply in flooded areas. In addition, university is also working on following concepts: (i) Automation of surface irrigation methods; (ii) Drip irrigated maize with micro sprinkler irrigated pulse as inter crop; (iii) Design of efficient surface irrigation methods with special reference to maize and sugarcane; (iv) design of efficient filter for ground water recharge; and (v) Drainage for sugarcane.

It is expected that these measures in field of water management will significantly reduce the cost of cultivation and increase productivity which will lead to doubling the farmers' income. However this will require concerted efforts on research as well as extension of technology to farmers.

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Strategies for Better Water Utilization in Agriculture - A Step Towards Doubling Farmers' Income

T.B.S. RAJPUT* AND NEELAM PATEL

Water is prime requirement for all aspects of life. It is imperative to make certain that adequate supply of water of good quality is maintained for all the needs of entire population, while preserving the hydrological and biological functions of ecosystems. Innovative technologies, including the improvements in the indigenous technologies, are needed to fully utilize limited water resources and to safeguard these resources against pollution.Water is essential for sustaining all forms of life, food production, economic development, and for general well being. The income of farmers in general and from farmng in particular is directly related on the water availability and its use at the farm level. It is impossible to substitute for most of its uses, difficult to de-pollute, expensive to transport, and it is truly a unique gift to mankind from nature. Water is also one of the most manageable of the natural resources as it is capable of diversion, transport, storage, and recycling. Technologies are available for location specific, crop specific, topography specific, and water availability wise efficient use of water. The objective today needs to revolve around optimal utilization of critical resources of land and water for generating sustainably high incomes from farming. Water poses a challenge as well as an opportunity to enhance farmers' income if used efficiently.

The surface water and groundwater resources of the country play a major role in agriculture, hydropower generation, livestock production, industrial activities, forestry, fisheries, navigation, recreational activities, etc. According to National Water Policy (MoWR, 2002) in the planning and operation of systems, water allocation priorities should be broadly as: (i) drinking water, (ii) irrigation, (iii) hydropower, (iv) ecology, (v) agro-industries and non-agricultural industries, and (vi) navigation.

Many land and water problems of significant importance now confront our irrigated agriculture. Large quantities of water pumped from groundwater or diverted from streams are lost by seepage and evaporation from tanks, canals, distributaries and field channels. Improperly designed field irrigation systems and uncontrolled water application methods are resulting into huge losses of water through seepage and deep percolation. In many cases not only the loss of water is concerned but also the damage it creates by way of water logging and accumulation of harmful salts.Sustainable use and management of water resources and effective conservation practices are the issues of prime importance to be looked upon for enhancing farmers income and for sustainable development of the country.

Water Resources of India

Although India occupies only 3.29 million sq. km geographical area, which forms 2.4% of the world's land area, it supports over 15% of the world's population. India supports about 1/6th of world population, 1/50th of world's land and 1/25th of world's water resources (The Institution of Engineers (India), 2003).

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The country gets about 400 million hectare-metres (mha-m) of precipitation annually, which is augmented by 20 mha-m contributed by rivers flowing in from the neighboring countries. Net evapo-transpiration losses are nearly 200 mha-m. About 135 mha-m is available on the surface and the remaining recharges groundwater. Water is a critical input for sustainability of agriculture, which consumes more than 80 per cent of available water resource. With increasing demand from other sectors, availability of water to agriculture is going to decline. This calls for efficient utilization of water to safe guard the livelihood security of over 600-million people dependent on agriculture. Although, India has the largest irrigation system in the world its water use efficiency has not been more than 40 per cent. If it continues, water crisis would lead to reduced production and productivity, which would reduce farmers' income and affect the quality of life of the people.

Apart from the water available in the various rivers of the country, the groundwater is also an important source of water for drinking, irrigation, industrial uses, etc. It accounts for about 80% of domestic water requirement and more than 45% of the total irrigation in the country. As per the international norms, if per-capita water availability is less than 1700 cubic metre per year then the country is categorized as water stressed and if it is less than 1000 cubic metre per capita per year then the country is classified as water scarce. In India per capita surface water availability in the years 1991 and 2001 were 2309 and 1902 cubic metre and these are projected to reduce to 1401 and 1191 cubic metre by the years 2025 and 2050, respectively. Hence, there is a need for proper planning, development and management of the greatest assets of the country, viz. water and land resources for raising the standards of living of the millions of people, particularly in the rural areas.

Water Requirement of Different Sectors

The irrigated area in the country was only 22.6 million hectare (Mha) in 1950–51. Since the food production was much below the requirement of the country, due attention was paid for expansion of

Table 1: Annual water requirement for different uses (in cubic km)

(MoWR, 1999)

Use	Year1997-98	Year 2010			Year 2025			Year 2050		
		Low	High	%	Low	High	%	Low	High	%
Surface Water										
Irrigation	318	330	339	48	325	366	43	375	463	39
Domestic	17	23	24	3	30	36	5	48	65	6
Industries	21	26	26	4	47	47	6	57	57	5
Power	7	14	15	2	25	26	3	50	56	5
Inland navigation		7	7	1	10	10	1	15	15	1
Environment-Ecology		5	5	1	10	10	1	20	20	2
Evaporation Losses	36	42	42	6	50	50	6	76	76	6
Total	**399**	**447**	**458**	**65**	**497**	**545**	**65**	**641**	**752**	**64**
Groundwater										
Irrigation	206	213	218	31	236	245	29	253	344	29
Domestic	13	19	19	2	25	26	3	42	46	4
Industries	9	11	11	1	20	20	2	24	24	2
Power	2	4	4	1	6	7	1	13	14	1
Total	**230**	**247**	**252**	**35**	**287**	**298**	**35**	**332**	**428**	**36**
Total water use										
Irrigation	524	543	557	78	561	611	72	628	807	68
Domestic	30	42	43	6	55	62	7	90	111	9
Industries	30	37	37	5	67	67	8	81	81	7
Power	9	18	19	3	31	33	4	63	70	6
Inland navigation	0	7	7	1	10	10	1	15	15	1
Environment-Ecology	0	5	5	1	10	10	1	20	20	2
Evaporation losses	36	42	42	6	50	50	6	76	76	7
Total	**629**	**694**	**710**	**100**	**784**	**843**	**100**	**973**	**1180**	**100**

irrigation. The ultimate irrigation potential of India has been estimated as 140 Mha. Out of this, 76 Mha would come from surface water and 64 Mha from groundwater sources. The quantum of water used for irrigation by the last century was of the order of 300 cubic km of surface water and 128 cubic km of groundwater, total 428 cubic km. The estimates indicate that by the year 2025, the water requirement for irrigation would be 561 cubic km for low-demand scenario and 611 cubic km for high-demand scenario. These requirements are likely to further increase to 628 cubic km for low-demand scenario and 807 cubic km for high-demand scenario by 2050.

Rainwater Harvesting

Rainwater harvesting is the process to capture and store rainfall for its efficient utilization and conservation to control its runoff, evaporation and seepage. Some of the benefits of rainwater harvesting include, (i) It increases water availability, (ii) It checks the declining water table, (iii) It is environmentally friendly, (iv) It improves the quality of groundwater through dilution, mainly of fluoride, nitrate, and salinity, and (v) It prevents soil erosion and flooding, especially in the urban areas.

Even in ancient days, people were familiar with the methods of conservation of rainwater and had practised them with success. Different methods of rainwater harvesting were developed to suit the geographical and meteorological conditions of the region in various parts of the country. Traditional rainwater harvesting, which is still prevalent in rural areas, is done by using surface storage bodies like lakes, ponds, irrigation tanks, temple tanks, etc. For example, *Kul* (diversion channels) irrigation system which carries water from glaciers to villages is practised in the Spiti area of Himachal Pradesh. In the arid regions of Rajasthan, rainwater harvesting structures locally known as *Kund* (a covered underground tank), are constructed near the house or a village to tackle drinking water problem. In Meghalaya, *Bamboo Rainwater Harvesting* for tapping of stream and spring water through bamboo pipes to irrigate plantations is widely prevalent. The system is so perfected that about 18–20 litres of water entering the bamboo pipe system per minute is transported over several hundred meters.

There is a need to recharge aquifers and conserve rainwater through water harvesting structures. In urban areas, rainwater will have to be harvested using rooftops and open spaces. Harvesting rainwater not only reduces the possibility of flooding, but also decreases the community's dependence on groundwater for domestic uses. Apart from bridging the demand–supply gap, recharging improves the quality of groundwater, raises the water table in wells/ bore-wells and prevents flooding and choking of drains. One can also save energy to pump groundwater as water table rises. These days rainwater harvesting is being taken up on a massive scale in many states in India. Substantial benefits of rainwater harvesting exist in urban areas as water demand has already outstripped supply in most of the cities.

Different ways of harvesting water include:

- capturing run-off from rooftops;
- capturing run-off from local catchments;
- capturing seasonal flood water from local streams; and
- conserving water through watershed management.

Apart from increasing the availability of water, local water harvesting systems developed by local communities and households can reduce the pressure on the state to provide all the financial resources needed for water supply. Also, involving people will give them a sense of ownership and reduce the burden on government funds.The principle of rainwater harvesting is to conserve rainwater where it falls according to local needs and geophysical conditions. Nevertheless, there are limits beyond which in-situ rainwater conservation cannot be stretched. Also, the value of soil-stored water is fixed up to a point i.e., from field capacity to wilting point. Therefore, if prolonged dry conditions prevail and the crop is exposed to moisture levels below the wilting point, the only way to sustain the withering crop would be irrigation. Apparently, runoff capturing and its recycling as irrigation holds the key to stable and sustainable development of rain fed agriculture. People across the various agro-ecological regions have come up with indigenous water harvesting structures, unique in mode and displaying basic engineering skills. These indigenous structures have been grouped together, based on geomorphic controls and climatic variables (Table 2).In areas where there are no other sources of water and it is termed as rain fed, harvesting maximum rainwater is the key for survival. Starting from field bunding to nalla plugging, gully plugging, de-silting of existing tanks, creation of additional storage reservoirs etc. need to be explored and implemented for exploiting the full potential of rain water harvesting.

Table 2: Indigenous water harvesting systems

Agro-ecological regions	Water harvesting structures
Hill Areas	Water was diverted with the help of simple engineering structures into artificial channels to carry it to agricultural fields. Known as *Kuhls* or *Kuls*.
Arid and Semi-arid areas	Rivers and seasonal streams were tapped and channels were directed into storage structures, viz., *Zing* in Ladakh, *keres* in Karnataka and *Ahar* in Bihar.
Cold and Arid Ladakh	In Ladakh, which depends on snow-melt for water, it is collected during the evenings in small reservoirs for use the following morning.
Eastern Himalayas	In Nagaland and Arunachal Pradesh villagers divert a channel through the cattle shed in order to harvest nutrients for agricultural fields.
Northeastern Hills	Bamboo network is used as pipeline to direct water to a convenient spot for collection as drinking water.
Meghalaya	In Meghalaya a bamboo drip system is in vague for ages.
Tamil Nadu	In Tamil Nadu a big stream is often diverted to feed a chain of 25 to 30 tanks in a sequence called system tanks.
Western and Central India	In MP water is collected in a tank (bandhis) to moisten the soil. In this traditional '*haveli*' system where water is stored in the field itself, crop is taken on residual soil moisture.
Arid Kutch	In Kutch, the Maldhari nomads collect sweet water for drinking from well in tanks called *virda*
Arid Rajasthan	In Jodhpur wells and step wells (Baoris), which are actually wells in the tank bottom, provide drinking water even in summers.

Watershed Management

Watershed is the unit of management in Integrated Water Resources Management (IWRM) where surface water and groundwater are inextricably linked and related to land use and management. Watershed management aims to establish a workable and efficient framework for the integrated use, regulation and development of land and water resources in a watershed for socio-economic growth. Local communities play a central role in the planning, implementation and funding of activities within participatory watershed development programmes. In these initiatives, people use their traditional knowledge, available resources, imagination and creativity to develop watershed and implement community-centered program.

Currently, many programmes, campaigns and projects are underway in different parts of India to spread mass awareness and mobilize the general population in managing water resources. The efforts of villagers are visible in the form of rising water table and regenerated forests. Undoubtedly, coordinated watershed development programmes need to be encouraged and awareness about benefits of these programmes must be created among the people.

Groundwater Management

Groundwater irrigation has played a major role in achieving food security in India and supplying potable water to millions in the country, besides supplying water for industrial use. It is a much dependable water source when compared with surface water. About 50% of the total irrigated area is dependent upon groundwater (CWC, 2000) and about 60% of irrigated food production comes from groundwater-irrigated land (Shah *et al.*, 2000). At a global level, the groundwater situation in India is comfortable. But at a micro level, there are regions where groundwater is mostly untapped and also there are regions where groundwater has been overexploited. This has caused water table rise over some regions and its considerable decline at other regions, resulting in reduction in discharge, saline water encroachment, arsenic and fluoride contamination, drying of springs and shallow aquifers, increased cost of groundwater lifting, and even local subsidence at some places. It has been reported that declining water level could reduce India's crop harvest by 25% or more (Seckler *et al.*, 1998). On the other hand, absence of conjunctive use of surface and ground water in the canal command areas has created problems of water logging and salinity.

It is not possible to enhance precipitation, but is possible to reduce water losses in the form of evaporation and runoff of surface water, and to increase the availability of renewable supplies by various artificial recharge methods. There is no single method of recharge, which can be used universally. Huge sums are spent annually for obtaining more and more ground water. Much emphasis is needed for efficient development and use of groundwater potential.

The traditional village ponds, which have been filled up in most of the villages, used to act as storage tanks for the cattle drinking and were the natural means for augmenting recharge to ground water. These ponds need to be rehabilitated and made usable for storage and to recharge ground water.

Conjunctive Use of Surface and Groundwater

Ground water resource is an important component of total water resource. The first rule for ground water exploitation is not to exceed its recharge for its long-term sustainable use. Ground water may be used alone and in conjunction with available surface water. Since ground water needs to be pumped for application on the surface. The same pumping unit may be used to develop some extra pressure so as to adopt pressurized irrigation water application methods. Besides offering a good control on its application pressurized irrigation methods do attempt to achieve higher efficiencies and in turn higher productivity of water. Thus, the optimal conjunctive use of the region's surface and groundwater resources would help in minimizing the problems of waterlogging and groundwater mining.

Recycle and Reuse of Water

Another way through which we can improve freshwater availability is by recycle and reuse of water. It is said that in the city of Frankfurt, Germany, every drop of water is recycled eight times. Use of water of lesser quality, such as reclaimed wastewater, for cooling and fire fighting is an attractive option for large and complex industries to reduce their water costs, increase production and decrease the consumption of energy. This conserves better quality waters for potable uses. Currently, recycling of water is not practiced on a large scale in India and there is considerable scope and incentive to use this alternative.

Demand *Management for Irrigation*

Simple techniques can be used to reduce the demand for water. The underlying principle is that only part of the rainfall or plants take up irrigation water, the rest percolates into the deep groundwater, or is lost by evaporation from the surface. Therefore, by improving the efficiency of water use, and by reducing its loss due to evaporation, we can reduce water demand. There are numerous methods to reduce such losses and to improve soil moisture including 1) Mulching, 2) Soil covered by crops, 3) Ploughing, 4) Shelter belts, 5) Planting of trees, 6) Contour farming, 7) Salt-resistant varieties, 8) Desalination technologies and 9) Use of efficient watering systems.

Efficient Utilization of Irrigation Water

Available water resource needs to be utilized efficiently for its sustainable use. There can be three basic types of village water resources including, harvested rain water, well/ tube well water or canal water supplies. All the three resources need to be conserved/ utilized efficiently so as to let the beneficiary area sustain usual activities of the village concerning water including, drinking, house hold uses and irrigation or any other. Water resource utilization for sustainable use under all three different types of resource situations need to be handled differently. The major management strategies for efficient utilization of irrigation water include:

a. *Land preparation for efficient use of irrigation and rain water*

In India mostly the irrigation is practiced through surface application methods. As most of the fields are not properly levelled, low irrigation efficiency is a common consequence. Precision land levelling is expected to enhance water use efficiency and consequently harness higher water productivity. Conventional surface irrigation practices in unlevelled bunded units normally result in over irrigation. This results in excessive loss of irrigation water as deep percolation, which in tune reduces the application efficiency up to 25 %. Precision land levelling helps in controlling the emergence of salt affected patches, increase cultivable land area up to 2-3 %, increase in cropping intensity and crop productivity, improves crop establishment, reduces weed problem (Rickman, 2002), saving in irrigation water (Jat *et al.*, 2003).

b. *Field rectangulation*

Fragmented land holdings with irregular field boundaries are a common feature of the canal command areas in the country. Scattered fields with irregular boundaries increase greatly the energy requirements in farming operations. They also require longer lengths of watercourses to convey water to different fields. They are often unsuitable to modern methods of water applications, like border strips and furrows. Converting the existing land into rectangular plots and their consolidation on ownership basis through suitable exchange between different owners are desirable features of an efficient on-farm water management program. Rectangulation of fields would not only provide for efficient mechanization but would also result into smaller lengths of watercourses. Rectangulation of fields would also enable the use of more efficient water application methods like border strips and furrows besides minimizing lengths of watercourses.

c. *Optimal alignment of conveyance network*

The lack of well maintained media of conveyance of water from the outlet to property heads remains a major bottleneck in the efficient functioning of the canal irrigation systems in the country. In some of the canal command areas, the watercourses from the outlets run in a random manner without much consideration of the local topographical features. It has also been observed that for most of the fields the watercourses do not exist even. For successful operation of any water distribution system, watercourses should touch each holding with at least one delivery point. A significant part of available water at the outlet is lost while conveying it to the different fields, through seepage from watercourses. Since the seepage losses below a canal outlet are a direct function of the length of watercourse, minimization of the total length of watercourses is essential. A properly designed water distribution system makes irrigation easy and efficient. Efficient structures will save labour, land and water. An on-farm irrigation water distribution system comprises several intricate hydraulic structures such as conveyance channels, check gates, distribution boxes, falls, turnouts and siphons etc.

The simplest method of aligning a watercourse system is to mark an arrow at the highest point on each square indicating the sanctioned nakka for that square. The best alignment of the watercourse system will be that giving the shortest possible line connecting the nakka. This could be achieved by applying network analysis techniques including, modified Minimal Spanning Tree Model.

d. *Lining for minimizing conveyance losses*

Watercourses account for water losses in excess of 20 per cent. Regular maintenance is the first step in terms of its reduction. Lining is the obvious answer but is expensive. Maintenance however, is the key for reduction in conveyance water losses in watercourses. Based on the available funds, appropriate criteria are available to decide for lining of different reaches of the watercourse for effectively minimizing the conveyance losses.

Seepage losses in the field watercourses are the single major cause of inequity in water distribution among different beneficiaries, even in those canal command areas where rotational water distribution system is in vogue. To achieve equity in water distribution and to save more than 20 per cent of the amount of water diverted from the canal system to different fields, lining of field watercourses becomes an obvious solution. For handling the discharges normally available at the field level, pre-cast concrete channel sections do become most suitable owing to their low-cost, effectiveness in seepage control and other operating advantages.

e. *Appropriate farm irrigation structures*

A properly designed water distribution system makes irrigation easy and efficient. Good irrigation structures are an essential part of an efficient irrigation layout. Efficient structures will save labour, land and water. An on-farm irrigation water distribution system comprises several intricate hydraulic structures such as conveyance channels, check gates, distribution boxes, falls, cutlets and siphons etc. complexities of their design and construction give rise to bottlenecks in the in-budget on-time completion of distribution network with sound workmanship. Several similar problems may be overcome by the use of the pre-cast concrete structures. The greatest advantage is the convenience of transporting a large assortment of these structures of remote and /or scattered areas often with different access and of their rapid installation with the help of only a few unskilled labourers.

f. *Raised bed planting systems*

This system of crop establishment is a modification of the ridge-furrow system in which the ridges have been replaced by flat beds. Crops are cultivated on the raised beds while the furrows are used for irrigation (Tomer *et al.,* 2002). Fertilizers can be placed on the raised beds. The width of the raised beds will depend on the crops to be grown. This crop establishment technique has many advantages as it improves both water and nutrient use efficiency, requires lower seed rates and the furrows act as drainage channels in case heavy rainfall preventing temporary water logging. Appropriate farm machinery is now available commercially for raised bed cultivation.

g. *Matching crop needs with expected water supplies*

Mismatch between available water supplies and crop water requirements both, in terms of quantity and timing are a major cause of low water use efficiency particularly in canal command areas. Models can play a useful role in developing practical recommendations for optimizing crop production under different canal water supply patterns. The applicability of FAO CROPWAT model has been established for determining optimal sowing schedule of crops in a crop calendar such that the actual crop water needs match with the probable amounts and timings of irrigation water availability. CROPWAT thus can be used as a powerful tool to simulate different crop water need scenarios under different planting dates and thus enable the user to select most optimal sowing dates of crops to realize high yields and water use efficiencies by matching the probable canal water supplies with crop needs.

h. *Use of modern water application methods*

Most surface irrigation methods result in very poor water application efficiency, only within the range of 30 to 35 per cent (Table 3). Among the surface irrigation methods, furrow method of water application is most efficient. Application of surge flow concepts in design and adoption of furrow irrigation system makes it more efficient. Highest water application efficiency is achieved through drip and sprinkler irrigation methods, up to 90 % and above. Pressurized methods of water application may be adopted wherever possible.

Table 3: Comparative irrigation efficiencies under different method of irrigation

Irrigation efficiencies	Irrigation efficiencies (%)		
	Flood irrigation	Sprinkler irrigation	Drip irrigation
Conveyance	40-50 (canal) 60-70 (well)	100	100
Application	60-70	70-80	90
Overall	30-35	50-60	80-90

Micro irrigation, which has application efficiency of more than 90 per cent has emerged as a viable option and has received the attention of the Government for it's promotion. It is proposed to cover 3 Mha in X Plan and 14 Mha in XI Plan having participatory approach through Micro irrigation. Sprinkler systems are effective and efficient way of water application to field crops. These provide enough control on water application. Proper design of the system also ensures high water application and distribution efficiencies. Micro irrigation systems include drip irrigation, micro sprinklers, mini sprayers, foggers, misters and bubbler systems. These systems are designed to irrigate only a part of the land area matching with the plant root zone. Micro irrigation systems achieve very high water use efficiency as well as nutrient use efficiency as these permit application of water-soluble nutrients along with irrigation water. These systems attempt to maintain favourable soil moisture levels all the time and thus ensures enhancement of quantity as well as quality of the produce. These systems are very suitable for water application in fruit and vegetable crops. Government of India has been partly supporting the expenses of the farmers on the purchase of these systems with a clear objective of achieving high water use efficiency.

i. *Equitable distribution of irrigation water*

In all irrigation schemes, the management of available water below the outlet is of vital importance and has long been neglected. Equitable distribution of water to the field and adoption of proper water application methods have great bearing on the benefits by way of returns per unit of irrigation water delivered to each hectare of land. The overall success of an irrigation project hinges around the management of water both above and below the outlet point. In the past, the irrigation engineers used to manage the irrigation supplies in the canals up to outlet point only. The management and distribution of water below the outlet was left to the beneficiary farmers. Experience has, however shown that many farmers, not knowing the implications of excessive water application to their fields, suffer by way of low production and also cause damage to their lands. They also deprive other farmers whose lands are situated in the tail reaches of the project, of their due share of irrigation supplies. Therefore, a need has been felt to ensure equitable, timely and efficient water utilization in the tertiary system below the outlet by organizing irrigation scheduling and coordinated water delivery plan.

j. *People participation and capacity building*

For making the people of various sections of the society aware about the different issues of water resources management, a participatory approach may be adopted. Mass communication programs may be launched using the modern communication means for educating the people about water conservation and efficient utilization of water. Capacity building should be perceived as the process whereby a community equips itself to become an active and well-informed partner in decision making. The process of capacity building must be aimed at both increasing access to water resources and changing the power relationships between the stakeholders. Capacity building is not only limited to officials and technicians but must also include the general awareness of the local population regarding their responsibilities in sustainable management of the water resources.

Conclusion

Ever increasing population in the country keeps exerting more and more pressure on our land and water resources to meet its growing food grain requirement and other demands. The projected food requirement in 2050 emphatically suggests a pronounced role for research, development and training in the water resources as well as agricultural sector. Some of the areas that need to be focused upon are:

- Development of crops which require less water and can sustain on poor quality/saline water;
- Laser levelling;
- Water harvesting through pond and bunding of fields;
- Modern irrigation techniques like sprinkler and drip should be promoted where water is scarce, and the topographic and soil conditions do not permit efficient irrigation by conventional methods.
- Water availability for crop production through life saving irrigation in rainfed areas;
- Augmenting water availability through:
  - Inter-basin and Intra-basin transfer of water;
  - Artificial recharge of ground water;
  - Recycling and reuse.
- Efficient use of irrigation water requires that water be applied to growing crops at appropriate times and in adequate amounts. Scheduling irrigation with limited water is a big challenge to agricultural scientists.
- Water use efficiency and fertilizer use efficiency always go hand in hand, therefore, increase in water use efficiency will automatically enhance nutrient use efficiency through water management.

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Enhancing Farmers' Income through Micro Irrigation Adoption

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India supports 17 per cent of the human and 15 per cent of the livestock population of the world with only 2.4 per cent of the land and 4 per cent of the water resources. Out of the total annual precipitation of 4000 billion cubic meters (BCM), the utilizable water resources of the country have been assessed as 1123 BCM, of which 690 BCM is from surface water and 433 BCM from groundwater sources. It has been projected that population and income growth will boost the water demand in future to meet food production, domestic and industrial requirements. The projected total water demand of 1447 BCM in 2050 will outstrip the present level of utilizable water resources (1123BCM) out of which 1074 BCM will be for agriculture alone. Since the total projected demand will be 324 BCM more than the present level of utilizable water resources, the challenge will be to (i) produce more from less water by efficient use of utilizable water resources in irrigated areas, (ii) enhance productivity of challenged ecosystems, *i.e.*, rainfed and waterlogged areas, and (iii) utilize a part of grey water for agriculture production in a sustainable manner.

In increasing the agricultural production to enhance the net income of farmers and thereby their livelihood and socio-economic status, the high yielding varieties, use of fertilizers and pesticides and improved farming technologies have been playing a significant role, but still it is difficult to realize the full potential of land without irrigation. As water is the most precious natural resource; it is essential for agricultural development and all organic life on the earth. Intensive agriculture and an ever-growing human population are fast depleting this already scarce natural resource. Now a days this is challenging situation and the need of time is to conserve "water" and ensure its "efficient use". Hence, irrigation has been considered essential for the fast growth in agriculture and it will continue to be a major factor in future too.The geographical area of the Gujarat State is 196 lakh hectare, while cultivable area of the state is 124 lakh hectare. The ultimate irrigation potential through the surface water is assessed at 39.40 lakh hectares including 17.92 lakh hectares through Sardar Sarovar (Narmada) Project. Similarly in respect of ground water resources, it is estimated that about 25.48 lakhs hectares can be irrigated. Thus, total ultimate irrigation potential through surface & ground water is estimated to be 64.88 lakh hectares while rainfed dependent area is 59.12 lakh hectare. Among total irrigated area, canal irrigated area is only 9.76 lakh hectare which is only 22 % and area irrigated by tank water is only 1%. Thus, remaining irrigated area 77% is irrigated through only groundwater and which requires electric pump and more energy to lift the irrigation water. Hence, the only Agriculture sector is consuming 49% of total electricity in the state.

The land water resources of Gujarat in comparison to India are given in table-1. Gujarat state occupying 6.3% of nations' total geographical area (311 mha) is having only 4.9% of total nation's water resources (1123BCM). Among which 38 BCM and 17 BCM are available as surface and groundwater respectively. The area under irrigation in Gujarat is only 50.01 lakh ha from available surface and ground water resources in the state which can be only

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44.65% of total cultivable land. The irrigation potential in the state can only be increased through adopting the water use efficient irrigation system adoptions like MISs. The total area under MIS in the Gujarat state is 12.81 lakh ha which includes drip (38.6%), mini sprinkler(9.83%), sprinkler (51.55%), oozing pipe (0.01%) and raingun irrigation (0.01%) systems which indicates huge scope for increasing irrigated area through MIS adoptions.

Table 1: Irrigation scenario: Gujarat State with reference to nation

S N	Particulars	National	Gujarat State
(A)	Geographical Area (Million Ha)	311.0	19.6 (6.30%)
(B)	Available Water (Billion Cum)	690	
	Surface Water	433	38 (5.50 %)
	Ground Water	11	17(3.92 %)
	Total	23	55 (4.90 %)
(C)	Irrigation Potential (Million Ha)		
	Ultimate	139.0	6.75 (4.86 %)
	Developed	93.95	6.00 (6.38 %)
	Actual Utilized	80.06	5.01 (6.25%)
(D)	Requirement Of Water For Irrigation (Billion Cum)	688	48 (6.98%)
(E)	Sector wise use of water		
	Irrigation	92%	89%
	Drinking	5 %	8 %
	SupplyIndustrial	3 %	3 %

Drip irrigation is an efficient method of providing irrigation water directly into soil at the root zone of plants and thus, minimizes conventional losses such as deep percolation, runoff and soil erosion. Unlike surface irrigation, drip irrigation is more suitable and economical if it is introduced in water scarce areas having undulated topography, shallow and sandy soils and for wide spaced high value crops. It also permits the utilization of fertilizers, pesticides and other water-soluble chemicals along with irrigation water resulting in higher yields and better quality produce. Hence, drip irrigation system is regarded as panacea for many of the problems in dry land agriculture and improving the efficiency in irrigated agriculture. In this direction Government of Gujarat (through GGRC, a nodal agency using state-of-the-art technology to implement the Micro Irrigation Scheme on behalf of Government of India and Government of Gujarat) provides subsidies to the farmers for installation of system. Thus, in the process of achieving higher efficiency of drip irrigation, it is necessary for the drip irrigation farmers to know the benefits and the constraints of the system. Keeping all these in view, extent of benefits derived from drip irrigation in major crops, an exhaustive study has been under taken.

Through, combine efforts of GGRC, State agriculture department, State agricultural universities, NGOs and farmers themselves, out of the total cultivable area, 12.81 lakh hectares has been covered under the Micro Irrigation Scheme, 4.94 lakh hectares has been covered under Drip Irrigation and 6.60 lakhhectares under Sprinkler Irrigation. Adoption percentage are 36.8% drip, 51.55% sprinkler, 9.83 % micro sprinkler, 0.01 % raingun sprinkler and 0.01% porous pipe. The major non horticulture crops, covered under the Micro Irrigation Scheme are Groundnut, Cotton, Sugarcane & castor while the major horticulture crops covered under the scheme are Potato, Banana, Mango, Papaya and Vegetables.

Approaches Towards the Farmers' Income Enhancement

The drip irrigation can increase income through increasing the crop yield and decreasing the cost of cultivation by saving inputs like water, fertilizers, energy, labors etc. The Gujarat State Agricultural Universities have made massive research efforts to assess the crop performance under MIS as compared to surface irrigation methods for various crops in different regions of Gujarat state. The results of the researches conducted at various locations for different crops are depicted in Table-2. It can be seen that the highest water requirements was observed as 1688mm and 1059mm for Banana crop under surface and drip irrigation respectively which indicated the saving of 629 mm (6290 cum/ha) irrigation water by drip system. The drip system can save 37% irrigation water as compared to farmers practices of furrow irrigation. The highest water saving of 60% due to drip irrigation was observed for Ladies finger crop while the lowest water saving of 12% was found for Ber plantation. The average water saving due to drip irrigation as compared to surface irrigation was observed as 40%. The yield increase was observed as 18 tone, 13 tone and 13 tone under drip irrigation as compared to surface irrigation for sugarcane, banana and pappaiya crop. The percentage increase in yield was observed as 16%, 26% and 27% higher under drip irrigation as compared to surface irrigation. The cotton is the major crops of Gujarat and its yield was found increased by the tune of 371kg/ha due to drip irrigation. The groundnut is the major crops of Saurashtra region and its yield was found increased

Table 3: Crop performance under drip irrigation as compared to surface irrigation in different agro climatic zones of Gujarat state.

Location	Cost of MIS (Rs./ha)	Crop & Variety	Crop water requirements(mm)		Yield(kg/ha)	
			Surface	MIS	Surface	MIS
1	2	3	4	5	6	7
North Gujarat	120000	Castor (GAUCH-4)	1198	1129	4300	4800
North Gujarat	30687	Guava (L-49)	622	477	26500	26600
North Gujarat	30687	Pomogranet (Ganesh)	544	275	4300	3800
North Gujarat	92000	Funnel (GF-1)	433	431	8300	9100
North Gujarat	30687	Ber (Gola)	275	243	8723	10256
North Gujarat	150000	Gurundnut (GG-2)	1034	972	3100	3610
North Gujarat	120000	Okra (Parbhani Kranti)	907	839	7600	8400
North Gujarat	120000	Cauliflower (early snow ball)	566	513	10510	13550
North Gujarat	106053	Brinjal (BSR-1)	1166	1072	29637	37783
North Gujarat	120000	Potato (Kufri badsha)	650	500	28000	36895
Saurashtra	180000	Amaranthus,GA 3	485	407	1581	2012
Saurashtra	120000	Papaya, Madhubindu	2052	2033	64918	81125
Saurashtra	170000	Bt. Cotton-RCH 2	1560	1529	2444	3645
Saurashtra	115190	Sesamum (GT-2)	698	698	1278	1413
Saurashtra	130796	Chickpea(GG-1)	348	348	1572	1699
Saurashtra	114400	Okra (GO-2)	617	617	14262	14719
Saurashtra	108540	Tomato	770	770	34212	35558
Saurashtra	90530	Brinjal	850	850	6685	10389
Saurashtra	90530	Coriander(Mini Sprinkler)	250	250	706	1205
Saurashtra	75550	Garlic(Mini Sprinkler)	675	550	1747	3974
Saurashtra	127683	Groundnut(GG-2)	650	530	1822	2455
Saurashtra	74892	Castor(GCH-4)	300	214	592	1715
Saurashtra	74892	Groundnut(GG-2)	695	570	1621	2131
Saurashtra	112394	Sugarcane Co N 05071	2314	1607	76858	1E+05
Saurashtra	130000	Chickpea(GG-5)	350	251.7	1160	1465
Saurashtra	170000	Summer groundnut	891	711	1490	1785
Saurashtra	170000	Summer groundnutDrip+Mulch	981	522	1490	3393
Saurashtra	100000	Water melon	398	320	1070	40450
Saurashtra	9883	Cotton	700	444.2	2658	4752
Saurashtra	120000	Groundnut(GG-2)	786	674	1988	2796
Saurashtra	100000	Groundnut(GG-2) Micro Sprinkler	786	700	1988	2384
Saurashtra	240926	okra GO3	624	498	20013	28814
Saurashtra	93712	Whet (GW396)	532	396	3409	4787
Saurashtra	72000	Sesame, Guj. Til-3	366	360	1182	1421
Saurashtra	36000	Guava Cv. Bhavnagar Red (6mx6m)	466.5	283.4	6070	9870
Saurashtra	35000	Acid lime Cv. Kagdilime(6mx6m)	719.5	480.6	12330	13420
Saurashtra	32000	Coconut cv. D x T(7mx7m)	532.7	283.2	23480	24745
South Gujarat	106444	Bt-Cotton (RCH-2)	719	431.4	3266	3637
South Gujarat	77262	Sugarcane (60x120 Paired) CoN 5071)	1263	720	1E+05	1E+05
South Gujarat	77262	Brinjal (surti ravya)	780	428	33000	46000
South Gujarat	61020	Banana (Grand Naine)	1688	1059	77000	97000
South Gujarat	77262	Castor (R)	546	334	2400	2670
South Gujarat	127066	Onion (pilly Patti)	540	330	26000	32000
South Gujarat	22863	Sapota (yound plantation)	620	381	12484	14195

Contd

Location	Cost of MIS (Rs./ha)	Crop & Variety	Crop water requirements(mm)		Yield(kg/ha)	
			Surface	MIS	Surface	MIS
South Gujarat	71191	Bitter gourd (Hybrid Namdhari)	802	479	21570	25370
South Gujarat	61020	Papaya (Tiwan-786)	1380	828	48000	61000
South Gujarat	71191	Water Melon (Red Hunny)	580	408	18300	27100
South Gujarat	106444	Turmeric(Sugandham)	860	588	16500	20700
Middle Gujarat	120000	Potato	900	510	28920	37500
Middle Gujarat	120000	Brinjal	550	222	39410	49606
Middle Gujarat	120000	Banana	1200	800	22550	43381
Middle Gujarat	120000	Okra	376	150	78000	95000
Middle Gujarat	120000	Cabbage	260	153	19480	25449
Middle Gujarat	95000	Papaya	986	744	52130	58600
Middle Gujarat	120000	Maize	340	229	10688	14754
Middle Gujarat	90000	Castor	541	267	2600	3072
Middle Gujarat	100000	Bt. Cotton	450	405	1723	3049
Middle Gujarat	120000	Fennel	415	345	1281	1637
Middle Gujarat	75000	Sapota	650	325	11890	14910
Middle Gujarat	90000	Guava	573	515	7000	9375

Source: Anonymous(2004-16)

by 128% along with 47% water saving under drip irrigation. The results indicates that the farmers can get 4.5 times higher groundnut production from the sae irrigation water resources if the drip irrigation system is adopted.

The drip irrigation can saves 50% irrigation water along with 25% higher Sapota yield. Thereby, the farmers can get 2.5 times sapota production from same water resources replacing surface irrigation by drip system. The drip irrigation can save 45% water with 39% yield increase by drip irrigation for major vegetable crop like brinjal also. The above results of crop performance under drip irrigation shows that the drip irrigation can save 10% to 50% fertilizer also. The highest fertilizer saving of 50% was found under Ladies finger crop.

RESULTS AND DISCUSSION

The research results as depicted in table- 3 were analyzed. The increase in yield and saving of water, labor, fertilizer and electricity were quantified on monetary platforms and discussed.

Water Saving

The results on per cent water saving due to drip irrigation in comparison to surface irrigation for the different crops of various regions of Gujarat state as depicted in table-4 has been analyzed. The additional area that can be brought under irrigation with the saved water has also been assessed. The crop wise water saving and additional area which can be brought under irrigation from the saved water are illustrated in table 4. It is evident from the table that through adoption of MIS, water saved per hectare is assessed as 37.76 % which is 3005 m^3 / ha(30 lakh litre). Thus, if we consider the total existing area under MIS, 3943 MCM water is saved. That saved water can bring the additional area of 8.47 lakh hectare under irrigation using MIS.

Energy Saving

The total water requirement of the crops in surface and drip irrigation system were computed based on the observations on various crops in different regions. Considering the total seasonal water requirements of the different crops, the average depth of groundwater table, total head of lifting frictional head losses, the energy consumption per unit volume of irrigation water were computed. The energy required for various crops is presented in table 5. It can be seen in table-5 that the surface irrigation method requires 2477 kwh/ha while the drip method requires 2100 kwh/ha which shows saving of 377 kwh/ha (15 % saving in energy). If the prevailing rate of energy is considered as Rs 5.00 kwh(unit), Rs 1885.00 per hectare can be saved and cost of lifting water can be reduced.

Hence, the existing area of 12.81 lakh hectare covered under MIS in the state saves 370 million kwh energy and thereby saves Rs 18.5 billion cost of energy consumed in irrigation.

Savings in cost of cultivation

The capital cost of MIS for the crop season based on initial investments is computed considering the 10year of life of the MIS system and rate of interest as 10%. The labor wages for applying irrigation is considered as Rs 150 per day. The cost of cultivations includes expenditure towards irrigation applications(labor wages), weeding, fertilizer and energy utilization of the pumping are computed for both surface and drip irrigation.

The detail of savings in cultivation cost is illustrated in table 6. It is seen that by adopting the drip irrigation system, the savings on irrigation applications, weeding, fertilizer and energy is found as Rs 2235, Rs 2449, Rs 2699 and Rs 1885 per hectare respectively. Thus, total savings in cost of cultivation due to drip irrigation adoptions can be reduced upto Rs 9357/ha. At state's present scenario, savings on irrigation, weeding, fertilizer and energy is found as Rs 176 crore, Rs 378 crore, Rs 202 crore and Rs 185 crore, respectively. Thus total savings in cost of cultivation is estimated to Rs 942 crore by adoption MIS in the state.

Table 4: Water saving and additional area bought under irrigation by using MIS

Crop	CWR(mm)		Water saving (mm)	Water saving(%)	Water saving (m^3/ha)	Per ha additional area brought under irrigation	Present status of drip, ha	Water saving, m^3	Additional are brought under irrigation ha
	Surface Flood	Drip							
1	2	3	4	5	6	7	8	9=6×8	10=7×8
Ber	275	243	32	12	320	0.13	718	229763	95
Potato	650	500	150	23	1500	0.30	3081	4621680	924
Groundnut(S)	981	522	459	47	4590	0.88	609	2794071	535
Guava	467	283	183	39	1831	0.65	580	1061257	374
Lemon	720	481	239	33	2389	0.50	4892	11684727	2431
Coconut	533	283	249	47	2494	0.88	743	1852379	654
Cotton	719	431	288	40	2876	0.67	370449	1065412302	246966
Sugarcane	1263	720	543	43	5430	0.75	8486	46077134	6400
Brinjal	780	428	352	45	3520	0.82	1974	6947776	1623
Banana	1688	1059	629	37	6290	0.59	18330	115293247	10887
Castor	546	334	212	39	2120	0.63	6280	13313006	3986
Onion	540	330	210	39	2100	0.64	22	46431	14
Bitter gourd	802	479	323	40	3230	0.67	768	2479413	518
Papaya	1380	828	552	40	5520	0.67	5128	28305787	3419
Watermelon	580	400	180	31	1800	0.45	727	1307736	327
Turmeric	860	588	272	32	2720	0.46	33	89515	15
Maize	340	229	111	33	1110	0.48	251	278566	122
Sapota	650	325	325	50	3250	1.00	556	1807260	556
Okra	942	376	566	60	5660	1.51	79	447480	119
Total	762	462	301	38	3005	-	-	-	-
Average(lakh)							4.23	13040.5	2.799
			Total considering area of 12.81 lakh under MIS				12.81	39431.6	8.477

Table 5: Energy saving and cost of energy by using MIS

Crop	Energy require unit/season/ha		Energy saving		Saving in cost of energy (Rs/ha/season)	Area of drip in the state, ha	Energy unit saving	Present savings in energy cost, Rs
	Surfac	Drip	Unit/ha	(%)				
1	2	3	4	5	6=4*5.00	7	8=4×7	9=6×7
Ber	3361	3240	121	3.60	606	718	86959	434795
Potato	7944	6667	1278	16.08	6389	3081	3936987	19684933
Groundnut(S)	2543	1933	610	23.98	3050	609	371325	1856627
Guava	1209	1050	160	13.22	799	580	92648	463239
Lemon	1865	1780	85	4.57	426	4892	416914	2084572
Coconut	1381	1049	332	24.03	1659	743	246503	1232517
Cotton	1864	1598	266	14.29	1331	370449	98649287	493246436
Sugarcane	3274	2667	608	18.56	3039	8486	5157396	25786978
Brinjal	2022	1585	437	21.61	2185	1974	862624	4313119
Banana	4376	3922	454	10.38	2270	18330	8323001	41615003
Castor	1416	1237	179	12.61	893	6280	1121046	5605232
Onion	1400	1222	178	12.70	889	22	3931	19653
Bitter gourd	2079	1774	305	14.68	1526	768	234266	1171331
Papaya	3578	3067	511	14.29	2556	5128	2620906	13104531
Watermelon	1504	1481	22	1.48	111	727	16145	80724
Turmeric	2230	2178	52	2.33	259	33	1706	8532
Maize	881	848	33	3.78	167	251	8365	41827
Sapota	1685	1204	481	28.57	2407	556	267742	1338711
Okra	2442	1393	1050	42.98	5248	79	82984	414919
Average	2477	2100	377	15	1885	-	-	-
Total lakh	4.23	1225	6125					
Total considering area of 12.81 lakh under MIS						12.81	3704.2	18520.8

Table 6: Savings in cost of cultivation by using MIS

Crop	Irrigation labour cost, ≠ /ha	Weeding, ≠ /ha	Fertilizer, ≠ /ha	Energy, ≠ /ha	Total saving, Rs/ha	Area of drip in the state, ha	Total saving Rs.) at state level
1	2	3	4	5	6=2+3+4+5	7	8=6×7
Ber	409	1980	1418	606	4413	718	3168534
Potato	790	1980	2372	6389	11531	3081	35527011
Groundnut(S)	2192	1980	398	3050	7620	609	4640580
Guava	2070	2970	1074	799	6913	580	4009409
Lemon	3784	2970	3450	426	10630	4892	52001862
Coconut	3342	2970	2848	1659	10819	743	8038398
Cotton	1141	2970	540	1331	5982	370449	2216025918
Sugarcane	1367	2970	5150	3039	12526	8486	106295636
Brinjal	2249	1980	1030	2185	7444	1974	14694456
Banana	3775	2970	19763	2270	28778	18330	527500740
Castor	2218	2970	284	893	6365	6280	39972200
Onion	325	1980	1030	889	4224	22	92928
Bitter gourd	4629	1980	819	1526	8954	768	6876672
Papaya	4747	2970	5154	2556	15427	5128	79109656
Watermelon	2811	1980	1159	111	6061	727	4406347
Turmeric	1941	1980	1092	259	5272	33	173976
Maize	414	1980	690	167	3251	251	816001
Sapota	3652	2970	1004	2407	10033	556	5578348
Okra	2314	1980	2000	5248	11542	79	911818
Average	2325	2449	2699	1885	9357	-	-
Total(lakh)	5804	12502	6669	6123	-	423706	31098
Total(12.81 lakh ha)	17578	37861	20195	18544	-	12.81	94177

Benefit Due to Increase in Production

The research results on various crops shows that the agricultural production is increased by using drip irrigation system. The increased in productivity due to drip irrigation adoptions is presented in table 7. It is obvious that the increases in income is estimated to Rs 42360 from the increased production from the existing area of MIS under studied crops only. If the same is computed for area under MIS in the Gujarat state, it can be Rs 2719 crore additional income due to increase in production.

Total Benefits of MIS

The total benefits in the adoption of MIS over surface irrigation method computed in terms of reduction in cost of irrigation system, energy of pumping, fertilizer, and labour wages (Irrigation and fertilizer applications, weeding) and additional income due to increase in yield of crop gives the huge amount of monetary profits. The total monetary benefits are presented in table 8. It is clearly seen in table that if the total MIS area of the state is considered, the monetary benefit due to present adoption level is reached to Rs 3695 crore.

The saving of water under the total area of 12.81 lakh ha MIS is 3.9432 BCM. This saved water can bring additional 8.48 lakh hectare area under irrigation. The additional income from that additional irrigated area can be Rs 1753.4 crore. If this income is taken into account, the total benefits can be upto [1] 5439 crore. Presently, the total irrigated area in Gujarat is 58.07 lakh ha and area under MIS is 12.81 lakh ha. The remaining area of 45.26 lakh ha is still irrigated with traditional surface method. If this remaining area of 45.26 lakh ha is covered under MIS, it can save 1360 crore cum of water. This saved water can bring an additional area of 29.44 lakh ha. Thus, it the state, the total of 87.51 lakh ha(12.81+45.26+29.4 lakh ha) can be brought under irrigation.

Table 7: Additional income due to increase in production when adopted MIS

Crop	Productivity, kg/ha		Increase in productivity		Rate of farm produce, Rs/kg	Additional income due to increase in production, Rs/ha	Area of drip in the state, ha	Additional income due to increase in production, Rs
	Surface	Drip	kg/ha	%				
1	2	3	4	5	6	7=4×6	8	9=7×8
Ber	8723	10256	1533	18	10	15330	718	11007093
Potato	28000	36895	8895	32	8	71160	3081	219252499
Groundnut(S)	1490	3393	1903	128	50	95150	609	57920660
Guava	6070	9870	3800	63	10	38000	580	22023660
Lemon	12330	13420	1090	9	10	10900	4892	53321165
Coconut	23480	24745	1265	5	5	6325	743	4697641
Cotton	3266	3637	371	11	40	14840	370449	5497468206
Sugarcane	112000	130000	18000	16	2	36000	8486	305483760
Brinjal	33000	46000	13000	39	5	65000	1974	128297000
Banana	77000	97000	20000	26	6	120000	18330	2199553200
Castor	2400	2670	270	11	40	10800	6280	67820976
Onion	26000	32000	6000	23	4	24000	22	530640
Bitter gourd	21570	25370	3800	18	10	38000	768	29169560
Papaya	48000	61000	13000	27	5	65000	5128	333310900
Watermelon	18300	27100	8800	48	5	44000	727	31966880
Turmeric	16500	20700	4200	25	15	63000	33	2073330
Maize	10688	14754	4066	38	20	81320	251	20408067
Sapota	11890	14910	3020	25	5	15100	556	8396808
Okra	7800	8940	1140	15	5	5700	79	450642
Average	23596	29372	5777	31	-	42359	-	-
Total lakh	4.23	89932						
			Total considering area of 12.81 lakh under MIS				12.81	271933

Table 8: Summary of different monetary benefits through MIS adoptions.

Crop	Area under MIS	Total saving due to MIS in Weeding, Fertilizer, labour cost and cost of cultivation Rs	Saving in Electricity cost, Rs	Additional income due to increase in yield, Rs	Total benefit due to Svings in cost and increase in yield, Rs	Income due to additional area covered due to water savings, Rs	Total benefit due to adoption of MIS, Rs	Total benefit by adoption of MIS, Rs /ha
1	2	3	4	5	6=3+4+5	7	8=6+7	9=8/2
Ber	718	2733464	434795	11007093	14175352	1449494	15624846	21762
Potato	3081	15843119	19684933	219252499	254780551	65775750	320556301	104043
Groundnut(S)	609	2781896	1856627	57920660	62559183	50930235	113489418	186354
Guava	580	3543361	463239	22023660	26030259.58	14230540	41877351	72202
Lemon	4892	49916340	2084572	53321165	105322076.6	26498798	214004052	43746
Coconut	743	6803105	1232517	4697641	12733262.77	4136456	29794477	40100
Cotton	370449	1722959880	493246436	5497468206	7713674522	3664978804	11378653326	30716
Sugarcane	8486	80503456	25786978	305483760	411774194	230385669	642159863	75673
Brinjal	1974	10380214	4313119	128297000	142990333	105515290	248505623	125889
Banana	18330	485881302	41615003	2199553200	2727049505	1306439058	4033488563	220048
Castor	6280	34362628	5605232	67820976	107788836	43048045	150836881	24019
Onion	22	73737	19653	530640	624030	337680	961710	43714
Bitter gourd	768	5701881	1171331	29169560	36042772	19669662	55712434	72542
Papaiya	5128	66000686	13104531	333310900	412416117	222207267	634623384	123757
Water melon	727	4322794	80724	31966880	36370398	14385096	50755494	69815
Termeric	33	164978	8532	2073330	2246840	959091	3205931	97149
Maize	251	773961	41827	20408067	21223855	9892120	31115975	123968
sapota	556	4240666	1338711	8396808	13976185	8396808	22372993	40239
Okra	79	497604	414919	450642	1363165	678360	2041525	25842
Total	4.23706	24975	6125	89932	121031	57899	179898	-
Total State	12.81	75508	18518	271896	365922	175050	543897	-

Rs in Lakh

Conclusions

The following outcomes could be emerged out through results analysis of the research experiments on crop performance under MIS for various locations in Gujarat state.

(i) The present irrigated area of 58.07 lakh ha can be enhanced to 87.51 lakh ha area by irrigating existing irrigation water resources through 100% MIS adoptions.

(ii) The proposed possible total 87.51 lakh ha under irrigation can save 25305 lakh unit of energy and Rs 91651 lakh of financial burden of energy subsidy given by state electricity board.

(iii) The proposed MIS adoptions can save Rs 120082 lakh cost of irrigation, Rs 258643 lakh cost of labour and interculturing on weeding, Rs 137960 lakh of cost of chemical fertilizers.

(iv) The increase in income due to increase in productivity by use of MIS can be as Rs 1857425 lakh.

(v) As compared to present irrigated area of 58.07 lakh ha, an additional area of 29.04 ha can be brought under irrigation by 100% MIs adoption in Gujarat State. The total benefits through inputs savings and increase in yield though 100% MIS adoptions in Gujarat state, the total net income of Rs 3715568 lakh (Rs 371.6 billion) can be enhanced to farmers accounts in state.

Summary

The massive research efforts were made by Gujarat State Agricultural Universities to assess the crop performance under MIS in comparison to farmers practices in different agro climatic zones and soils of Gujarat state. The increase in yield and saving of water, labour, fertilizer and electricity were quantified on monetary platforms and were compared. The adoption of MIS can result water saving of 37.76 % (3005 m^3/ha) which can be 3943 MCM water due to the total existing area under MIS. That saved water can bring the additional area of

8.47 lakh hectare under irrigation using MIS. The drip method requires 2100 kwh/ha energy in pumping irrigation water which shows saving of 377 kwh/ha (15 % saving in energy) as compared to surface methods and Rs 1885.00 per hectare can be saved in cost of lifting irrigation water. The saving in cost of irrigation applications, weeding, fertilizer, energy due to drip adoptions in comparison to surface method is assessed as 2325 Rs /ha, 2449 Rs/ha, 2699 Rs/ha, and 1885 Rs/ha respectively. The total saving can be as 9357 Rs/ha. The present area under MIS in the state gives the total monetary benefit of [1] 3695 crore. The adoptions of the drip irrigation system, the savings on irrigation applications, weeding, fertilizer and energy is found as Rs 2235, Rs 2449, Rs 2699 and Rs 1885 per hectare respectively. If existing irrigation water resources are utilized for irrigating through MISs, instead of present irrigated area of 58.07 lakh ha, an additional area of 29.04 ha can be brought under irrigation which is an increase of 71%. The proposed possible total 87.51 lakh ha under irrigation can save 25305 lakh unit of energy and Rs 91651 lakh of financial burden of energy subsidy given by state electricity board. It can save Rs 120082 lakh cost of irrigation. It also saves the Rs 258643 lakh cost of labour and interculturing on weeding. The cost of chemical fertilizers of Rs 137960 lakh can be saved. The increase in income due to increase in productivity by use of MIS can be as Rs 1857425 lakh. As compared to present irrigated area of 58.07 lakh ha, an additional area of 29.04 ha can be brought under irrigation by 100% MIs adoption in Gujarat State. The total benefits through inputs savings and increase in yield though 100% MIS adoptions in Gujarat state, the total net income of 13715568 lakh (1371.6 billion) can be enhanced to farmers accounts in state.

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New Paradigms in Soil Health Management in Fruit Crops for Improving Farmers' Income

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Perennial fruit crops represent hardly 1% of the global agricultural land area, but Mediterranean region covers maximum of 11% area, which are of great economic importance in world trade and tariff (FAO, 2011). On the other hand, Indian fruit industry occupies 6.82 million ha with a total production of 80.96 million tons (IHB, 2013). Approximately 1.7 million (2.8%) of deaths worldwide are attributable to micronutrient deficiency induced through lesser consumption of fruits and vegetables and regarded as top 10 selected risk factors for global mortality (WHO, 2014). In the 21st century, nutrient efficient plants will play a major role in increasing crop yields compared to the 20th century, mainly due to limited land and water resources available for crop production, higher cost of inorganic fertilizer inputs, declining trends in crop yields globally, and increasing environmental concerns. Furthermore, at least 60% of the world's arable lands have mineral deficiencies or elemental toxicity problems, and on such soils fertilizers and lime amendments are essential for achieving improved crop yields (Pathak and Nedwell, 2011).

Fruit crops by the virtue of their perennial nature of woody framework (Nutrients locked therein), extended physiological stages of growth, differential root distribution pattern (root volume distribution), growth stages from the point of view of nutrient requirement and preferential requirement of some nutrients by specific fruit crop, collectively make them nutritionally more efficient than the annual crops (Srivastava and Singh, 2008a; Srivastava *et al*., 2015a, Scholberg and Morgan, 2012). There will be an increasing importance of nutrient efficient cultivars that are higher producers. Nutrient efficient plants are defined as those plants, which produce higher yields per unit of nutrient, applied or absorbed than other plants (standards) under similar agroecological conditions. Horticultural crops occupy 10% of cultivated area. Share of fertilizer use in horticulture has risen from 2% in 1990s to 8% in 2012-13 (Average application rate: 159 kg/ha with N:P:K use ratio 1.6:0.9:1.0), with banana and grapes being two most heavily fertilized fruit crops (Chanda, 2014). According to Malhotra and Srivastava (2015), estimated fertilizer requirement of fruit industry comes out as 7.56 million tons, out of which 75% and 60% of total fertilizers used in horticultural sector, are consumed by potato and grapes, respectively. Ghosh (2012) while analysing the carrying capacity of Indian horticulture observed, annual growth rate in domestic demands for fruits is estimated at 3.34% with nearly 76% of fruits still consumed as fresh.

During the last three decades, much research has been conducted to identify and/or breed nutrient efficient plant species or genotypes/cultivars within different fruit species but the success in releasing nutrient efficient cultivars has been limited. The main reasons for limited success are that the genetics of plant responses to nutrients and plant interactions with environmental variables are not well understood (Fageria *et al*., 2008). Fruit crops by the virtue of their perennial nature of woody framework (Nutrients locked therein), extended physiological stages of growth, differential root distribution pattern (root volume distribution), growth stages from the point of view of nutrient requirement and preferential

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requirement of some nutrients by specific fruit crop, collectively make them different than the annual crops (Srivastava *et al*., 2008; Srivastava, 2013a; 2013b).

Microbes are considered gateway to improved use efficiency of applied fertilizers. A still bigger question emerges, whether rhizosphere competent microbes could collectively contribute towards improved resilience of plant's rhizosphere (Wang *et al*., 2014). And if those microbes are so successful in promoting growth response, addition of starter nutrients in such combination may further magnify the magnitude of response called nutrient-microbe synergy. Our earlier studies have shown that rhizosphere effective microbes have the tendency to play multiple roles (Rao and Dass, 1989; Srivastava and Singh, 2005; Keditsu and Srivastava, 2014) to overcome various biotic and abiotic stresses while interacting with an environment. A sound understanding of nutrient- microbe synergy could possibly lay a solid foundation in unlocking the productivity potential of perennial fruit crops, besides safeguarding the soil health, both physic-chemically as well as biologically. In this background, incise efforts have been made to analyse various aspects of an effective nutrient management in giving the desired fillip to the productivity of fruit crops.

Soil Fertility and Functions: Some Facts

- It can take up to 1 000 years to form one centimeter of soil. A shortage of any one of the 15 nutrients required for plant growth can limit crop yield. It is estimated that soils can sequester around 20 PgC (petagrams of carbon) in 25 years, more than 10 % of the anthropogenic emissions.
- Soil function fertility refers to the ability of soil to support and sustain plant growth, which relates to making all the essential nutrients available for root uptake. This is facilitated by their storage in soil organic matter, nutrient recycling from organic to plant available mineral forms, and physicochemical processes that control their fixation and release (Srivastava and Kohli, 1997). On the other hand, managed soils are highly dynamic system that makes the soil work and supply ecosystem services to humans. Overall, the fertility and functioning of soils strongly depend on interactions between soil mineral matrix, plants and microbes. These are responsible for both building and decomposing soil organic matter, and therefore for the preservation and availability of nutrients in soils, cycling of nutrients in soils must be preserved (Srivastava *et al*., 2008).
- Soil health considers the physical, chemical/biological properties of the soil and the disturbance and ameliorative responses of land managers. Soil health also describes the capacity of a soil to meet performance standards relating to nutrient and water storage and supply, biological diversity and function and resistance to degradation. The most important of these manageable services include BNF (Biological nitrogen fixation), other symbiotic and beneficial organisms, nutrient and moisture supply, carbon storage and protection from erosion (Srivastava *et al*., 2014). Let us look at soil nutrient imbalances, nutrient mining and sustainability of nutrient management practices.
- Managing soil carbon for multiple benefits address to enhance a range of ecological services. Increasing the soil organic matter of degraded soils can boost crop productivity, sequester CO_2, enhance soil microbial growth and activities and improve water capture and retention. Soil carbon stocks, highly vulnerable to human activities, decrease significantly in response to changes in land capability and land use such as deforestation and increased tillage continues (Srivastava and Singh, 2009b; Tagaliavini *et al*., 2007).
- Opportunity to use existing mechanisms to encourage active management of soil carbon – land use planning that excludes vulnerable soils from land uses that lead to soil organic carbon losses. Promotion of proper management practices to protect and enhance soil organic matter as an essential element of good soil and environmental quality. Promotion of sources of plant nutrients (e.g. cover crops, legumes, crop diversification that enhance soil organic carbon stocks. Integration of several crops in a field at the same time to increase soil organic matter, soil biodiversity and soil health. Decline in soil fertility is the major constraint limiting the productivity of fruit crops. Continuous reduction in nutrient density of differ-

ent fruit crops is an indication of nutrient mining induced decline in fruit crop productivity (Srivastava and Ngullie, 2009).

Improving soil fertility: Nutrient mining (extracting more nutrients than are returned) is a major factor impoverishing the soil. Massive mobilisation programmes have been proposed, especially for phosphorus, but their economic benefit and long term sustainability need case-by-case evaluation. Mineral fertilisers have had greater impact, particularly when subsidised, but continuously using them alone is not sustainable (Srivastava *et al*., 2002; Srivastava and Malhotra, 2014).

Integrated soil- fertility management is an ecological approach that uses locally available amendments and inorganic fertilisers in an integrated way. Standard technology packages, delivered in a top-down manner, are inappropriate; rather, approaches must help farmers make decisions based on a combination of their own knowledge and research based options. Synergistic fertility management packages are being tested that include soil amendments like organic matter and rock phosphate, and wise fertiliser applications, aiming at sustainable and profitable crop production (Mengel and Kirby, 2000). Programmes to promote fertiliser use alongside other improved practices have had considerable impact for some marketable crops in high potential areas. But remote areas and those with marginal agro-ecology are riskier, so often require different approaches.

Organic alternatives to mineral fertilisers, such as manure and compost, are bulky and often scarce and of poor quality. Using them needs a lot of labour, which is in short supply in many places. Improved transport and research to develop labour- saving techniques may overcome this problem. The small but growing demand for organic fruits, and the higher prices it fetches, have stimulated organic production, often by smallholders. Certified organic systems prohibit the use of mineral fertilisers, but farmers may be confused, if fertilisers are promoted in other circumstances (Srivastava *et al*., 2002; Srivastava and Shyam Singh, 2004c).

Fruit Crops as Carbon Sink

Pedospheric, atmospheric, and biotic carbon pools contain 2400, 750 and 550 Gt of carbon, respectively (Brady and Weil, 2004). In particular, about 80% of the biotic pool of carbon is fixed in plants and fungi (Kimmins, 1997). Modern agricultural practices convert the pedosphere, which is normally a carbon sink, into a significant carbon source, a process which is resulting in significant repercussions on the total amount of CO_2 in the atmosphere. This is the case in modern fruit orchards, especially in areas where rainfall is infrequent during the growing season and the soil is managed with shallow and repeated tillage (Xiloyannis *et al*., 2002).

Fruit production and quality depend on adequate source-sink relationships. Carbohydrates (CH) translocated from leaves or reserve organs are the most important for the growth and development of sink organs (mainly fruits). Up to 60% of CH produced daily can be lost through respiration. Carbohydrates constitute over 65% of the dry matter of tree crops. Increasing the leaf-fruit ratio generally increases fruit growth and CH content. Photosynthesis increases with fruit load and the leaves next to fruits are strong sources for CH. The leaf-fruit ratio is species, cultivar and geographic location dependent. The optimal leaf area in various species is 200 cm^2 per 100 g of fruit. (Fischer *et al*., 2012). Several studies have recently documented the effects of elevated atmospheric CO_2 concentrations on photosynthesis in various fruiting trees. In a longer three-month study, Keutgen and Chen (2001) noted that cuttings of *Citrus madurensis* exposed to 600 ppm CO_2 displayed rates of photosynthesis that were more than 300% greater than rates observed in control cuttings exposed to 300 ppm CO_2. Likewise, in the review paper of Schaffer *et al*. (1997), it was noted that atmospheric CO_2 enrichment had previously been shown to enhance rates of net photosynthesis in various tropical and sub-tropical fruit trees, including avocado, banana, citrus, mango and mangosteen.

There is a little information in the literature on the effects of atmospheric CO_2 enrichment on mineral element concentrations in tissues of tropical C_3 plants (Hocking and Meyer, 1991a; 1991b). Conroy (1992) observed that atmospheric CO_2 enrichment aletrs foliar nutrient concentrations required to maintain maximum productivity (critical concentrations). Critical concentrations in leaves are routinely used to evaluate nutrient status of crops and manage fertilizer programs (Conroy, 1992). Since atmospheric CO_2 is expected to increase steadily (Ehleringer and Cerling, 1995; Houghton and Skole, 1990), knowledge of changes in foliar nutrient concentrations in response to CO_2 enrichment is important for diagnosing nutrient deficiencies that are based on critical concentrations (Conroy, 1992; Hocking and Meyer, 1991b). Leaf mineral element concentrations were generally lower for trees grown at the higher ambient CO_2 concentration, presumably due to a dilution effect from an increased growth rates (Schaffer *et al*., 1997). Under changing pattern of climatic condition there is need to classify the plant species for their efficient response to enhance CO_2 to climate change. Nutrient concentration in various tree components varies in accordance to their utilization for regulating different physiological processes. These nutrients are also translocated to various components as and when required. Most of the macronutrients (N, P, K, Mg, S and Na) are highly mobile and leachable except for Ca. Ca being an immobile element, can be used as indicator of carbon content in different tree components (Negi *et al*., 2003).

The total carbon emission and the heterotrophic carbon emission in the grape orchard were estimated to be 422.7g C m sup(-2)y sup(-1) and 222.5g C m sup(-2) y sup(-1), respectively, and both values were one half of those in the peach orchard. The total carbon supply was 401.0g C m sup(-2)y sup(-1) in the grape orchard (litter from floor vegetation 54.5%; litter from grapevine 34%, and fertilizer 11.5%), and was only one-third of the value in the peach orchard. It was determined that carbon from floor vegetation is the largest input to the soil in the grape orchard, which is similar to that in the peach orchard. These results indicate that the grape orchard sequestered carbon of 178.5g m sup(-2)y sup(-1), which is one third of that in the peach orchard suggesting that soil in orchards acts as a carbon sink owing to a large amount of carbon input from the floor vegetation (Sekikawa *et al*., 2003).

Trials were carried out in southern Italy on olive (*Olea europaea* L.) and peach orchards (*Prunus persica* L.) at different age and plant densities. At the end of each vegetative season, values of fixed atmospheric CO_2 were calculated by measuring dry matter accumulation and partitioning in the different plant organs. In the early years, sequestered CO_2 was primarily distributed in the permanent structures and in the root system while in mature orchards the fixed CO_2 was distributed in leaves, pruning materials and fruit. Significant differences in amounts of fixed CO_2 were observed in peach orchards cultivated using different planting and training strategies. The results underline the importance of training system, plant density and cultivation techniques in the absorption of atmospheric CO_2 and its storage as organic matter in the soil (Sofo *et al*., 2005). Of all the component parts i. e. fruits, stem, bark, branches, twigs and roots, the carbon storage was maximum in fruits followed by roots. The present studies indicate the innate potential of Nagpur mandarin as CO_2 sequester being dependent on stem, leaf and root biomass under different diameter classes (Bhatnagar *et al*., 2016).

Elevated CO_2 enhances the photosynthetic rates of fruiting trees, it should also lead to increased biomass production in them. And it does. In the two-year study of Centritto *et al*. (1999a), cherry seedlings grown at 700 ppm CO_2 exhibited photosynthetic rates that were 44% greater than those displayed by seedlings grown in ambient air, independent of a concomitant soil moisture treatment.In the two-year study of Centritto *et al.* (1999b), for example, well-watered and water-stressed seedlings growing at twice-ambient CO_2 concentrations displayed basal trunk areas that were 47 and 51% larger than their respective ambient controls. Similarly, in a study spanning more than thirteen years, Idso and Kimball (2001) demonstrated that the aboveground wood biomass of mature sour orange trees growing in air enriched with an additional 300 ppm of CO_2 was 80% greater than that attained by control trees growing in ambient air. However, elevated (CO_2) did not improve plant water relations (for example, bulk leaf-water potential, osmotic potentials at full and zero turgor, relative water content at zero turgor, bulk modulus of elasticity of the cell) and thus did not increase water-stress tolerance of cherry seedlings (Centritto *et al*., 1999a) but accelerated ontogenic development, irrespective of water status (Centritto *et al*., 1999b). According to Pan *et al*. (1998), elevated CO_2 enhanced the photosynthesis of apple plants and altered carbohydrate accumulation in mature leaves in favour of starch and sorbitol over sucrose. While, Idso and Kimball (2001) observed that CO_2 enriched sour orange trees may have reached an equilibrium condition with respect to the CO_2 – induced enhancement of wood biomass and fruit production, and that they will not substantially depart from these steady- state responses over the remainder of their lifespan.

In the light of climate change related issues, perennial fruit trees play an important role in carbon cycle of terrestrial ecosystems and sequestering atmospheric CO_2 (Lobell *et al*., 2005; Guimarães *et al*., 2014). According to Wu *et al*. (2012), net C sink and C storage in biomass of apple orchard ranged from 19 to 32 Tg C, respectively, and from 230 to 475 Tg C in 20 years period, amounting to 4.5% of total net C sink in the terrestrial ecosystems in China. In an estimate, Lakso (2010) observed that an acre of apple orchard fixed about 20 tons of CO_2 from the air each season, and provided over 15 tons of O_2, equivalent to over 5 billion BTU's of cooling power. While Mwamba (2013) showed that citrus trees carbon sequestration in biomass ranged from 23.9 tons CO_2/ha for young trees to 109 tons CO_2 / ha for mature trees. Perennial fruit trees act as strong carbon sink by sequestering the atmospheric carbon (Sugiura *et al*., 2007). Studies in the past have shown increase in yield of fruit crops like apple (Wu *et al*., 2012), grape (Bindi *et al*., 1997), Japanese pears (Ito *et al*., 1999), mango (Goodfellow *et al*., 1997), citrus (Peng *et al*., 2000) etc. in response to elevated CO_2 concentration. However, conversion of forest land into fruit orchard cultivation led to a decrease of 5-23% and 4-21% reductions in soil organic carbon and N-stock, respectively. Compared to other soil uses guava, mango and sapota contributed to improving of soil organic carbon stratification index (Bernardi *et al*., 2007)

Nutrients Removal Patterns

Fruit crops by the virtue of their perenniality longer growth period, and developing fruits acting as major sink, are considered nutrient extracting in nature, and hence so nutrient responsive. Interestingly, nutrient uptake pattern (Table 1) by major fruit crops display the fact that K – removal is far higher than N or K, however P-removal is nearly half of N- removal. Crops like banana, citrus, grape, kiwifruit, mango etc are considered highly nutrient exhausive crops, warranting their replenishment on long term basis sustainability in production is to be ensured (Tandon and Muralidharadu, 2010 ; Srivastava and Singh, 2004a, 2004b).

Nutrients Diagnosis for Early Removal

Plant nutritionists across the globe are on their toes to find ways and means to identify nutrient constraints as early in standing crop season as possible while dealing with perennial crops (Srivastava *et al.,* 2014; Srivastava and Singh, 2005). Exciting progress has been made over the years, and accordingly, the basis of nutrient management strategy has experienced many paradigm shifts (Srivastava, 2013a). While doing so, it is being increasingly felt to have some diagnostic tool to identify nutrient constraint as and when it originates by capturing the signals released at subcellular level (Srivastava and Singh, 2003b; 2004a). On the other hand, conventionally used diagnostic tools of identifying nutrient constraints such as leaf analysis**,** soil analysis, juice analysis, and to some extent, metalloenzyme-based biochemical analysis, all have been under continuous use and refinement (Srivastava and Singh, 2001a; 2001c; 2007; Srivastava, 2010a; 2013a). But despite so much of genuine efforts worldwide, no one of these alone provides complete information, except the combined use of leaf and soil analysis, which are used on a comparatively wider scale (Srivastava *et al*., 2006). Establishment of absolute figures of normal, deficient or excess nutrient level are not real, unless the dynamic aspect of leaf nutrient concentration is considered, especially when various nutrients interactions produce resonance within close space of tissue composition (Srivastava, 2013c; Srivastava and Singh, 2008b). Tertiary diagrams and nutrient ratios are early representation of interacting nutrients in the tissue compositional space (Srivastava, 2013c).

Productivity of the plant depends essentially on the nutrient balance and the biological activity (Srivastava *et al*., 2007). There are definite limitations with the leaf analysis application which is largely dependent upon composition of index leaves or any other plant parts. On the other hand, overlapping phenotypic symptoms of plants deficient in N, S or Fe accompanied by lowered chlorophyll concentration makes the distinction between nutrients most often very difficult (Srivastava and Singh, 2006; 2009a). Other example of Fe-deficiency showing typical chlorosis pattern due to interrupted chlorophyll synthesis may be cited, even though chlorophyll chelates Mg rather than Fe. Nutrient deficiency, thus, involves degradative changes in chloroplast components and additional cellular compartments (Srivastava , 2013d). In the light of these information, an integrative physiological approach was suggested. For example, the use of the peroxidase in the diagnosis of Fe- and Mn-deficiencies prompted checking the utility of the

Table 1: Nutrient removal pattern by major fruit crops.

Crops	Nutrients removal (kg/ha)			
	N	P_2O_5	K_20	Yield (t/ha)
Apple(*Malus pumila*)	100.0	45.0	180.0	25.0
Avocado (*Persea americana*)	11.3	3.9	23.4	10.0
Banana(*Musa acuminata* L.)	250.0	60.0	1000.0	40.0
Citrus *spp.*				
Nagpur mandarin(*Citrus reticulate* Blanco)	3.4	0.37	3.72	1.0
Khasi mandarin (*Citrus reticulata* Blanco)	1.81	0.16	2.18	1.0
Coorg mandarin (*Citrus reticulata* Blanco)	3.04	0.27	3.31	1.0
Kinnow mandarin (*C.nobilis*T.x *C. deliciosa* L.)	2.40	0.57	2.35	1.0
Acid lime (*Citrus aurantifolia* Swingle)	1.22	0.21	4.06	1.0
Durian (*Durio zibethinus* L.)	16.1	6.6	33.5	6.7
Grapes (*Vitis vinifera* L.)	170.0	60.0	220.0	20.0
Guava (*Psidium guajava* L.)	120.0	50.0	150.0	20.0
Ber (*Ziziphus mauritiana* L.)	80.0	35.0	125.0	20.0
Kiwifruit (*Actinidia deliciosa Chev.*)	165.0	50.0	273.0	40.0
Mango (*Mangifera indica* L.)	100.0	25.0	110.0	15.0
Papaya (*Caria papaya* L.)	90.0	25.0	130.0	50.0
Pecan (*Carya illinoinensis* W.)	9.7	5.3	5.4	1.2
Pistachio (*Pistacia vera* L.)	30.0	12.0	15.0	0.057
Passion fruit (*Passiflora Spp.* F.)	60.0	15.0	75.0	15.0
Pineapple (*Ananas comosus* L.)	185.0	55.0	350.0	50.0
Sapota (*Achras zapota* L.)	130.0	50.0	170.0	80.0
Strawberry (*Frageria ananassa* D.)	200.0	100.0	900.0	0.75
Walnut (*Jugulans regia* L.)	37.9	10.7	21.2	2.7

Note : In case of citrus, figures are expressed as g/ton fruits.
Source : Tandon and Muralidharadu (2010), Srivastava *et al*. (2008), Chadha and Bhargava (1997), Kemmeler and Hobt (1985), Chadha (2007), Sparks (1989)

method for citrus cultivars grown on differentially fertile soils. Parallel to what was observed with peroxidase, catalase, and aconitase reduced their levels of activity with Fe-deficiency and increased with Mn-deficiency, facilitated to establish the possibility of using the latter enzyme as an alternative mean of diagnosing Fe- and Mn- deficiencies. In the early diagnosis of mineral deficiencies in lemon trees, aconitase has proved as precise as peroxidase, a specific Fe-metalloenzyme or even more so (Srivastava and Singh, 2008a; Srivastava and Singh, 2006; Aseri *et al*., 2008).

Studies have shown that nutritional status of the responsive tissues transmits signals as a regulator of gene expression and at times, that can become a limiting factor in the process of plant development. There are other interesting improvements such as the determination of the nutrient evolution along the vegetative cycle, the substitution of the critical levels by the critical zone, fractionating the nutrient contents (especially the biologically active ones), and finally implementing the biochemical diagnosis. For the latter, the use of activities of specific enzymatic systems and also of metabolites concerned with photosynthesis, has a good potential to improve the accuracy of nutrient constraint diagnosis over other conventional diagnostics. Many studies suggested that the levels of enzymatic activity could be effectively used as an alternative diagnostic tool to leaf analysis. Since functional analysis of the nutrients is, thus, based on the examination of certain molecular compounds linked with their functional activity (Srivastava and Singh, 2006; Aseri *et al*., 2008).

Not surprisingly, proximal sensing through spectral signatures of crop canopies in the field are more complex and often quite dissimilar from those of single green leaves measured under carefully controlled conditions (Van Maarschalkerweerd and Husted, 2015; Das *et al*., 2015). Even when leaf spectral properties remain relatively constant throughout the season, canopy spectra change dynamically depending upon variation in soil type, vegetation, and architectural arrangement of plant components. Vegetation indices provide a very simple yet elegant method for extracting the green plant quantity signal from complex canopy spectra (Adams *et al.*, 2000). Narrower band indices such as the photochemical reflectance index, water band index, and normalized pigment chlorophyll ratio index are examples of reflectance indices that are correlated with certain physiological plant responses, and have promise for diagnosing water and nutrient stress. Such studies hold promise for nutrient like nitrogen. Ironically, micronutrient deficiencies are diagnosed through specific pattern of chlorosis, e.g., Fe versus Mn or Fe/Mn versus Zn backed up by nutrient concentration, capturing symptomatic pattern of chlorosis via spectral norms (signatures) irrespective of crop species further limit this concept towards more wider application (Adams *et al.*, 2000). Spectral reflectance method show significant promise as an alternative to traditional wet chemistry anahbes with regard to ease, costs and speed with wider range of applicalhous including natural resources (Mylavarapu, 2010).

Specific nutrient-signalling pathways, have made it feasible to enhance the uptake and use efficiency of applied nutrient. Nutrient mobility in the phloem from the leaves to the fruits and from the older to the younger fruits is reported in perennial crop like banana. Considering the thumping success of trunk nutrition, won't it be more advisable to analyse the xylem sap or phloem tissue for chemical and microbial constituents since the signal transduction for various nutrients functioning mediate through these tissues only (Srivastava and Singh, 2006). Such attempts could provide some meaningful clues about the presence or absence of those signals to be later utilized in understanding the underlying principles of nutrient stress induced warning mechanism. These studies could lay the solid foundation for developing some probe linked to transpiration stream of plant to act as early warning system for identifying deficiencies of various nutrients. In this regard, functioning of nutrients linked through metalloenzymes and enzyme antioxidants would be the target areas to uphold such novel possibilities as research and development issues related to perennial trees (Srivastava, 2013c; Srivastava *et al.*, 2014).

Potential response of nutrient application is largely jeopardized in the absence of precision-based nutrient diagnostics capable of diagnosing nutrient deficiency early in the season (independent of crop stage) or early signaling towards origin of nutrient deficiency so that strategic changes in fertilizer schedule could be effectively exercised within the same crop season. In this background, it is strongly advocated to develop early warning system for nutrient deficiency by developing metalloenzyme-based probe or trapping the functioning of regulator(s) associated with nutrient signaling at cellular level using genomics. Once such probes are in contact with trunk sap flow, signals of nutrient deficiency can be befittingly used in more effective nutrient management in years to come.

Inorganic Fertilizers and Fertigation

Inorganic fertilizer use: Optimum soil fertility induced plant nutrition has a key role to maximise yield and quality production of perennial fruit crops. The fertilizer requirement of perennial fruit crops is determined by many approaches, including surveys, growers' experience, following the fertilization program of high yielding orchards, replacing the amount of nutrients removed by fruits, deficiency symptoms, applying results from sand or soil culture and field experiments and leaf/soil analysis, with each one of these having distinct advantages and limitations.

Soil provides nearly all the nutrients essential to complete the life cycle of a plant. Different soil properties primarily determine the extent of a fertilizer response (Bronick and Lal, 2005) and the crop rotation on some recently published review articles changes in physico-chemical (Lehoczky *et al.*, 2005) and biological properties of soil (Manna *et al.*, 2005; Srivastava, 2013a). Since the subject of fertilization in horticultural crops is so vast and complex, the readers may refer to the few review articles exclusively devoted to different issues of nutrient management in perennial fruit crops (Lipecki and Barbeæ, 1997; Zahir *et al.*, 2003; Hazarika and Ansari, 2007; Srivastava, 2009, 2013a; Malhotra and Srivastava, 2015; Berg, 2009; Srivastava and Ngullie 2009; Maity *et al.*, 2012; Singh *et al.*, 2012). However, the subject dealing with multipronged action to rhizocompetent microbes in combination of various nutrient sources in fruit crops, is distinctly missing.

Three approaches to fertilizer recommendations that are widely used: the deficiency correction philosophy (originates from nutrient constraints based crop response through nutrient additions to the point of maximum economic yield), maintenance concept (aims to maintain soil fertility level slightly above the point of maximum economic yield), and nutrient removal or balanced philosophy (emphasizes the return to the soil what is removed by the crop to maintain productivity, but often over recommends nutrient need, since it does not take into account for the soil's ability to supply available nutrients to the plants over time) (Srivastava *et al.,* 2008). According to summarized work of Tandon and Tiwari (2008), different fruit crops have been observed remove nutrients (kg/ha) as : 100 N – 45 P – 180 K (1.00 : 0.45:1.80) for 25 tons yield of apple, 250 N – 60 P – 100 K (1.00 : 0.24:4.00) for 40 tons yield of banana, 100 N – 60 P – 35 K (1.00 : 0.60:3.50) for 30 tons yield of citrus, 170 N – 60 P – 200 K (1.00:0.35:1.30) for 20 tons yield of grapes, 100 N – 25 P – 110 K (1.00:0.25:1.10) for 15 tons yield of mango, 90 N – 25 P – 130 K (1.00:0.28:1.40) for 50 tons yield of papaya and 185 N – 55 P – 350 K (1.00:0.30:1.90) for 50 tons yield of pineapple. Hence optimum fertilizer requirement is governed by expected yield level. A soil fertility level optimum for a given yield level, will become sub-optimum at higher yield level. *Optimum macronutrients:* There are varied fertilization and doses schedules followed across a variety of crops (Table 2). Some fertilization plans recommend N application since the beginning of bud break until 6 weeks after full bloom for bearing pear trees (Neto *et al*., 2008), whereas others defend that N must be applied during the whole growth cycle considering that after harvest, trees can still improve their reserves through N uptake from soil. Some authors have studied the fertilizer N use efficiency in pears and apples (Cheng *et al*., 2001; Neilsen *et al*., 2001; Chen *et al*., 2004). Most studies were performed in pots in sand culture, comprising its applicability to field conditions. The re- cycling of N as a result of the decomposition of senescent leaves in soils was only addressed in one study with apple trees (Tagaliavini *et al*., 2004; 2007). Fertilizer N use efficiency by trees increased from the first to the third year, but was generally small (6, 14, and 33%), and estimated N losses were large (89, 46, and 53%, respectively, in the first, second, and third year). Irrigation water and soil provided more N to the trees than fertilizer N (Neto *et al*., 2008).

For many years, several authors have tested the response of different crops to application of different nutrients, especially K, with respect to yield and quality, in many crops like coffee, *Coffea arabica* L.(Silva *et al*., 2001); almond, *Amygdalus communis* L. (Reídel *et al*., 2004); pistachio, *Pistacio vera* L. (Zeng *et al*., 2001); pecan, *Carya illinoinensis* Koch (Worley, 1994); olive, *Olea europaea* (Jasrotia *et al*., 1999) etc. However, such basal fertilizer application technique is greatly conditioned by different soil properties, particularly soil moisture, which affects the mobility of the supplied nutrients (Mengel and Kirkby, 2000). This is mainly attributed to large variation in fertilizer doses to be really effectivein different crops, annual versus perennial fruit crops. Such variation in optimum doses is dictated by climate, soil types, crops, and farming practices in such a way that the correct balance of nutrients necessary for one farm, may be quite different from that necessary for a farm somewhere else in the

Table 2: Optimum nutrient requirement for different fruit crops

Fruit crop (g/tree)	N	P_2O_5	K_2O	Source
Mango (*Mangifera indica* L.)	800	200	300	Sharma *et al*. (2000)
Acid lime (*Citrus aurantifolia* Swingle L.)	800	200	100	Huchche *et al*.(1996)
Guava (*Psidium guajava*L.)	500	250	250	Singh and Singh (2007)
Grape (*Vitis vinifera* L.)*	300	500	1000	Patil *et al*. (2008)
Pomegranate (*Punica granatum* L.)	400	100	300	Ghosh *et al*. (2012)
Ber (*Zyzyphus mauritiana* Lank)	500	200	300	Lal *et al.*(2003)
Aonla (*Emblica officinalis* Gaertn)*	212	55	234	Biswas *et al*. (2012)
Sapota (*Achras zapota* Mill.)	400	100	300	Ghosh *et al*. (2012)
Date palm (*Phoenix dactylifera* L.)	460	500	500	Munir *et al*. (1992)
Fig (*Ficus carica* L.)**	430	200	430	Irget *et al.*(2008)
Phalsa (*Grewia subinaeuqualis* DC)	200	75	100	Sharma *et al*. (2008)
Apple ((*Malus domestica* Borkh.)	1065	650	1500	Singh *et al*. (2011)
Litchi (*Litchi chinensis* Sonn.)***	600	350	140	Pathak and Mitra (2008)
Pear (*Pyrus communis* L.)	1000	2000	1500	Arora and Singh (2006)

* Figures in kg/ha; ** Addition of 280 g/tree Ca;* ** Addition of B at 7 g/plant

world. Therefore, determining the appropriate balance of nutrients to increase crop yield and soil fertility will require localized research.

Optimum micronutrients: Soil application of micronutrients, especially inorganic salts, is often not so effective due to immediate reaction of added micronutrient cations with the mineral portion of soil through various processes like adsorption, fixation, chemical precipitation, etc. (Srivastava and Singh, 2008b) irrespective of crop, annual or perennial in nature. This issue in the past has been addressed in depth. Researchers even today are not unanimous about the efficacy of soil versus foliar fertilization with reference to micronutrients (Srivastava and Singh, 2002, 2003b). Elevating Zn concentration only in the tops of Zn-deficient sour orange (*Citrus aurantium* L.) plants with foliar sprays partially restored normal root growth but clearly was not as effective as the roots absorbing Zn directly from high Zn concentration solutions (Swietlik and Zhang, 1994). Duxbury *et al*., (2006) suggested that micronutrient-enriched seed successfully addressed Zn and Mo deficiencies in rice and wheat, and increased yields beyond those achieved by soil fertilization due to difference in root health activating early seedling emergence.

Interestingly, some recommendations have advocated soil application of micronutrients as one of the means to realize good yield of a crop, e.g., $ZnSO_4$ (300 g/tree) – $FeSO_4$ (300 g/tree) – 600 N – 200 P_2O_5 – 100 K (g/tree) in citrus (Srivastava *et al*., 2006; Srivastava, 2011; Srivastava and Singh, 2015). The micronutrient-based Zn chelater complexes on the other hand are poorly or not at all absorbed by plant roots, as demonstrated through water culture studies (Chaney, 1988; Swietlik and Zhang, 1994). Under field conditions, however, the addition of Zn micronutrient-chelate elevated the amount of exchangeable nutrients in the soil solution due to adsorption and exchange properties of minerals present in soil (Chaney, 1988). Soil application of a micronutrient, e.g., Zn from $ZnSO_4$ is fixed in the surface soil, while the chelated-Zn remains soluble and becomes distributed evenly throughout the soil, as evident from 46-times higher uptake of Zn by a perennial fruit crop like citrus from Zn-EDTA than $ZnSO_4$ on sandy soils (Parker *et al*., 1995). In non-citrus crops like wheat (Modaihsha, 1997), banana (Mostafa *et al*., 2007), pear, apple, grapevine (Sohlegel *et al*., 2006) etc. similar results have been reported. Of late, micronutrient seed treatment including seed priming and seed coating have offered an attractive and easy alternative (Farooq *et al*., 2012). One of the major obstacles of conventional practices of addressing nutritional requirements of perennial fruit crops, either through soil fertilization or through foliar feeding, is the precise diagnosis if the nutrient constraint type, their doses as per crop age and soil type, with the result more often such practices have not been able to facilitate the realisation of potential productivity of fruit crops. Neither any due consideration is given to exploit the nutrient reserve of the plant's rhizosphere (native nutrient supplying capacity of soil) while formulating the fertilizer doses. And most importantly in perennial fruit crops, nutrient doses need to be recommended in tandem with level of fruit yield targeted, a nutrient dose optimum for one fruit yield target, will become suboptimum for higher targetted fruit yield level in couple in subsequent years. Where is such nutrient monitoring tool to keep vigil on nutrient input and output relationship, a kind of nutrient budgeting (Srivastava *et al*., 2008; 2013b).

Fertigation: Intensive growing of perennial fruit crops under high density and ultra-high density plant population has further put an additional pressure on soil fertility conservation. But, concept of fertigation in perennial crops has given a definite edge over conventionally used basin method of irrigation coupled with basal or top dressing of fertilizers within the perimeter of trees (Shirgure and Srivastava, 2013a, Shirgure *et al*., 2014). Fertigation is considered synonymous to nutrient use efficiency which can further be fine tuned with nitrification inhibitors (restrict the microbial conversion of ammonium to nitrate that it is mobile in soils) or plant growth-promoting bio-effectors (microorganisms and active natural compounds involved in plant growth). Thus, in addition to all these, precise soil sampling, whether to take samples from below drippers or in between drippers or mixing soil samples from both the sites and finally, drawing a representative soil samples, find a greater intervention while evaluating nutrient-water interaction in citrus(Srivastava *et al*., 2003, Srivastava and Singh, 2009a, 2009b). Another prominent concern is often raised with regard to threshold values of leaf nutrient diagnostics. Whether or not, optimum leaf nutrient values hold some application efficacy when compared with basin irrigation coupled with basal fertilizer application. Under two contrasting fertilizer application techniques, due to difference in nutrient use efficiency, optimum values could warrant minor adjustments (correction factor), depending upon mode of fertilizer application (Schumann *et al*.,2006).

Agriculture has advanced at a rate that should complement the net food requirement for ever growing population either at regional level or global level. Perennial fruits of tropical nature (Citrus, banana, mango, papaya, guava) have emerged as an alternative source of nutrients to lessen the burden on per capita consumption of cereals crops. Intensive growing of perennial fruit crops under high density and ultra-high density plant population has further put an additional pressure on soil fertility conservation. But, concept of fertigation in perennial crops has given a definite edge over conventionally used basin method of irrigation coupled with basal or top dressing of fertilizers within the perimeter of trees (Shirgure *et al*., 2001a). Reports are candidly visible on fruit yield, quality indices soil fertility improvements coupled water use efficiency (WUE) and fertilizer use efficiency (FUE) covering a variety of fruit crops (Shrigure *et al*., 2001c; 2004b; Srivastava *et al*., 2003). Hence, fertigation has proved beyond doubt about its utility to fruit culture (Solaimali *et al.,* 2005).

Techniques and managements of perennial fruits production are nowadays directed towards the need to conserve resources, energy and a commitment to the environment. In this sense, fertigation has risen as a valuable tool in recent years spreading around the world in major fruit belts. The million dollar question strikes why does fertigation out-perform conventional basin method of irrigation carrying fertilizers. A plant exposed to uniform regime of moisture and nutrient flow within rhizosphere zone has to spend much less energy than the growing conditions constantly changing over time. Fertigation, is thus, energy efficient as well (Shirgure *et al*., 2001d). This has led to an increase in both fertilizer use efficiency and water use efficiency. In the future, fertigation would continue to replace traditional flood irrigation so extensively adopted in water surplus irrigated fruit growing areas (Srivastava *et al*., 2008).

Open hydroponics (OH), a concept synonymous to fertigation is a management practice to address low fertility gravel base soils and saline water. The nutrient uptake is maximised, if the ratio of ions in the solution matches with scion/stock requirements. In Spain, the performance of 'Nova', 'Marisol', and 'Dalite' mandarins at density of 1000 plants/ha under OH system was evaluated (Krugger *et al*., 2000). The average yield in sixth year was 60-75 tons/ha, which is much higher than many conventionally managed orchards. In Israel the response of 'Shamouti' orange under restricted root zone practices, a sprinkler versus drip irrigation treatment with three fertilizer rates, maintained at high moisture status (8-12 Kpa) as a part of intensive OH program. A significant increase in yield in the restricted root zone drip irrigation compared treatment was observed with the highest rate of fertilizer application, 400 kg N/ha. Similar promising results were obtained in South Africa where OH system increased the yield of 'Valencia' orange and 'Clementine' orange by 19% and 25%, respectively, using 16% less water with 25-31% higher returns compared to micro-irrigation with broadcast method of fertilizer application as control (Martinez and Fernandez, 2004). More information on critical issues like capability of manipulate the soil solution as a restricted root zone versus conventional drip irrigation root zone, buffering capacity of soil manipulating specific nutrient ratios at different physiological stages, evaluating orchard productivity-energy relationship through ionic balanced nutrient solution, planting density etc. are further required before OH system under citrus is adopted on a commercially large scale. Therefore, OH and IFP use a more intensive nutrition program that may push the trees into a higher level of vigor and productivity requiring higher nutrient application rates to maintain production, besides higher nutrient use efficiency (Shirgure *et al*., 2000; 2001b; 2013b).

Assessment of off-site movement of applied nutrients and their implications on temporal changes in ground water quality is still in a inconclusive stage, needs an elaborate study in the larger context of sustainability in quality production in addition to in-situ conservation of applied nutrients and nutrient use efficiency. Possibility of integrating liquid biofertilizers (broth using native isolates) as a starter with nutrients in order to further hasten the bioavailablity of nutrients within plant rhizosphere needs to be looked afresh (Ngullie *et al*., 2015; Srivastava *et al*., 2002). Concept of rhizosphere hybridization triggering the nutrient dynamics across crop phenophases then finds its candid way into the curriculum of fertigation oriented research (Srivastava *et al*., 2007, 2010). However, it remains to be seen that net impact on soil solute fluctuations in both soluble and exchangeable phase of soil if nutrient use efficiency has to be targeted, besides an eye on changes in soil salinity buildup. While addressing these concerns, however, the major concern emerges as orchard efficiency vis-a-vis water use efficiency/nutrient use efficiency by adopting variable rate fertilizer application taking into consideration the spatial variability in soil properties in a time domain manner known as automated fertigation or pulse-based fertigation (Shirgure, 2012a).

Large number of studies have, however, demonstrated much better Nutrient-use-efficiency with fertigation in crops like guava (Ramniwas *et al*., 2012), banana (Reddy *et al*., 2002), apple (Banyal and Sharma, 2011), kiwifruit (Chauhan and Chandel, 2008), sweet cherry (Ahmed *et al*., 2010), litchi (Dey *et al*., 2010), sapota (Khot *et al.*, 2012), mango (Singh *et al*., 2009), Banana (Pawar and Dingre,

Table 3: Fertigation requirement of major fruit crops

S. No.	Crops	Fertigation requirement	Crop response
1.	Mango (*Mangnifora indica* L.)Variety : Dashenari10 x 10 m spacing	75% RDF (380 g N-380 g P_2O_5-380 g K_2O/tree) + mulch + drip irrigation in V-area of hasin in 16 year old orchard	Increase in growth yield and quality, in addition to soil fertility
2.	Mango (*Mangnifora indica* L.) Variety : Alphonso2.5 x 2.0 m spacing	100% RDF (120 g N-100 g P_2O_5-100 g K_2O/tree) + 24 trees water/day in 3 year old orchard	Increase in fruit yield and quality
3.	Mango (*Mangnifora indica* L.) Variety : Dashenari10 x 10 m spacing	75% RDF (750 g N-375 g P_2O_5-750 g K_2O/tree) + 100% irrigation through drip based 0.60W/C PE ratio in 30 year old orchard	Improvement in nutrition distribution nutrient use efficiency coupled with better soil moisture distribution and yield
4.	Guava (*Psidium guajava* L.) Variety : Shweta2 x 1 m spacing	75% RDF (30 g N-10 g P_2O_5-10 g K_2O/tree) + 75% irrigation requirement based on CPE in 3 year old meadow orchard	Increase in flowering leaf nutrient status, growth, yield and quality
5.	Guava (*Psidium guajava* L.) Variety : Shweta2 x 1 m spacing	100 RDF + surface drip irrigation at 1.0 W/CPE ratio	Increase in growth and fruit yield response
6.	Pomogranate (*Puncia granatum* L.) Variety : Bhgwa2 x 2 m spacing	100% RDF (200 g N-200 g P_2O_5-500 g K_2O/tree using water soluble 19:19:19 fertilizer) + 100% irrigation at alternate daythrough drip irrigation in 4 year old orchard	Better soil moisture distribution, fruit yield and quality
7.	Pomogranate (*Puncia granatum* L.) Variety : Bhgwa2 x 2 m spacing	50% RDF using water soluble fertilizer + drip irrigation at 100% CPE in 2 year old orchard	Improvement in flowering soil available nutrients and fruit yield
8.	Almond (*Prunus dulcis* L.) Variety : Waris	75% RDF (330 g N-45 g P_2O_5-455 g K_2O/plant through water soluble fertilizers) + drip irrigation based on pan evaporation in 8 year old orchard	Increase in growth response and yield in addition to soil fertility
9.	Banana (*Musa paradisica* L.) Variety : Robusta	Fertigation along with microbial consortium	Increase in uptake of secondary nutrients and micro nutrients besides fruit yields
10.	Banana (*Musa paradisica* L.) Variety : Robusta	100% RDF (13 g N-40 g P_2O_5-13 g K_2O/plant using urea, DAP and KNO_3 + drip irrigation at 1.0 IW/CPE	Improvement in growth, yield and quality
11.	Apple (*Malus domestica Borkh* L.) Variety : Gala on M-26 rootstock 2 x 4 m spacing	40 g N-17.5 g P_2O_5 using ammonium nitrate and ammonium pyrophosphate (10 N – 15 P – 0 K) in 5 year old orchard	Improved root distribution and alleviated K-deficiency
12.	Apple (*Malus pumilaalill* L.) Variety : Gala on M-9 rootstock 3.5 x 1.25 m spacing	60% RDF + irrigation based on pan evaporation	Improved growth and yield initially with N-fertigation and later NPK fertigation proved better
13.	Strawberry (Fragaria x anananssa) Variety : Chandler25 x 50 m spacing	75% RDF (112 kg N-75 kg P_2O_5-90 kg K_2O/ha + 100% ETC	Increase in growth yield and quality
14.	PapayaVariety : Taiwan2.5 x 2.0 m spacing	100% RDF (250 g N-250 g P_2O_5-500 g K_2O/plant) + 50 mm CPE as 100%CPE	Improvement in growth, yield and quality
15.	Acid lime (Citrus aurantifolia Swimgle) Variety : Kagzi lime6 x 6 m spacing	75% RDF (450 g N-150 g P_2O_5-175 g K_2O/tree) + irrigation at 30% AWC depletion	Improvement in growth, yield, quality and leaf nutrient composition
16.	Nagpur mandarin (Citrus reticulata Blanco) Variety : Nagpur mandarin6 x 6 m spacing	80% RDF (48 g N-160 g P_2O_5-240 g K_2O/tree) + irrigation at 20% AWC depletion	Increase in growth, yield, quality, leaf nutrient composition and soil fertility

2013), citrus (Shirgure *et al*., 2002; 2003b; Srivastava *et al*. 2012; 2015b), papaya (Jeyakumar *et al*., 2010), pomegranate (Haneef *et al*., 2014; Shanmugasundaram and Balakrishnamurthy, 2015), Peach (Baldi *et al*., 2010) etc. using various bases of drip irrigation scheduling and NPK-based fertilizers, but without much success with micronutrient fertigation. These studies have provided a wealth of information with unanimous result that fertigation reduced both irrigation and nutrient requirement by 30-50% compared to conventional split application within plant basin. Open hydroponics (Krugger *et al*., 2000;Martinez and Fernandez, 2004) and variable rate fertilizer linked site specific nutrient management (Zaman and Schumann, 2006; Johnston *et al*., 2009; Srivastava and Singh 2015; Srivastava *et al*., 2006) in fruit crops like citrus, olive, avocado, coconut etc. have also started showing their utility in improving fertilizers use efficiency to various dimensions.

Several experiments were carried out in Egypt and Germany to study whether fruit shrubs and trees can be fertilized by injection through the trunk. Results showed that dicotyledonous vascular trees (mango and grapevine) can be fully fertilized by injection through xylem. Only 5-10% of the levels used in soil fertilization were sufficient for good growth and high yield. Growth of the injection-fertilized mango (*Mangifera indica* var. 'Sukkary white') trees was 20-25% higher than soil fertilized plants while in grapevine (*Vitis vinifera* vars.

Panwar *et al*., 2007; Prakash *et al*., 2015; Adak *et al*., 2014; Ramniwas *et al*., 2013; Sharma *et al*., 2013;

Mohd Haneef *et al*., 2014; Shanmugasundaram *et al*., 2013; Dinesh Kumar and Ahmed 2014;Senthilkumar *et al.* 2014; Mahendran *et al*., 2013; 11. Neilsen *et al.,* 1996; Treder, 2006; Kachwaha *et al*., 2013;

Deshmukh Hardaha, 2014; Shirgure *et al*., 2016b; Srivastava *et al*., 2003;

'White Riesling' and 'Spacet Burgunder') fruit yield increases were 32-49% higher compared to soil fertilization Fruits quality of grapevine clusters assessed (juice Brix, pH, reduced sugars, total acidity, grape vinegar, apple vinegar, ethanol and glycerine content) of the plants fertilized through injection was better that those fertilized through soil. Grapevine fresh juice content of the reduced sugars and ethanol increased by 7.5-11.9 and 41.4-50%, respectively while the total acidity decreased by 6.2-19.7%. Using injection fertilization, there was no need to control weeds because they never competed with tree roots for nutrient absorption. Since there is no soil fertilization, there was no use of herbicides or pesticides, nor leaching of these compounds to underground water, which was expected to be clean enough to be used as drinking water with no or less health hazards (Shaaban, 2009).

Nutrient and irrigation partitioning vis-a-vis crop phenology: Tailoring the nutrient and water application as per crop phonological stages is a pre-requisite to an elevated nutrient use efficiency (Shirgure, 2013b; Shirgure and Srivastava, 2014; 2016a; Srivastava *et al*., 2009; 2014). And occurrence of nutrient constraint or water stress at any - phenological growth stage in any perennial fruit crop e.g. citrus, could jeopardize the incentive accruing through other management practices. Studies on dynamics of different nutrients and water application (ER-based) across all six growth stages (January-February as Stage I, March-April as Stage II, May-June as Stage III, July-August as Stage IV, September-October as Stage V and November - December as Stage VI) of Nagpur mandarin trees grown on alkaline calcareous Haplustert, have shown some interesting observations (Table 4).

Different treatments having varying schedules of fertilization as well as irrigation based on evaporation rate influenced both the production oriented parameters viz., canopy volume, fruit yield and fruit quality parameters (Table 4)through treatments T_2 and T_4, respectively. These studies revealed application of 30% N , 40% P and 10% K out of total requirement at fruit set stage ; 30% N , 35% P and 10% K at marble size stage; 30% N , 25% P and 55% K during fruit development stage and remaining 10% N and 25% K during fruit maturity colour break stage. While, irrigation requirement across crop phenophases showed 9%, 18%, 45%, 20% and 8% out of total water requirement needs to be given to corresponding stages of flowering, fruit set, fruit development, harvesting and colour break stage. Thus, such studies on partitioning nutrient and water requirement across crop phonological stages would lay a sound research and development strategy for scheduling fertigation for any perennial fruit crop with improved demand-driven nutrient-use-efficiency (Srivastava, 2009, 2011). Such attempt on nutrient and water partitioning has been attempted in other fruit crops like apple, banana, grapes, mango crops but distinctly lacking in other perennial fruit crops to develop crop demand oriented fertigation scheduling including variable rate fertigation technique. Reports are candidly visible on fruit yield, quality indices soil fertility improvements coupled water use efficiency and nutrient-use-efficiency covering a variety of fruit crops (Panigrahi *et al*., 2012a, 2012b; Panigrahi and Srivastava, 2016). Hence, fertigation has proved beyond doubt about its utility to fruit culture.

Emitters arrangements of drip irrigation: Soil moisture deficit stress-induced reduction in fruit yield and quality in citrus is most common across major commercial citrus cultivars, irrespective of soil and climate (Shirgure and Srivastava, 2012a). At the same time, it is equally important to rationalise the water use synchronising right amount of water across different critical growth stages, collectively to enhance the growth, yield and fruit quality (Shirgure and Srivastava, 2012b). The common methods of applying irrigation water to the citrus orchards include: basin, micro-jet irrigation and drip irrigation (Cevik *et al*., 1987). Surface basinirrigation using the circular ringgenerally followed in early establishment phase of trees (Shirgure, 2012b; 2013a). Drip irrigation have the distinct advantage over surface irrigation methods, due to more constant, uniform and complete wetting of effective rootzone of the plant(Dasberg 1995) in addition to better water use efficiency at lesser expense of energy(Kanber *et al*., 1996). Uneven water distribution and associated complexity involved in application of water, the importance of surface irrigation in perennial crop like citrus is fast diminishing very fast(Peng and Rabe 1999; Shirgure *et al*., 2001a; 2003a). While, under tree drip irrigation with more number of emitters, better option having more uniform distribution of soil moisture and accurate amount of irrigation water has made definite inroads to exploit for better crop responses. With the drip irrigation systems, water savings may be obtained because water is applied only to the active rootzone, leaving the inter-plant area un-irrigated (Shirgure and Srivastava, 2015).

Of late, there is a gradual shift from surface irrigation involving furrow irrigation to under-tree surface drip irrigation systems (Smajstrala 1993; Dasberg 1995). Various developments in surface drip irrigation systems have been reported from time-to-time with regard to improvements in water-use-efficiency *vis-a-vis* quality citrus production worldwide (Grieve 1988; Germana 1994; Cevik *et al.,* 1987). However, some studies in citrus comparing irrigation methods and irrigation schedules showed higher yield and quality with better performance using drip irrigation systems in India (Kumar and Bhojappa 1994; Shirgure *et al.,* 2004a; 2004c) our studies showed maximum plant canopy

Table 4: Response of Stagewise Nutrient and Water Treatment on Tree Volume, Fruit Yield and Fruit Quality Parameters of Nagpur Mandarin(Pooled data 2006-12)

Treatments	Tree volume(m^3)	Fruit yield(kg/tree)	Fruit quality (%)		
			Juice	TSS	Acidity
Stagewise nutrient requirement					
T_1 (100% N and 50% K upto stage IV; 100% P upto stage III; 50% K divided at V and VI)	19.62*(16.47)	42.77**(11.85)	45.79	8.58	0.81
T_2(80% N, 100% P and 50% K upto stage IV; 20% N and 50% K divided at V and VI)	19.11(15.91)	56.52(15.66)	48.01	9.40	0.71
T_3(100% N, 100% P and 30% K upto IV; 70% K divided at V and VI)	19.31(13.51)	45.41(12.58)	46.03	8.66	0.76
T_4(67% N and 100% P upto IV; 33% N and 100% K at V)	19.47(16.51)	46.24(12.81)	46.99	8.54	0.80
CD (*P=0.05*)	0.19	1.95	0.86	0.26	0.05
Stagewise water requirement					
T_1 (30% ER in stage I, III and V + 40% ER in stage II, IV and VI)	63.22 *(61.06)	34.62**(9.59)	36.10	9.46	0.81
T_2 (40% ER in stage I, III and V + 60% ER in stage II, IV and VI)	69.53(67.28)	55.09(15.26)	36.80	9.52	0.80
T_3 (60% ER in stage I, III and V + 80% ER in stage II, IV and VI)	71.18(68.01)	65.45(18.13)	37.42	10.04	0.77
T_4 (80% ER in stage I, III and V + 80% ER in stage II, IV and VI)	73.75(70.05)	74.11(20.53)	39.00	10.09	0.78
CD (*P=0.05*)	0.30	1.94	1.03	0.38	0.07

*Figures in parenthesis indicate initial values; ** Figures in parenthesis indicated fruit yield in tons/ha
Source: Shirgure *et al*. (2016b), Srivastava *et al*. (2014)

Table 5: Plant canopy volume, fruit yield and fruit quality of Nagpur mandarin in response to different treatments (Pooled data: 2010-13)

Treatments	Plant growth			Fruit yield			Fruit quality		
	Plant height (m)	Canopy volume(m^3)	No. of fruits	Average fruit weight (g)	Yield (tons/ha)	Juicecontent (%)	TSS(%)	Acidity (%)	TSS/ acidityratio
T_1	5.2	69.89	580	139.5	24.02	41.95	9.84	0.80	12.3
T_2	5.4	79.98	583	143.4	23.14	40.91	8.87	0.85	10.4
T_3	5.8	84.96	724	142.7	28.78	42.90	10.16	0.72	14.1
T_4	5.0	81.87	676	147.3	27.26	39.10	10.43	0.75	13.9
LSD(*P*=0.05)	0.32	1.68	32	2.1	1.32	1.01	0.40	0.06	-

- T_1 (4 lph six emitters per plant in hexagonal arrangement), T_2 (4 lph three emitters on double lateral arrangement at 1 meter spacing), T_3 (4 lph eight emitters on single lateral in octagonal arrangement), T_4 (3 lph inline emitters at 0.75 meter spacing on the lateral and double lateral arrangement 3 feet apart from the trunk)
- Note: lph stands for litre per hour

Source : Shrigure and Srivastava (2015), Shirgure *et al*.(2016a)

volume was observed with T_3 (84.96 m^3) followed by T_1 (81.87 m^3) due to better soil moisture distribution coupled with higher nutrient availability-induced changes in leaf nutrient concentration in the former treatment. While maximum fruit yield was observed with treatment T_3 (28.78 tons/ha) followed by T_4 (27.26 tons/ha). The TSS/acidity ratio as the major fruit quality parameter followed the same pattern of response. Similarly, leaf analysis displayed maximum concentration of nutrients in treatment T_3 compared to other treatments. These observations suggested T_3 as the best emitters arrangement for harnessing maximum water-use-efficiency vis-a-vis quality production of Nagpur mandarin (Table 5).The conventional drip-irrigation method does not cover even 60-70 % soil water regime of the basin area of Nagpur mandarin compared to requirement of higher soil moisture to be constantly maintained throughout the period of plant growth and fruit development (Shirgure *et al.,* 2001a). With expanding scarcity of available irrigation water, intervention of drip irrigation is gradually gaining momentum in citrus orchards (Koo and Smjstrala, 1984).

Interactive effect of irrigation schedules and fertigation levels: There are two major production constraints viz., irrigation and fertilization warranting right amount of water and nutrients to be added across different growth stages to enhance the growth, yield and fruit quality of Nagpur mandarin (Bielorai *et al.,* 1984; Shirgure *et al.,* 2016a; 2016b). The water need for 6-year-old *Kinnow* mandarin, varied from 539-1276 mm depending upon the level of irrigation with average consumptive use from 66.7-132.5 cm for *Kinnow* mandarin. (Mageed *et al.,*1988), in contrast, the water requirement of young, middle age and mature mandarin trees was 651.9, 849.0 and 997.3 mm/year, respectively, under clean cultivation (Ghadekar *et al.,* 1989). Past research work on irrigation scheduling and fertigation in perennial fruit crop like citrus indicated the irrigation at 65% field capacity caused drought injury symptoms, excessive defoliation and less water consumption compared to irrigation at 85% field capacity in citrus. It was observed that partial fertigation of N and K resulted in lower N content in leaves with higher total soluble solids and acid concentration in juice and the yield remained unaffected in Valencia orange (Koo and Smjstrala 1984,Smajstrla *et al.*,1986, Ferguson 1990, Smajstrla 1993, Panigrahi *et al*., 2008; 2012c). Fertigation has shown good responses on growth, yield, quality and uniform distribution pattern of applied water as well as nutrients within the active rootzone compared to band placement involving localized fertilization (Shirgure *et al*., 2000; Shirgure and Srivastava, 2013b). Interestingly yield efficiency computed as fruit yield per unit canopy volume was also observed maximum (0.26) with treatment carrying irrigation at 80% ER and fertigation with 80% RDF. The sustained productivity of Nagpur mandarin can be achieved with irrigation scheduled at 80 % ER along with fertigation technology at 80 % RDF without any potential nutrient mining (Table 6).

Table 6: Effect of irrigation and fertigation schedules on growth, yield, leaf nutrient composition and plant available nutrients in Nagpur mandarin (Pooled data : 2010-13)

Treatments		Canopy volume (m^3)	Yield(t/ha)	Yieldefficiency (t/m^3)	Leaf nutrient composition (%)			Plant available nutrients (mg/kg)		
Irrigation	Fertigation				N	P	K	N	P	K
I_1	F_1	71.8	8.4	0.12	2.03	0.08	0.92	115.8	11.8	241.3
	F_2	71.3	9.9	0.14	2.07	0.08	0.97	115.8	11.1	243.3
	F_3	74.2	10.9	0.15	2.10	0.09	0.98	116.8	11.8	246.3
I_2	F_1	72.8	11.0	0.15	2.15	0.09	1.00	117.1	11.3	251.8
	F_2	72.3	14.8	0.20	2.16	0.10	1.07	119.3	13.0	231.8
	F_3	74.9	19.2	0.26	2.21	0.10	1.17	123.8	14.8	261.2
I_3	F_1	74.1	12.6	0.17	2.16	0.09	0.98	121.1	14.1	248.1
	F_2	73.8	15.4	0.21	2.16	0.09	1.03	120.2	14.0	241.1
	F_3	74.4	17.6	0.24	2.17	0.08	1.08	122.3	14.2	252.3
LSD	(I)	0.95	1.2	---	0.04	0.006	0.04	1.2	0.70	1.2
(*P* = 0.05)	(F)	0.24	0.71		0.03	NS	0.02	0.8	0.6	1.8
	(I x F)	0.14	023		0.06	NS	0.07	2.1	41.40	3.2

I_1, Irrigation at 70% ER; I_2, Irrigation at 80% ER; I_3, Irrigation at 90% ER; F_1, Fertigation at 60 % RDF; $F_{2,}$ Fertigation at 70 % RDF and F_3, Fertigation at 80 % RDF. Source:
Source : Shirgure *et al*. (2016b)

Development of Rationale of Fertilizer Use

Of late, there has some distinct headways towards development of rationale of fertilizer use. In this regard, exploiting spatial variability has huge practical significance. Characterizing spatial variability of soil physico-chemical properties is a fundamental element of : i. soil quality assessment, ii. modeling non-point source pollutants in soil and iii. Site-specific crop management. The heterogeneity of soil physico-chemical properties has been known since the classic study of (Nielsen *et al.,* 1973), which characterized the spatial variability of soil-water properties for a 150 ha field at the University of California's West Side Field Station in the San Joaquin Valley. The protocols developed by (Corwin and Lesch 2005) for site specific evaluation of soil properties (EC appraisal) comprised of eight general steps : i. site description, and EC_a, survey design; ii. EC_a data collection with mobile GPS-based equipment; iii. Soil sampling design; iv. Soil core sampling; v. laboratory analysis; vi. calibration of EC_a to EC_e; vii. spatial statistical analysis and viii. GIS database development and graphic display. Of late, (Siqueira *et al*., 2010) suggested that relief may be considered an integrating factor that expresses the interaction of various soil and plant attributes. The study further analyzed the potential use of landforms to predict the variability of soil and orange attributes, with large spatial variability in soil and temporal variability in orange quality.

Soil Fertility - Based Spatial Variogram as a Decision Support Tool

Soil fertility - based spatial variograms were developed based on georeferenced grid -based soil sampling. As many 56 grid based plants identified within the Nagpur mandarin orchard using two layered variograms (spatial variogram for fruit yield and other soil test values for various nutrients and delineating different management zones using DRIS-based analysis and formulated variable rates of fertilizer doses depending upon the soil test value of various grids (Srivastava 2013b) These variable rates of fertilizer doses comprised of:

- 200 g N – 100 g P_2O_5 – 200 g K_2O – 100 g $FeSO_4$ – 100 g $MnSO_4$ – 100 g $ZnSO_4$
- 400 g N – 150 g P_2O_5 – 300 g K_2O – 200 g $FeSO_4$ – 200 g $MnSO_4$ – 300 g $ZnSO_4$
- 600 g N – 200 g P_2O_5 – 400 g K_2O – 300 g $FeSO_4$ – 300 g $MnSO_4$ – 300 g $ZnSO_4$

After the application of variable rates of fertilizers, the difference in yield responses over initial values, and likewise differences in soil test values with respect to $KMnO_4$-N, Olsen-P, NH_4OAc-K, DTPA-Fe, DTPA-Mn, DTPA-Cu and DTPA-Zn were computed and summarized as below highlighting the magnitude of different types of responses:

Response variability	Yield (qha[1])	N(mg kg^{-1})	P(mg kg^{-1})	K(mg kg^{-1})	Zn(mg kg^{-1})	Fe (mg kg^{-1})	Mn (mg kg^{-1})
Fertilizer doses : 200 g N – 100 g P_2O_5 – 200 g K_2O – 100 g $FeSO_4$ – 100 g $MnSO_4$ – 100 g $ZnSO_4$							
Initial	85.79	114.0	12.00	147.0	0.82	11.64	8.72
Final	163.74	116.8	12.78	152.3	0.88	12.42	9.68
Difference	37.45	2.8	0.78	5.3	0.06	0.77	0.96
Fertilizer doses : 400 g N – 150 g P_2O_5 – 300 g K_2O – 200 g $FeSO_4$ – 200 g $MnSO_4$ – 200 g $ZnSO_4$							
Initial	90.63	106.8	9.95	120.5	0.66	8.65	5.97
Final	102.30	113.3	11.36	128.9	0.78	10.35	8.12
Difference	11.68	6.63	1.40	8.41	0.12	1.70	2.15
Fertilizer doses : 600 g N – 200 g P_2O_5 – 400 g K_2O – 300 g $FeSO_4$ – 300 g $MnSO_4$ – 300 g $ZnSO_4$							
Initial	47.82	98.5	8.83	110.3	0.51	8.58	6.11
Final	85.79	117.3	11.07	138.9	0.87	11.29	9.24
Difference	37.95	19.01	2.23	28.9	0.35	2.70	3.30

Source: Srivastava *et al.* (2014), Srivastava *et al.* (2015)

The changes in area distribution either with regard to fruit yield or with regard to different nutrients ($KMnO_4$-N, Olsen-P, NH_4OAc-K, DTPA-Fe, DTPA-Mn and DTPA-Zn)as a result of variable doses of fertilizer application (Table 7) further revealed some distinct reorientation. Out of different grid sizes, the grid size upto 40 x 40 m, 42.42 – 43.02% area of the identified orchard (Total area of 11,184 sq.m) was observed to possess optimum fruit yield. While, sampling with both grid size of 60 x 60 m, as high as 68.33% area was observed having optimum yield, suggesting further the optimum grid size of 40 x 40 m, using all the grid sizes (20 x 20 m to 60 x 60 m) no significant area under any category was observed to be significantly influence since most of the orchard area 99.77 to as much as 10% area was observed within the optimum range. Across all the three grid size sampling from 20 x 20 m to 60 x 60 m, an area ranging from 99.83 to as high as 100% area was observed to fall within optimum range. On the other hand, zoning of NH_{-4}OAc-K based on variograms developed through soil sampling via three grid sizes of 20 x 20 m, 40 x 40 m and 60 x 60 m, 73.93%, 72.40% and 73.14% area were observed within low range. While rest of the 26.07%, 27.60% and 26.86% area, respectively showed NH_{-4}OAc-K within optimum range at grid size of 20 x 20 m, 40 x 40 m and 60 x 60 m. Under grid size of 20 x 20 m, 40 x 40 m and 60 x 60 m, respectively, 29.54%, 21.50% and 25.67% area of the orchard was observed displaying optimum range of DTPA-Fe. While other 70.47%, 78.50% and 74.33% area of the orchard showed low level of DTPA-Fe under grid size sampling of 20 x 20 m, 40 x 40 m and 60 x 60 m. DTPA-Mn showed a distant variation under differing zone when compared across three grid size sampling. Under the grid size sampling 20 x 20 m, 6.34%, 44.05 and 49.60% area of the orchard was registered to fall within deficient, low and optimum range, respectively. Likewise under grid size of 40 x 40 m, 3.5%, 39.56% and 56.86% area of the orchard, respectively, showed low, optimum and optimum range of DTPA-Mn. These changes were well corroborated with changes in fruit yield zones (Fig. 1)

Table 7: Distribution of area statistics (Sq. m) of nutrients under different grid size sampling at village Ladgaon, Katol, Nagpur (Total Area: 11,184 sq.m)

Nutrientindices	Grid size (m)					
	20 x 20		40 x 40		60 x 60	
	Area	% age	Area	% age	Area	% age
Iron						
	(m^2)		(m^2)		(m^2)	
Deficient	0.0	0.0	0.0	0.0	0.0	0.0
Low	7881.5	70.47	8780.0	78.50	8313.0	74.33
Optimum	3302.5	29.53	2404.0	21.50	2871.0	25.67
High	0.0	0.0	0.0	0.0	0.0	0.0
Excess	0.0	0.0	0.0	0.0	0.0	0.0
Manganese						
Deficient	711.8	6.34	400.3	3.58	108.5	0.97
Low	4926.7	44.05	4424.5	39.56	6561.0	58.67
Optimum	5545.0	49.60	6359.3	56.86	4514.5	40.36
High	0.0	0.0	0.0	0.0	0.0	0.0
Excess	0.0	0.0	0.0	0.0	0.0	0.0
Zinc						
Deficient	0.0	0.0	0.0	0.0	0.0	0.0
Low	1456.5	13.02	494.0	4.42	564.3	5.04
Optimum	9727.5	86.98	10690.0	95.58	10619.8	94.96
High	0.0	0.0	0.0	0.0	0.0	0.0
Excess	0.0	0.0	0.0	0.0	0.0	0.0
$KMNO_4$-N						
Deficient	0.0	0.0	0.0	0.0	0.0	0.0

Contd.

Nutrientindices	Grid size (m)					
	20 x 20		40 x 40		60 x 60	
	Area	% age	Area	% age	Area	% age
Low	25.5	0.23	0.0	0.0	15.8	0.14
Optimum	11158.5	99.77	11184.0	100	11168.3	99.86
High	0.0	0.0	0.0	0.0	0.0	0.0
Excess	0.0	0.0	0.0	0.0	0.0	0.0
Olsen-P						
Deficient	0.0	0.0	0.0	0.0	0.0	0.0
Low	0.0	0.0	0.0	0.0	0.0	0.0
Optimum	11177.0	99.94	11164.5	99.83	11184.0	100
High	7.0	0.06	19.5	0.17	0.0	0.0
Excess	0.0	0.0	0.0	0.0	0.0	0.0
NH_4OAc-K						
Deficient	0.0	0.0	0.0	0.0	0.0	0.0
Low	8268.8	73.93	8097.0	72.40	8180.3	73.14
Optimum	2915.3	26.07	3087.0	27.60	3003.8	26.86
High	0.0	0.0	0.0	0.0	0.0	0.0
Excess	0.0	0.0	0.0	0.0	0.0	0.0
Fruit yield						
Deficient	62.3	0.56	3.3	0.03	3.0	0.02
Low	6377.3	57.02	6369.3	56.95	7663.5	68.53
Optimum	4744.5	42.42	4811.5	43.02	3517.5	31.45
High	0.0	0.0	0.0	0.0	0.0	0.0
Excess	0.0	0.0	0.0	0.0	0.0	0.0

Source: Srivastava *et al*. (2014; 2015)

Development of Fertilizer Prediction Models

Basic data developed for targeted yield using prediction model

Nutrients	Parameters		
	NR	CS	CF
Nitrogen	4.49	81.5	34.3
Phosphorous	0.27	65.0	5.55
Potassium	1.10	21.1	64.9
Zinc	0.01	30.4	1.23
Iron	0.04	8.69	2.06
Manganese	0.01	1.98	1.30

Where, NR (Nutrient requirement) computed as the amount of nutrient required (kg) to produce one quintal of fruits, using formula: NR = Uptake of nutrient (kg ha^{-1})/Fruit yield (q ha^{-1}) CS (Percent contribution from soil to total nutrient uptake) computed as the amount of per cent contribution of soil nutrient, using formula: CS = Uptake of nutrient (kg ha^{-1}) by fruits x 100/ Available soil test value for nutrient (kg ha^{-1}) from control treatment CF (Percent contribution from fertilizer to total uptake) computed as the amount of per cent contribution of fertilizer nutrient, using the formula: CF = Uptake of nutrient (kg ha^{-1}) from fruit crop)-(Avail. STV from nutrient (kg ha^{-1}) x CS/100 x 100 / Fertilizer nutrient applied (kg ha^{-1}).The Following predication equations for computing fertilizer doses were developed:

i. Fertilizer Nitrogen = 13.09 (Targeted fruit yield) – 2.37 (Soil test value for $KMnO_4$-N))

ii. Fertilizer Phosphorous = 4.08 (Targeted fruit yield) – 26.83 (Soil test value for Olsen-P)

iii. Fertilizer Potassium = 1.69 (Targeted fruit yield) – 0.39 (Soil test value for NH_4OAc-k)

iv. Fertilizer Zinc=0.98 (Targeted fruit yield) - 24.73 (Soil test value for DTPA-Zn)

v. Fertilizer Iron = 1.94 (Targeted fruit yield)- 4.21 (Soil test value for DTPA-Fe)

vi. Fertilizer Manganese=0.77 (Targeted fruit yield)-1.52 (Soil test value for DTPA-Mn)

Using these fertilizer prediction equation, ready reckoner (Table 8) developed for different soil test values-based fertilizer recommendation in relation to different target fruit levels, have shown good promise to rationalized the soil test-crop response based fertilizer recommendations (Srivastava *et al*., 2014; 2015).

Tailoring Fertilizer Requirements

Experiments have shown that soils initially rich in fertility developed a variety of nutrient constraints following the non-synchronisation in demand and supply of nutrients with advancing orchard age (Tiwari, 2007; Srivastava and Singh, 2015). For example when exchangeable K is not rapidly replenished, crops start drawing on the non-exchangeable K, resulting in soil mining and depletion in soil K reserve (Srivastava *et al*., 2006; Srivastava, 2011). A nutrient level sufficient for one particular productivity level may not hold sufficient for other higher productivity levels. An extensive survey of 18,000 ha area of Nagpur mandarin orchards of central India showed large scale deficiency of three nutrients viz., N, P and Zn, with most of the sites expressing multiple nutrient deficiencies (Srivastava and Singh, 2015). Reduced longevity of commercial citrus orchards due to varying nutritional constraints is one of the major production related constraint heavily responsible for poor orchard efficiency (Srivastava *et al*., 2006; 2009). On the other hand, conventionally designed long term fertilizer trials revealed that: i. omission of limiting macro- or micronutrients led to their progressive deficiencies due to heavy removals; ii. sites initially well supplied with P, K or S become deficient when continuously cropped using N alone and iii. fertilizer rates considered optimum still resulted in nutrient depletion at higher productivity levels, if continued, become sub-optimum rates (Tiwari, 2002).

Table 8: Soil test -based fertilizer recommendation in relation to different targeted fruit yield of Nagpur mandarin as a ready reckoner

Soil test value(kg/ha)	Targeted fruit yield (q/ha)				
	100	150	200	250	270
Soil nitrogen test-based fertilizer recommendation					
100	107.2	172.65	238.10	303.55	369.0
200	101.27	166.72	232.17	297.62	363.07
300	95.35	160.80	226.25	291.70	357.15
400	89.42	154.87	220.32	285.77	345.30
500	83.50	148.95	214.4	279.85	315.22
Soil phosphorous test-based fertilizer recommendation					
5	345.85	585.85	825.85	106.5	130.5
10	211.7	451.7	691.7	931.7	117.1
15	77.55	317.55	557.55	797.55	103.7
20	-56.6	183.4	423.4	663.4	903.4
25	-190.8	49.25	289.25	529.25	769.25
Soil potassium test-based fertilizer recommendation					
100	130.10	214.70	299.30	383.90	468.50
200	91.00	175.60	260.20	344.80	429.40
300	51.90	136.50	221.10	305.70	390.30
400	12.80	97.40	182.00	266.60	351.20
500	-26.30	58.30	142.90	227.50	312.10
Soil zinc test-based fertilizer recommendation					
0.89	75.84	124.84	173.84	222.84	242.44
1.79	53.68	102.68	151.68	200.68	220.28
2.68	31.53	80.53	129.53	178.53	198.13
3.58	9.37	58.37	107.37	156.37	175.97
4.48	-12.79	36.21	85.21	134.21	153.81
Soil iron test-based fertilizer recommendation					
8.96	156.28	253.28	350.28	427.88	486.08
13.4	137.42	234.42	331.42	409.02	467.22
17.9	118.56	215.56	312.56	390.16	448.36
22.4	99.70	196.70	293.70	371.30	429.50
26.8	80.84	177.84	274.84	352.44	410.64
Soil manganese test-based fertilizer recommendation					
11.2	59.98	98.48	136.98	175.48	190.88
20.1	46.36	84.86	123.36	161.86	177.26
29.1	32.74	71.24	109.74	148.24	163.64
38.0	19.12	57.62	96.12	134.62	150.02
44.8	8.90	47.40	85.90	124.40	139.80

Source: Srivastava *et al.* (2014; 2015)

Knowing the required nutrients for all stages of growth, and understanding the soil's ability to supply those needed nutrients are critical to profitable crop production. The recommendations on fertilizer application may not, however, produce the same magnitude of results when practiced on an orchard of large area, because of its inability to accommodate variation in soil fertility status (Srivastava and Singh, 2001a). Slight changes in the nature of soil, local climate, and agronomic practices etc. may seriously affect the nutrient utilization capacity of the plant. However, application of a single rate of nutrients may result in over-application of nutrients at some sites and under-application at others often lead to reduced fertilizer use efficiency. Under such circumstances, site specific nutrient management (SSNM) is adopted in orchards requiring different treatment in patches as per the nature of surface and sub-surface soil properties so as to improve the orchard efficiency (Average yield of specified trees in relation to average orchard yield) in ultimate terms (Srivastava *et al.*, 2007). Therefore, fertilizer application should be tailored according to the crop's need keeping in view, the capacity of these soils to fulfill various demands (Srivastava *et al.*, 2006, 2009). To achieve this, it is necessary to keep an overall nutrient balance in relation to total crop load. This may indicate the need for the application of different nutrients at specific times, in a particular order to derive the maximum benefit from the application of a given quantity of nutrients keeping in mind the spatial variability in availability of different nutrients within an orchard. In this background, the present experiment was carried out to determine fertilizer doses of Nagpur mandarin grown on a orchard having large spatial variability in soil fertility under sub-humid tropical climate of central India.

Conventional nutrient management practices in perennial crop like citrus hardly exploit the spatial variability in soil fertility, with the result, fertilizer recommendation is always inclined to reduced fertilizer-use-efficiency. Efforts were made to develop soil fertility variogram-based site specific nutrient management (SSNM) practices in Nagpur mandarin (*Citrus reticulata* Blanco) grown on smectite rich black clay soil (Typic Ustorthent and Typic Haplustert) of central India. Different SSNM treatments were observed more responsive on shallow (Typic Ustorthent) than deep soil (Typic Haplustert) due to difference in the type and magnitude of multiple nutrient deficiencies (Fig. 2). Best SSNM treatment in terms of response on canopy growth, yield, fruit quality and soil-plant nutrient buildup were observed to be T_9 (N_{1200} + P_{600} + K_{600} +

M_1S_1)and T_6 (N_{600} + P_{400} + K_{300} + M_1S_1) on shallow soil (Typic Ustorthent) and deep soil (Typic Haplustert), respectively, within the same orchard. And fertilizer use needs to be tailored as per these doses instead of using recommended doses of fertilizers (RDF) (T_{16}) as a basis. Higher application of K at the rate of 900 g/tree alongwith 600 g N + 400g P(T_8) produced much higher acidity which imparted greener colour to the fruits, thereby, took comparatively longer time for colour break and attain fruit maturity on both shallow as well as deep soil types. Increasing application of K from 0 to 900 g/ tree with N_{600} + P_{400} or from 600 to 1500 g/tree with N_{1200} + P_{600} maintained concurrently higher DTPA-Zn in both the soil types which aided in higher Zn accumulation in index leaves. Effect of K was more pronounced at N_{600} + P_{400} (T_5–T_8) than at N_{1200} + P_{600} (T_9 – T_{12}), irrespective of soil types. The synergism between Zn and K can be befittingly exploited with the objectivity of fertilizer-use-efficiency vis-à-vis quality citrus production, besides dictating the time of fruit maturity (Table 9).

Nutrient-Microbe-Crop Synergy

The use of inorganic fertilizers continuously and excessively without using organic fertilizers as a balancer may result in soil becoming barren and decrease productivity. "Microbial consortia" is a beneficial microbial mixture that has been developed to improve soil quality and crop yield while simultaneously dramatically reducing inorganic chemical application (Maiyappan *et al*., 2010) Rhizospheric microbe plant interactions have a great influence on plant health and soil nutritional and soil borne pathogen stress conditions (Lareen *et al*., 2016). Plant growth promoting rhizobacteria (PGPR) can be considered among rhizosphere beneficial microorganisms (Poszytek *et al*., 2016). Rectifying the disadvantages of the carrier based biofertilizers, liquid biofertilizers have been developed which would be the only alternative for the cost effective sustainable production (Pindi and Satyanarayana, 2012). These PGPRs (*Bacillus pumilus* INR7), *Bacillus subtillis* (GB03) and *Curtobacterium flaccumfaciens* (ME1) have capacity to act as antagonist against certain diseases in crop like cucumber (Raupach and Kloepper, 1998).

Table 9: Response of different site specific nutrient management-based treatments on canopy growth, fruit yield and quality of Nagpur mandarin on Typic Ustorthent (S_1) and Typic Haplustert soil (S_2) soil types (Pooled data)

Treatments	Canopy volume (m^3)*		Fruit yield (kg/tree)		Fruit quality parameters(%)					
					Juice content		TSS		Acidity	
	Tu	Th	S_1	S_2	S_1	S_2	S_1	S_2	S_1	S_2
T_1 (N_{600} + P_{400} + K_{600} + M_1S_1)	3.9(25.7)	3.5(19.3)	37.4	58.9	45.7	45.5	8.2	8.1	0.56	0.77
T_2 (N_{600} + P_{200} + K_{600} + M_1S_1)	3.7(27.3)	2.7(21.3)	30.6	57.2	44.5	41.6	8.5	7.6	0.64	0.68
T_3 (N_{600} + P_0 + K_{600} + M_1S_1)	3.4(29.5)	3.1(23.0)	27.9	57.1	44.1	42.4	9.1	8.4	0.60	0.75
T_4 (N_{600} + P_{600} + K_{600} + M_1S_1)	4.6(28.7)	2.9(20.6)	39.2	58.0	44.7	43.7	8.8	7.9	0.63	0.68
T_5 (N_{600} + P_{400} + K_0 + M_1S_1)	4.2(31.7)	2.4(21.4)	33.4	55.3	41.9	42.4	9.6	8.7	0.56	0.64
T_6 (N_{600} + P_{400} + K_{300} + M_1S_1)	4.7(32.6)	5.4(21.7)	33.9	68.5	44.9	49.8	9.3	8.6	0.58	0.67
T_7 (N_{600} + P_{400} + K_{600} + M_0S_0)	3.8(27.0)	2.6(19.6)	25.1	39.2	45.2	46.5	8.6	7.8	0.62	0.81
T_8 (N_{600} + P_{400} + K_{900} + M_1S_1)	5.7(28.5)	4.3(20.5)	49.9	48.7	48.6	48.2	8.2	7.9	0.75	0.82
T_9 ($N_{12\ 00}$ + P_{600} + K_{600} + M_1S_1)	6.6(31.2)	3.7(23.4)	52.7	60.9	45.4	42.7	8.9	8.8	0.55	0.62
T_{10} (N_{1200} + P_{600} + K_{900} + M_1S_1)	6.6(29.1)	3.3(23.4)	41.8	50.4	42.6	43.6	8.6	8.2	0.59	0.71
T_{11} (N_{1200} + P_{600} + K_{1200} + M_1S_1)	5.8(30.0)	3.9(20.5)	39.3	56.1	44.9	44.8	8.5	8.1	0.62	0.76
T_{12} (N_{1200} + P_{600} + K_{1500} + M_1S_1)	4.6(28.4)	4.3(19.7)	36.3	56.3	48.4	46.3	8.2	7.6	0.80	0.86
T_{13} (N_{1200} + P_{600} + K_0 + M_1S_1)	3.8(26.6)	3.3(19.5)	33.3	46.5	41.6	42.5	8.2	9.1	0.51	0.66
T_{14} (N_{1200} + P_{600} + K_{1200} + M_0 S_1)	4.5(28.1)	2.9(21.2)	33.9	46.3	43.2	43.7	9.5	8.5	0.64	0.77
T_{15} (N_{1200} + P_{600} + $K_{12\ 00}$ + M_0S_0)	3.9(27.2)	2.9(23.2)	30.0	45.5	44.6	43.8	9.6	8.2	0.63	0.74
T_{16} (N_{600} + P_{200} + K_{100}) – RDF	3.5(24.5)	3.0(23.7)	31.5	43.7	44.0	43.1	8.6	8.5	0.57	0.68
LSD (*p=0.05*)	1.2	0.8	8.0	8.1	3.1	2.2	0.5	0.6	0.09	0.08

M_1 stands for application of 300 g each of $ZnSO_4$, $FeSO_4$, $MnSO_4$ and 100 g borax/tree; Mo stands for no application of micronutrient fertilizers;S_1 stand for application of 400 g $MgSO_4$/tree and 100 g elemental S/tree; Tu and Th stand for Typic Ustorthent and Typic Haplustert, respectively ;So stands for no application of Mg and S;RDF stands for recommended doses of fertilizers; *expressed as increase over initial value as given in parenthesis

Source: Srivastava and Singh (2015)

M_1 stands for application of 300 g each of $ZnSO_4$, $FeSO_4$, $MnSO_4$ and 100 g borax/tree; Mo stands for no application of micronutrient fertilizers;S_1 stand for application of 400 g $MgSO_4$/tree and 100 g elemental S/tree; Tu and Th stand for Typic Ustorthent and Typic Haplustert, respectively ;So stands for no application of Mg and S;RDF stands for recommended doses of fertilizers; *expressed as increase over initial value as given in parenthesis

Microbial consortium and plant response: Coinoculation or combined inoculation of different microbe types is another area which can be gainfully exploited in formulating the microbially-rich substrate, provided that information on the synergism between different microbes is known (Marschner *et al.,* 2004). In the past, a number of studies have suggested the coinoculation of different microbes, which can be summarized as: *Bacillus subtillis, B. licheniformis, B. megatericum, B. polymyxa, B. macerams, Pseubomonas fluorescens, Pseubomonas putida, Nocardia corallina, Sacharomyces cerivisiae* and *Thichoderma viride* (20g dissolved in 4 litres water with 200 ml/pot to have 10^6 cfu/ml (Schoebitz and Vidal. 2016); combination of *Funelifirnus mosseae* and *Bacillus sonorensis* in chilly (Thilagar *et al.,* 2016); C2 and C25 strains as *Bacillus spp.* and C32 strain as *Streptomyces sp.* in chilli (Datta *et al*., 2011); combination of PGPR strains Sp7 and UPMB10 as crop-enhancer and bio-fertilizer in banana (Mia *et al*., 2010); consortium of Bacillus in banana (Jaizme-Vega *et al*., 2003) in banana. for vigor seedling and production of banana. Many studies on coinoculation of microbes involving AM fungi and bacteria havae also been suggested for improvement in both yield and quality. These include: *A. brasilense- G. fasciculatum* in wheat (Gori and Favilli 1995), strawberry (Bellone and de Bellone 1995); *A. brasilense-Pantoea dispersa* in sweetpepper (Amor *et al.,* 2008); and *A. chroococcum – G. mosseae* in pomegranate (Aseri *et al.,* 2008).

Differential response of inoculation of different microbes of microbial consortium on seed germination, at various dates of observation. The germination was observed to increase from 1.0% at 10 days to 35.2% at 100 days of germination with treatment T_0,0.83% to 46.4% with T_1, 10.8% at 20 days of germination (First 10 days, no germination was observed) with treatment T_2, 10.8% at 20 days of germination to 23.9% with T_3, 1.9% to 73.9% with T_4 and 1.7% to 76.4% with T_5 during 100 days of observations. But first 30 days of observations showed almost maximum germination in all the treatments (Fig. 4). The maximum seed germination of 76.4%, was observed with treatment T_5 (*Th + Bm + Pp+ Ac + Pf)*, while treatment T_3 (*Th + Bm + Pp*) observed minimum seed germination of 23.95%, significantly lower to even control treatment T_0 (35.20%). The maximum seed treatment T_3 (*Th+ Bm + Pp).* The maximum reduction in germination percentage of 76.0% was observed with treatment T_3 followed by T_2, T_0, T_1, T_4 and T_5 in decreasing order (Table 10).

Seed inoculation of microbial consortium influenced the seed germination to varying proportions, (Table 11) and at various dates of observation. The maximum seed germination of 72.29%, was observed with treatment T_5 (*Th + Bm + Pp + Ac + Pf)*, while treatment T_1 (*Th*) showed minimum seed germination of 61.66%, statistically inferior to control treatment T_0 (63.33%) at all the stages of observation.The maximum seed viability

Table 10: Growth response of acid lime seedlings in response to different microbial inoculations (Period: 120 days)

Treatments	Shoot parameters			Root parameters		
	Shoot length (cm)	Shoot weight (g)	No. of leaves/plant	Girth (mm)	Root length (cm)	Root weight (g)
T_0(Control)	18.6	1.60	14	1.87	10.5	0.40
T_1 (*Th*)	21.5	1.72	16	2.03	11.1	0.43
T_2(*Th+Bm*)	22.7	2.53	19	2.32	13.6	0.67
T_3(*Th+Bm+Pp*)	23.9	2.64	19	2.38	8.6	0.71
T_4(*Th+Bm+Pp+Ac*)	24.9	2.60	22	2.21	11.1	0.78
T_5(*Th+Bm+Pp+Ac+Pf*)	23.4	2.81	26	3.09	19.4	0.89
CD(*P=0.05*)	1.2	0.10	1.8	0.11	0.40	0.06

Th, Bm, Pp, Ac and *Pf* stand for *Trichoderma harzianum, Bacillus mycoides, Paenibacillus polymyxa*, *Azotobacter chroococcum* and *Pseudomonas fluorescens* respectively.
Source: Srivastava *et al.* (2015)

Table 11: Growth response of acid lime seedlings in response to different microbial inoculants (Period : 120 days)

Treatments	Shoot parameters				Root parameters	
	Shoot length (cm)	Shoot weight (g)	No. of leaves/plant	Girth (mm)	Root length (cm)	Root weight (g)
T_0(Control)	16.6	1.61	19	1.96	9.6	0.38
T_1 (*Th*)	17.5	2.12	21	1.99	10.7	0.43
T_2(*Th+Bm*)	22.5	2.26	28	2.16	15.3	0.51
T_3(*Th+Bm+Pp*)	20.1	2.56	32	2.46	15.5	0.64
T_4(*Th+Bm+Pp+Ac*)	21.4	3.25	33	2.92	17.1	0.77
T_5(*Th+Bm+Pp+Ac+Pf*)	23.3	3.48	38	3.17	19.1	1.01
CD(*P=0.05*)	0.50	0.20	3	0.18	0.82	0.22

Th, Bm, Pp, Ac and *Pf* stand for *Trichoderma harzianum, Bacillus mycoides, Paenibacillus polymyxa*, *Azotobacter chroococcum* and *Pseudomonas fluorescens,* respectively.
Source: Srivastava *et al*. (2015)

index of 2.76 was observed with treatment T_5 (*Th + Bm + Pp + Ac +Pf)* followed by 2.68 with T_4 (*Th + Bm + Pp + Ac*), 2.57 with T_3(*Th + Bm + Pp*), 2.53 with T_2 (*Th + Bm*), 1.73 with T_1 (*Th*) and 1.65 with T_0 (Control). The changes in reduction in germination percentage over time in response to different microbial inoculants likewise showed a similar response (Table 19), with a 27.77% reduction with T_5(*Th + Bm + Pp + Ac + Pf*), 30.37% reduction with T_4 (*Th + Bm + Pp + Ac*), 33.33% reduction with T_3(*Th + Bm + Pp*), 32.91% reduction with T_2 (*Th + Bm*), 38.33% reduction with T_1 (*Th*) and 36.66% reduction with T_0 (Control). These observations while comparing the response of different microbial inoculants in soil, showed much higher germination percentage of seeds in soil inoculated with broths of different microbes constituting microbial consortium.The maximum reduction in germination percentage of 38.33% was observed with treatment T_1 (*Th)*, while treatment T_5 (*Th + Bm + Pp + Ac + Pf)* observed minimum reduction in germination percentage of 27.70%.

INM and Nutrient Dynamics: In recent years, nutrient additions have been exclusively in favor of inorganic fertilizers (IF) due to demographic pressure and demands related to life styles and trade involvement. While the quick and substantial response to fruit yield due to IF eclipsed the use of organic manures (OM), the inadequate supply of the latter sources exacerbated this change (Srivastava, 2009). Although, differential efficacy of two conventional methods of fertilization (soil versus foliar application) has helped in improving the quality production of citrus (Srivastava *et al*., 2008) and other fruits (Singh *et al*., 2011; 2012).

In recent years, continuous fertilization has failed to sustain the yield expectancy on a long term basis due to depletion of soil carbon and consequently, multiple nutrient deficiencies have emerged irrespective of soil type (Srivastava and Singh, 2009). The menace of multiple nutrient deficiencies has further been triggered through increase in air temperature via changes in microbial communities and activities within the rhizosphere in the light of climate change (Wu and Srivastava, 2012). Such changes will adversely dictate on the orchard's productive life in long run. Gradual shift from purely IF to OM started gaining wide scale application for enhanced nutrient cycling (Srivastava *et al*., 2002).

Integrated nutrient management (INM) as a dynamic concept of nutrientmanagement considers the economic yield in terms of fruit yield coupled with quality on one hand, and soil physico-chemical and microbial prospects on other hand as a marker of resistance against the nutrient mining (arises because of failure to strike a balance between annual nutrient demand and quantity of nutrients applied). Soils under citrus differ from other cultivated soils, with respect to fallow period of 3–6 months every year forcing depletion of soil organic matter in latter case (Bhargava, 2002). In contrast, biological oxidation of existing carbon (C) continues in soil covered under citrus (Srivastava *et al*., 2002). Multiple nutrient deficiencies are considered to have a profound effect on potential source of atmospheric carbon dioxide (CO_2). Soil carbon stock is, hence, considered as an important criterion to determine the impact of INM in the longer version of impact assessment (He *et al*., 1997). The amount of accumulated C within the rhizosphere soil does not continue to increase with time with increasing C outputs. An understanding of the mechanism

Table 12: Response of microbial consortium loaded INM - treatments on canopy volume, fruit yield and soil fertility changes on Vertic Ustochrept (Pooled data 2010-16)

Treatments	Canopy volume (m^3)	Fruit yield (kg /tree)	Plant available nutrients in soil (mg /kg)						
			Macronutrients			DTPA-micronutrients			
			$KMnO_4$-N	Olsen-P	NH_4OAc-K	Fe	Mn	Cu	Zn
T_1 (100% RDF)	14.69 (13.04)*	58.07	145.6	9.22	184.5	10.40	10.54	2.13	0.96
T_2 (75% RDF + 25% Vm)	21.36(18.51)	60.23	148.2	9.31	193.2	12.91	11.38	2.39	1.21
T_3 (75% RDF + 25% Vm +MC)	23.12(20.28)	65.68	153.7	9.85	204.6	15.81	12.74	2.80	1.37
T_4 (50% RDF + 50% Vm)	25.20(22.42)	72.66	160.6	10.38	221.5	17.22	11.93	2.88	1.47
T_5 (50% RDF + 50%Vm+ MC)	21.45(18.33)	80.95	175.0	11.42	233.6	19.11	13.13	2.95	1.57
CD (*P=0.05*)	-	3.20	1.4	0.41	5.3	0.90	NS	NS	0.10

*Initial observations

RDF, Vm and MC stand for recommended doses of fertilizers, vermicompost and microbial consortium (*Paenibacillus polymyxa*, *Trichoderma harzianum*, *Bacillusmycoides*, *Azotobacter chroococcum* and *Pseudomonas fluorescens*), respectively.

Source : Srivastava *et al*. (2012; 2015b)

involved in C stabilization in soils is needed for controlling and enhancing soil C sequestration (Goh, 2004) under different modes of nutrient management. In this background, studies were carried out with three major objectives: i. response of INM on canopy growth, fruit yield and quality indices, ii. soil carbon dynamics related fertility changes in response to INM, and iii. INM-induced changes in plant nutrition. These objectives are anticipated to collectively provide a strong database support for suitability of INM module versus sole application either Inorganic fertilizers or green manure.

Different treatments displayed significant response on fruit yield (Table 12). The results on response of various treatments revealed diverse effect on the yield/tree at maturity. The maximum fruit yield of 80.95 kg tree^{-1} was observed with treatment T_5 which was better than 72.66 kg tree^{-1} with T_4 or 65.68 kg tree^{-1} with T_3 than 60.23 kg tree^{-1} with treatment T_2. However, all these treatments were far superior in magnitude of response when compared with 100% RDF as T_1 (58.07 kg tree^{-1}). Various fruit quality parameters including fruit weight, juice content, peel colour, disease infestation on trees, fruit firmness, shape at maturity, uniformity in yield/tree, uniformity in fruit size, peel smoothness, TSS, Acidity, fruit diameter, number of seeds/fruit, etc were considered in such comprehensive evaluation of fruit quality. Based on accumulated index value of 100, highest index value was observed with treatment T_5 (69/100) which was significantly higher than other treatments such as 66/100 with T_3, 65/100 with T_4, 57/100 with T_1 and 55/100 with T_2 in decreasing order.

Nutrient Dynamics: The changes in concentration of crunch nutrients like N, K, and Zn were started across crop critical growth stages in response to different treatments (Fig 3, 4 and 5).

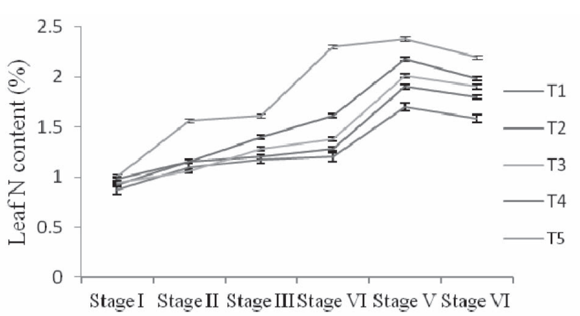

Fig. 3: Response of different treatments on the N accumulation across critical growth stages of Nagpur mandarin

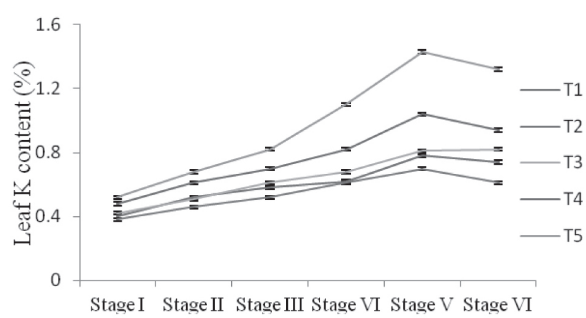

Fig. 4: Response of different treatments on K accumulation across critical growth stages of Nagpur mandarin

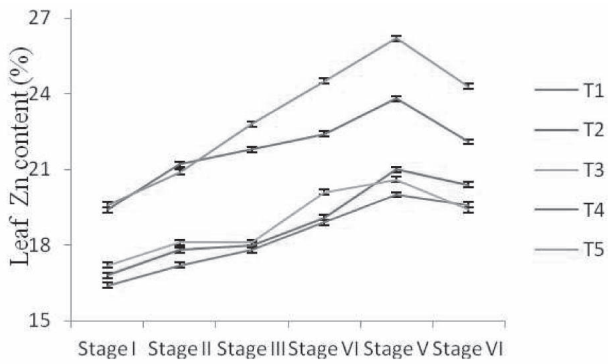

Fig. 5: Response of different treatments on Zn accumulation across critical growth stages of Nagpur mandarin
Source : Srivastava *et al.* (2015)

Leaf nitrogen concentration was observed maximum as 1.01% at stage I,1.56% at stage II, 1.61% at stage III, 2.30% at stage IV,2.38% at stage V and 2.20% at stage VI, which significantly superior to T_4 (0.98% at stage I,1.16% at stage II,1.40% stage III,1.61% at stage IV, 2.18% at stage V and 1.98% at stage VI),T_3 (0.94% at stage I,1.06% at stage II, 1.28% at stage III, 1.38% at stage IV, 2.01% at stage V and 1.90% at stage VI),T_2(0.92% at stage I, 1.16% at stage II, 1.20% at stage III, 1.28% at stage IV, 1.90% at stage V and 1.80% at stage VI) and T_1 (0.87% at stage I,1.10% at stage II, 1.18% at stage III,1.20% at stage IV, 1.70% at stage V and 1.58% at stage VI) in decreasing order of their effectiveness (Fig.3).

Likewise the treatment T_5 maintained almost optimum K-concentration from 0.68% at stage II to as high as 1.43% at stage V and 1.32% at stage VI, significantly superior to any of the other treatments including T_4 (Fig.4).

Like other two nutrient (N and K), dynamics of Zn was also observed to follow the same physiological pattern of accumulation at various crop phenophases (Fig.5). These observations suggested that better nutrient dynamics is maintained across all critical growth stages by mobilising the both the nutrient fractions, applied nutrients as well as the native source of nutrients through treatment T_5. And this is the reason for better effectiveness of treatments, comparatively higher nutrient concentration is maintained across all important growth stages, since our earlier findings advocated, it is not possible to forego the nutrient application at any growth stage considered critical to that crop.

An array of fruit crops have been reported to respond to the synergies originated through combination of organic nutrient-microbe-inorganics (Table 13). And such associations have invariably witnessed substantially higher productivity than any single component alone. However, there is a greater need to expand such plant response advantages using more rhizocompetent microbes preferably in consortium mode, plant response as well as soil health response both have to be sustained on a long term basis.

Way Forward

Despite many cutting edge technologies, addressing a variety of core issues on role of soil type-based nutrient management (Lipecki and Berbec, 1997) in raising the productivity of perennial fruits is the major research and developmental issue. Fruit crops, despite some distinct developments, are confronted with number of soil- fertility challenges. These challenges could be convincingly elaborated as: sustaining the sustainable soil fertility management, we need to define role of rhizosphere in ecological service (CO_2 sink), integrating soil nutrient and microbial pool over different spatial and temporal scales cropwise, soil fertility resilience and human health, plant-soil-microbial interface (For example, crop microbiome), coupled reaction processes in soil to add new frontiers of soil fertility management, besides robust and dynamic crop-based nutrient modelling duly tested spatio- temporally.

Until recently, research has focused on those organisms that are culturable. However a wealth of information is now being collected from both culturable and, as yet, unculturable organisms. Functions of the soil microbial population impact many processes and, therefore, productivity (Kennedy and Gewin, 1997), if mechanisms involved in the plant-microbe interaction are better understood, since, a plant manufactures microbial communities according to its metabolic requirements. The microbial biomass is one of the biological properties of soil that undergoes immediate change in response to fertilizer like input. Studies, therefore, need to be undertaken with a view to explore the possibility of which soil microbial property could be used as a potential tool for finding out soil health related constraint instead of concentration of available nutrients in soil using some indicator fruit crop(s). While the genetic, functional and metabolic diversity

Table 13: Different components of integrated nutrient management recommended for different fruit crops

Crop	Nutrient-microbe combination	Reference
Guava(*Psidium guajava* L.)	FYM 50 kg/plant – *Azotobacter sp* 50 g/plant - *Azospirillum sp* 50 g/plant – *Sesbaniasp* as green manure	Ram and Rajput (2000)
Pomegranate(*Punica granatum* L.)	400 g N- 100 g P_2O_5 – 300 g K_2O /plant – FYM 20 kg/plant,	Ghosh *et al*. (2012)
Papaya(*Caria papaya* L.)	Vermicompost 20 kg/plant – rhizosphere culture 50 g/plant- 150 N – 200 P_2O_5 – 200 K_2O g/plant (75% RDF)	Kirad *et al*. (2010)
Banana(*Musa acuminata* L.)	FYM 12 kg/plant – *Azospirillumsp* 50 g/plant - Phosphate Solubilising Bacteria 50 g/plant *T.harzianum* 50 g/plant	Hazarika and Ansari (2010)
Banana(*Musa acuminata* L.)	50% RDF- FYM 20 kg/plant – *Azotobactersp* 50 g/plant – Phosphate solubilising bacteria 50 g/plant –VAM 250 g/plant	Patil and Shinde (2013)
Guava(*Psidium guajava* L.)	488 g N – 244 g P_2O_5 - 281 g K_2O/plant – FYM 50 kg/plant – *Azotobacter* 250 g/plant – phosphate solubilising bacteria 25 g/plant	Barne *et al*. (2011)
Strawberry (*Fragaria ananassa* Duches)	75% N as RDF – 25% N as FYM – *Azotobacter sp*	Umer *et al*. (2009)
Pomegranate(*Punica granatum* L.)	300 g N/plant – neem cake 1 kg/plant	Ray *et al.* (2014)
Banana(*Musa acuminata* L.)	100% RDF – 40% Wellgrow organic manure	Kuttimani *et al*. (2013)
Peach (*Prunus persica* (L.) Stokes)	75% RDF - 25% N equivalent FYM	Shah *et al*. (2014)
Lemon(*Citrus limon* (L.)Burm.f.)	N 525 g/plant – FYM 150 kg/plant – *Azotobactersp* 18 g/plant	Khehra and Bal (2014)
Apricot(*Prunus armeniaca*(Linn.))	75% RDF – 25% FYM	Shah *et al*. (2006)
Papaya(*Caria papaya* L.)	50% RDF (100 N – 100 P_2O_5 – 125 K_2O g/plant)- *Azotobactersp* 50 g/plant – Phosphate solubilising bacteria 2.5 g/m^2	Singh and Varu (2013)
Guava(*Psidium guajava* L.)	50% RDF (250 g N – 100 g P_2O_5 - 250 K_2O g/plant) - FYM 25 kg/plant – vermicompost 5 kg/plant	Dwivedi (2013)
Sapota(*Achras zapota* L.)	75% RDF + 25% RDF equivalent vermicompost	Hebbarai *et al.* (2006)
Mango(*Mangifera indica* L.)	500 g N - 250 g P_2O_5 – 250 K_2O g/plant –50 kg FYM/plant – *Azospirillumsp* 250 g/plant	Singh and Banik(2011)
Mango(*Mangifera indica* L.)	250 N – 425 P_2O_5 – 1000 K_2O – *Azospirillumsp* 250 g/plant – PSB – 250 g/plant – $ZnSO_4$ 100 g/plant – Borax 100 g/plant	Hasan *et al*. (2012)
Banana(*Musa acuminata* L.)	100 % RDF – FYM 10 kg/plant – *Azospirillum sp* 25 g/pant Phosphate solubilising bacteria 250 g/plant	Bhalerao *et al*. (2009)
Guava (*Psidium guajava* L.)	236 g N – 66 g P_2O_5 – *Azospirillumsp* 30 g/plant – VAM 30 g/plant	Dutta *et al*. (2009)
Mosambi(*Citrus sinensis* Osbeck)	300 g N – 250 g P_2O_5 – 300 g K_2O – AMF 10 g/plant - *Azospirillumsp* 25 g/plant	Patel *et al*. (2009)
Guava(*Psidium guajava* L.)	250 g N – 100 g P – 250 g K_2O /plant – *Azotobacter sp* 250 g/plant	Shukla *et al.* (2009)
Litchi (*Litchi chinensis* Sonn.)	500 g N – 250 g P_2O_5 – 500 g K_2O /plant – FYM 50 kg/plant – *Azotobacter sp* 150 g/plant – VAM 100 g/plant	Dutta *et al*. (2010)
Aonla (*Emblica officinalis* Gaertn.)	50% NPKS (105 kg N – 7.20 kg P_2O_5 – 125.25 kg K_2O/ha) – Biofertilizers (*Azotobactersp* – *Azospirillumsp* – Phosphate solubilising bacteria) – FYM (2 tons/ha)	Yadav *et al.* (2007)
Aonla(*Emblica officinalis* Gaertn.)	100 g N – 25 g P_2O_5 – 150 g K_2O/plant – FYM 10 kg/plant – Phosphate solubilising bacteria 50 g/plant	Mandal *et al*. (2013)
Sapota(*Achras zapota* L.)	1500 g N – 1000 P_2O_5 – 500 g K_2O/plant – 75 kg FYM – 12.5 g/plant PSB	Dalal *et al*. (2004)
Guava(*Psidium guajava* L.)	50% RDF (225 g N – 195 g P_2O_5 – 150 g K_2O/plant)- FYM 50 kg/plant – *Azospirillum* 250 g/plant	Goswami *et al*.(2012).

of soil microorganisms within the rhizosphere of wide range of fruit crops is important, the capacity of soil microbial communities to maintain functional diversity of those critical soil processes could ultimately be more important to ecosystem productivity and stability than mere taxonomic diversity (Caldwell, 2005).

- RDF and PSB stand for recommended doses of fertilizers and phosphate solubilising bacteria predominantly (*Pseudomonas fluorescens*), respectively
- FYM and AMF stand for farmyard manure, and arbuscular mycorrhizal fungi, respectively

In this context, it remains to be assessed how nutrient-microbe synergism is associated with productivity of perennial fruits. New research methods involving molecular techniques will extend our understanding of taxonomic and functional diversity in soil systems. With the availability of more technical know-how on combined use of organic manures, prolonged shelf life of microbial bio-fertilizers, and inorganic chemical fertilizers, an understanding on nutrient acquisition and regulating the water relations would help switch orchards to CO_2 sink (expanding carbon capturing capacity of rhizosphere) so that a more sustainable fruit-based integrated crop production system under biotic and abiotic stress could be evolved. The molecular approach to breeding of mineral deficiency resistance and mineral efficiency would facilitate to produce nutritionally efficient biotypes in order to maximise the quality production of fruit crops on sustained basis. The work related to microbial inoculants for mass production, formulation coupled with innovative marketing, interaction and signalling with the plant and soil environment need further redressal to reorient fruit nutrition research. The further efforts on homologous microbes as rhizosphere microbes versus plant endophytes would further after way forward approaches in identifying more crop endosphere competent microbes for elevated crop response. It remains to be investigated, how nutrient-microbe association could bring better dividends to accurate estimation of orchard C budget vis-a-vis time scale and feedback mechanisms of changes in soil carbon pool and steady state level under specific fruit crop in order to expand potential of C credits through perennial fruit crops.

The above nutrient management-based issues and strategies would find their worth only when backed up with sound methodologies of nutrient constraints diagnosis. The currently available leaf nutrient standards for different fruit crops have certain distinct limitations in terms of: i. Sampling index plant part(s) leaving very short time for remediation of identified constraints, ii. application of diverse interpretation tools bring out varying limits of nutrient concentration and iii. do we need to apply some correction factor when such nutrient standards are applied in fruits under fertigation. A better rationale of nutrient constraints diagnosis as early as possible in a standing crop would surely pave the way for precision-based nutrient response accruing in elevated productivity. Proximal sensing, preferably hyper-spectral analysis would add a new dimension in this regard, since the current basis of nutrient constraints diagnosis is skewed more towards next season crop than current season crop. An early warning system exploiting the metallo-enzyme sensor could be another viable option in years to come. Delineation of production management zones linked with variable rate fertilizer application as per the crop phenology is expected to tailor the fertilizer requirement without altering the fertilizer requirement of a crop soil fertility based spatial variogram would further act as a decision support tool for precise fertilizer recommendation. Evaluating nutrient response at a cellular, sub-cellular, tissue level and plant part level instead of whole plant basis, would lay a solid foundation of nutrient management strategy in fruit crops. Eventually, such attempts warrant for developing Nutrient Experts based on 4R Stewardship Concept advocated by International Plant Nutrition Institute, Gurgaon which have displayed some definite yield advantages in cereal crops, but such serious efforts are direly needed in fruit crops, if nutrient management is to be linked with nutrient use efficiency. On the line of 4R in plant nutrition, there is also a need to look 4W in terms of irrigation management, so that 4R and 4W operate complimenting each other to facilitate not only the sustained quality production, but aid in moderating the climate change – related issues as well.

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Role of Microbial Bioproducts in Sustainable Agriculture

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India is an agricultural based country. In order to nourish the ever growing populations, India has to increase the *per* unit area productivity. According to United Nations Food and Agriculture Organization (FAO) estimations, the average demand for the agricultural commodities will be 60% higher in 2030 than present time and more than 85% of this additional demand will be from developing countries (Mia and Shamsuddin, 2010). Since the beginning of the "Green Revolution" in the late sixties, which focused on food crop productivity, through high-yielding varieties, agrochemicals, irrigation system and chemical fertilizers were extensively used throughout India. Chemical fertilizers are industrially manipulated, substances composed of known quantities of nitrogen (N), phosphorus (P) and potassium (K) and their exploitation causes air and ground water pollution by eutrophication of water bodies (Youssef and Eissa, 2014). In this regard, recent efforts have been channelized more towards the production of 'nutrient rich high quality food' in sustainable manner to ensure bio-safety.

The innovative view of farm production attracts the growing demand of microbial bioproducts exclusive of alternative to agro-chemicals with the additional advantages of longer shelf life causing no adverse effects to ecosystem (Sahoo *et al.,* 2014).Globally microbial bioproducts make up approximately two thirds of the agricultural biologicals industry. Representing roughly US$ 2.3 billion in annual sales, agricultural biologicals have posted double-digit sales growth each of the last several years. There are numerous biological products currently on the market that contain microorganisms as active ingredients, including seed treatment and foliar applied products (Thomas and Tom, 2015). Microbial technologies can help improve nutrient acquisition, promote growth and yield, control insects and protect against disease. These emerging agricultural biological technologies complement the integrated systems approach that is necessary in modern agriculture, bringing together breeding, biotechnology and agronomic practices to improve and protect crop yields.

The uniqueness of microorganisms and their often unpredictable nature and biosynthetic capabilities, given a specific set of environmental and cultural conditions, have made them potential for sustainable agriculture. Natural microflora of the soil constitutes all kinds of useful bacteria and fungi including the arbuscular mycorrhizal fungi (AMF) and plant growth promoting rhizobacteria (PGPR). The products deriving from such microbes keep the soil environment rich in all kinds of micro- and macro-nutrients via N_2 fixation, P and K solubilisation or mineralization, release of plant growth regulating substances, production of antibiotics and biodegradation of organic matter in the soil (Sinha *et al.,* 2014). When microbial products are applied as seed or soil inoculants, they multiply and participate in nutrient cycling and benefit crop productivity (Singh *et al.,* 2011). In general, 60% to 90% of the total applied fertilizer is lost and the remaining 10% to 40% is taken up by plants. In this regard, microbial bioproducts have paramount significance in integrated nutrient management systems to sustain agricultural productivity and healthy environment (Adesemoye and Kloepper,

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2009). The PGPR or co-inoculants of PGPR and AMF can advance the nutrient use efficiency of fertilizers. A synergistic interaction of PGPR and AMF was better suited to 70% fertilizer plus AMF and PGPR for P uptake. Similar trend were also reflected in N uptake on a whole-tissue basis which shows that 75%, 80%, or 90% fertilizer plus inoculants were significantly comparable to 100% fertilizer (Adesemoye *et al.,* 2009).

The principal abiotic stresses in India are drought or soil moisture stresses that affect nearly two-thirds area forming parts of the arid and semi arid eco systems, high temperatures, soil salinity/alkalinity, low pH and metal toxicity. Nearly 11 m ha area is affected by salinity, a chemical stress and another 16 m ha by water logging, a physical stress. Extensive research has been carried out on occurrence and functional diversity of agriculturally important microbes in stressed environments as reviewed by several authors (Grahm, 1992; Zahran, 1999; Venkateswarlu, *et al*., 2008). There is a promising need to develop microbial bioproducts that help in alleviating abiotic stress conditions in different crop systems for sustainable agriculture.

Microbial control agents, based on naturally occurring fungi, bacteria, viruses or nematodes have offered some realistic alternatives to chemical pesticides when used as part of an ecologically based integrated pest management (EBIPM) or area-wide pest management strategy (AWPM) (Koul and Cuperus, 2007). As the development of resistance to conventional synthetic pesticides, a decline in the rate of discovery of novel insecticides, increased public perception of the dangers associated with synthetic pesticides and host-specificity of microbial pesticides, the improvement in the production and formulation technology of microbial control agents was reported (Koul, 2011).

Several microbial bioproducts with growth-stimulating activities of seaweed extracts are used in crop production (Sivasankari *et al.,* 2006; Khan *et al.,* 2009; Rathore *et al.,* 2009). Seaweed liquid extracts have become more significant in agriculture as foliar sprays because they contain promoting hormones or trace elements (Fe, Cu, Zn, and Mn) which, added to the soil or applied to seeds, stimulate plant growth (Sivasankari *et al.,* 2006). Bioproducts used in agriculture and horticulture are mainly prepared from brown seaweeds of *Ascophyllum nodosum, Ecklonia maxima,* and *Macrocystis pyrifera* (Gupta *et al.,* 2011).Some of the novel approaches of microbial bioproducts include the concepts of effective microorganisms (EM) (Higa and Parr, 1994) and probiotics (Song *et al.,* 2012) for improved crop yield and stress tolerance.

The review focuses on the exploitation of microbial bioproducts for safe and nutritious crop yield in sustainable agriculture. It describes the potential role of microorganisms and their possible benefits to sustainable agriculture and production. Further, studies on some efficient microbial bioproducts and their effect on crop yield are discussed.

Microbial Bioproducts: A Boon in Agriculture Industry

Overall the agricultural bioproducts are products of natural origin, and therefore fully biodegradable and non-toxic either to plants and their consumers. As a result, there is no problem of toxicity or ecotoxicity, harmful residues, fate and behaviour in the environment. Microbial bioproducts are produced under controlled biotechnological processes, in order to achieve the desired growth of microorganisms or the production of metabolites (bio-extract) of interest in a concentrated comportment. It is worth noting that there are bio- active substances which may be a species of microorganism or a mixture of several species, and usually are formulated for commercial use. These formulations are safe for the operator of the dispensing agent. They are used in fertilization, plant growth stimulation or biological control, and their active ingredients can be extracts of plants, algae; microorganisms or active metabolites. Accordingly they are broadly classified as biofertilizers, biostimulants and biopesticides for their role in agriculture as crop nutrition, enhancement and protection, respectively. They differ in purpose of use and mechanism of action.

a. Biofertilizers

The microorganisms which improve nutrient acquisition are known as biofertilizers. The biofertilizers are microbial preparations containing living cells of different microorganisms, which have the ability to mobilize plant nutrients in soil from unusable to usable form through biological process. They are eco-friendly and play a significant role in crop production. Biofertilizers play significant role in improving the soil fertility by N_2 fixing bacteria both in association with plant roots and without it. They help in solubilising insoluble soil phosphate and produces plant growth substances in the soil.A biofertiliser is any bacterial or fungal inoculants applied to plants with the aim to increase the availability of nutrients and their utilization by plants, regardless of the nutrient content of the inoculant itself' (du Jardin, 2015).

These microorganisms are either free living in soil or symbiotic with plants and contribute directly or indirectly towards N and P nutrition of the plants. Biofertilizers add nutrients through the natural processes of N_2 fixation, P solubilisation and plant growth stimulation through the synthesis of growth promoting substances. They can be grouped in different ways based on their nature and function.

N_2 fixing biofertilizers

Biofertilizers fix atmospheric N in the soil and root nodules of legume crops and make it available to the plants. Efficient strains of *Azotobacter*, *Azospirillum*, *Phosphobacter* and *Rhizobacter* can provide significant amount of N to sunflower plant (*Helianthus annus*) and to increase the plant height, number of leaves, stem diameter, percentage of seed filling and seed dry weight (Dhanasekar and Dhandapani, 2012). Equally, in rice, addition of *Azotobacter*, *Azospirillum* and *Rhizobium* promotes the physiology and improves the root morphology (Choudhury and Kennedy, 2004).*Azotobacter* plays an important role in the N cycle in nature as it possesses a variety of metabolic functions (Sahoo *et al.,* 2013a). Also, *Azotobacter* has the capacity to produce vitamins such as thiamine and riboflavin (Revillas *et al.,* 2000), and plant hormones viz., indole acetic acid (IAA), gibberellins (GA) and cytokinins (CK) (Abd El-Fattah *et al.,* 2013). *A. chroococcum* improves the plant growth by enhancing seed germination and advancing the root architecture (Gholami *et al.,* 2009) by inhibiting pathogenic microorganisms around the root systems of crop plants (Mali and Bodhankar, 2009). This genus includes diverse species, namely, *A. chroococcum*, *A.vinelandii*, *A. beijerinckii*, *A. nigricans*, *A. armeniacus* and *A. paspali*. It is used as a biofertilizer for different crops viz., wheat, oat, barley mustard, seasum, rice, linseeds, sunflower, castor, maize, sorghum, cotton, jute, sugar beets, tobacco, tea, coffee, rubber and coconuts (Wani *et al.,* 2013).

Azospirillum is another free-living, motile, gram variable and aerobic bacterium that can thrive in flooded conditions (Sahoo *et al.,* 2014) and promotes various aspects of plant growth and development (Bhattacharyya and Jha, 2012). *Azospirillum* was shown to exert beneficial effects on plant growth and crop yields both in greenhouse and in field trials (Saikia *et al.,* 2013). Diverse species of the genus *Azospirillum* including *A. lipoferum*, *A. brasilense*, *A. amazonense*, *A. halopraeferens* and *A. irakense* have been reported to improve productivity of various crops (Sahoo *et al.,* 2014). Interestingly, it was observed that *Azospirillum* inoculation can change the root morphology via producing plant growth regulating substances (Bashan *et al.,* 2004) via siderophore production (Sahoo *et al.,* 2014). It also increases the number of lateral roots and enhances root hairs formation to provide more root surface area to absorb sufficient nutrients (Mehdipour-Moghaddam *et al.,* 2012). This improves the water status of plant and aids the nutrient profile in the advancement of plant growth and development (Sarig *et al.,* 1992; Ilyas *et al.,* 2012). Co-inoculation of *Azospirillium brasilense* and *Rhizobium meliloti* plus 2,4D posed positive effect on grain yield and N, P, K content of Triticum aestivum (Askary *et al.,* 2009).

Rhizobium has been used as an efficient N_2 fixer for many years. It plays an important role in increasing yield by converting atmospheric N into usable forms (Sharma *et al.,* 2011). Being resistant to different temperature ranges *Rhizobium* normally enters the root hairs, multiplies there and forms nodules (Nehra *et al.,* 2007). *Rhizobium* inoculants in different locations and soil types were reported to significantly increase the grain yields of bengal gram (Patil and Medhane, 1974), lentil (Rashid *et al.,* 2012), pea, alfalfa and sugar beet rhizosphere (Ramachandran *et al.,* 2011), berseem (Hussain *et al.,* 2002), ground nut (Sharma *et al.,* 2011) and soybean (Grossman *et al.,* 2011). These *Rhizobium* isolates obtained from wild rice have been reported to supply N to the rice plant to promote growth and development (Peng *et al.,* 2008). One of the species of *Rhizobium*, *Sinorhizobium meliloti* 1021 infects plants other than leguminous plants like rice to promote growth by enhancing endogenous level of plant hormone and photosynthesis performance to confer plant tolerance to stress (Chi *et al.,* 2010). In groundnut, IRC-6 strain of *Rhizobium* has resulted in the enhancement of several useful traits such as increased number of pink coloured nodules, nitrate reductase (NRase) activity and leghaemoglobin content in 50 days after inoculation (Sharma *et al.,* 2011). Rhizobial symbiosis provides defence to plants against pathogens and herbivores, such as example, Mexican bean beetle (Thamer *et al.,* 2011) and the green house whitefy *Trialeurodes vaporariorum* (Menjivar *et al.,* 2012) (Fig. 1).

N_2 fixing cyanobacteria such as *Aulosira*, *Tolypothrix*, *Scytonema*, *Nostoc*, *Anabaena* and *Plectonema* are commonly used as biofertilizers (Abdel-Lateif *et al.,* 2012; Roy and Srivastava, 2013).

P solubilizing biofertilizers

These biofertilizers solubilise the insoluble forms of phosphates like tricalcium iron and aluminium phosphates into soluble or available form using P solubilising microbes.

A key advantage of beneficial microorganisms is to assimilate P for their own requirement, which in turn available as its soluble form in sufficient quantities in soil. *Pseudomonas*, *Bacillus*, *Micrococcus*, *Flavobacterium*, *Fusarium*, *Sclerotium*, *Aspergillus* and *Penicillium* have been reported to be active in the solubilisation process (Pindi and Satyanarayana, 2012). A phosphate-solubilizing bacterial strain NII-0909 of Micrococcus sp. has polyvalent properties including phosphate solubilisation and siderophore production (Dastager *et al.,* 2010). Similarly, two fungi *Aspergillus fumigates* and *A. Niger* were isolated from decaying cassava peels were found to convert cassava wastes by the semi-solid fermentation technique to phosphate biofertilizers (Ogbo, 2010). *Burkholderia vietnamiensis*, stress tolerant bacteria, produces gluconic and 2-ketogluconic acids, which involved in phosphate solubilisation (Park *et al.,* 2010a). *Enterobacter* and *Burkholderia* that were isolated from the rhizosphere of sunflower were found to produce siderophores and indolic compounds (ICs) which can solubilize phosphate (Ambrosini *et al.,* 2012).

Phosphate mobilising biofertilizers

Phosphate mobilising *Mycorrhiza* scavenges phosphate from soil layers. Mycorrhizal mutualistic symbiosis with plant roots satisfies the plant nutrients demand (Kogel *et al.,* 2006), which leads to enhance plant growth and development, and protect plants from pathogens attack and environmental stress (Lamabam *et al.,* 2011). It leads to the absorption of phosphate by the hyphae from outside to internal cortical mycelia, which finally transfer phosphate to the cortical root cells (Smith *et al.,* 2011).

K solubilising microorganisms such as genus *Aspergillus*, *Bacillus* and *Clostridium* are found to be efficient in K solubilisation in the soil and mobilize in different crops (Mohammadi and Yousef Soh*Rabi*, 2012).

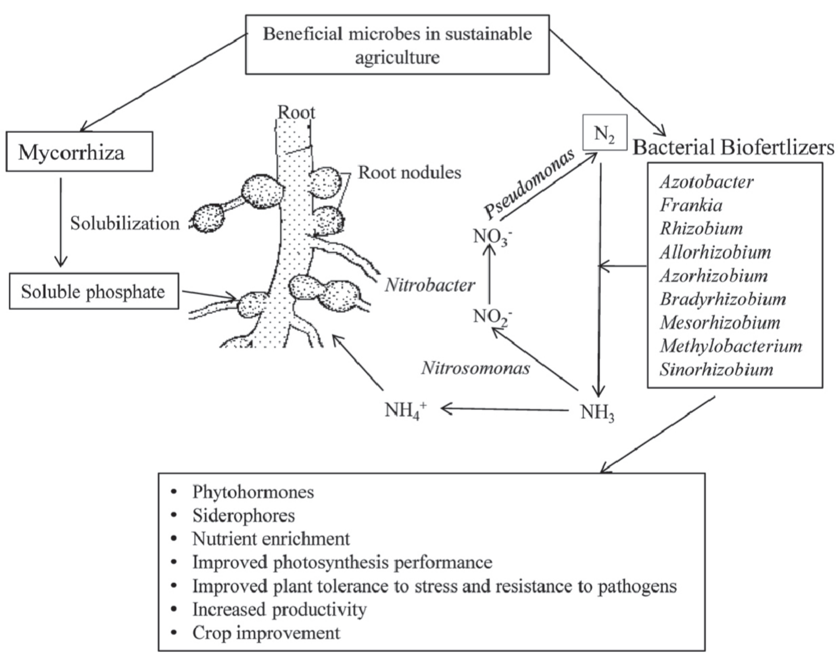

Fig. 1: Potential use of soil microbes in sustainable crop production:

The soil micro-organisms act as biofertilizers (Sahoo *et al.,* 2013b) or symbiont (Nina *et al.,* 2014) to sustain crop production by performing nutrient solubilisation, availability and thereby nutrient uptake (Dogan *et al.,* 2011; Aziz *et al.,* 2012). They improve the plant growth by advancing the root architecture (Gholami *et al.,* 2009). Their activity provides numerous beneficial characters to plants primarily increased root hairs, nodules and nitrate reductase activity (Sharma *et al.,* 2011). Efficient strains of *Azotobacter*, *Azospirillum*, *Phosphobacter* and *Rhizobacter* can provide significant amount of available N through cycling (Dhanasekar and Dhandapani, 2012). The biofertilizers produced plant hormones, which include IAA, GA and CK (Abd El-Fattah *et al.,* 2013; Chi *et al.,* 2010). Biofertilizers improve photosynthesis performance to confer plant tolerance to stress (Chi *et al.,* 2010) and increase resistance to pathogens (Thamer *et al.,* 2011) resulting in crop yield (Sahoo *et al.,* 2013a).

Plant growth promoting biofertilizers

PGPR are a group of bacteria that actively colonize plant roots and enhance plant growth and yield. Concerning the major role of PGPR, these biofertilizers produce hormones and anti metabolites which promote root growth. Free-living PGPR have shown promise as biofertilizers. Many studies and reviews have reported plant growth promotion, increased yield, solubilization of P or K, uptake of N and some other elements through inoculation with PGPR. In addition, studies have shown that inoculation with PGPR enhances root growth, leading to a root system with large surface area and increased number of root hairs.

Many tools of modern science have been extensively applied for crop improvement under stress, of which PGPRs role as bio protectants has become paramount importance in this regard (Yang *et al.,* 2009). *Rhizobium trifolii* inoculated with *Trifolium alexandrinum* showed higher biomass and increased number of nodulation under salinity stress condition (Hussain *et al.,* 2002; Antoun and Prevost, 2005).

Pseudomonas aeruginosa has been shown to withstand biotic and abiotic stresses (Pandey *et al.,* 2012). Paul and Nair (2008) found that *P. fluorescens* MSP-393 produces osmolytes and salt-stress induced proteins that overcome the negative effects of salt. *P. putida* Rs-198 enhanced germination rate and several growth parameters viz., plant height, fresh weight and dry weight of cotton under condition of alkaline and high salt via increasing the rate of uptake of K^+, Mg^{2+} and Ca^{2+} and by decreasing the absorption of Na^+ (Yao *et al.,*2010). Few strains of *Pseudomonas* conferred plant tolerance via 2,4-diacetylphloroglucinol (DAPG) (Schnider-Keel *et al.,*2000). Interestingly, systemic response was found to be induced against *P. syringae* in *ARabidopsis thaliana* by *P. Fluorescens* DAPG (Weller *et al.,* 2012). Calcisol produced by PGPRs viz., *P. Alcaligenes* PsA15, *Bacillus polymyxa* BcP26 and *Mycobacterium phlei* MbP18 provides tolerance to high temperatures and salinity stress (Egamberdiyeva, 2007). *Pseudomonas spp.* was found to cause positive effect on the seedling growth and seed germination of *A. officinalis L.* under water stress (Liddycoat *et al.,* 2009).

It has been demonstrated that inoculation of plant with AMF also improves plant growth under salt stress (Ansari *et al.,* 2013). *Achromobacter piechaudii* was also shown to increase the biomass of tomato and pepperplants under 172 mM NaCl and water stress (Alavi *et al.,* 2013). Interestingly, a root endophytic fungus *Piriformospora indica* was found to defend host plant against salt stress (Ansari *et al.,* 2013). In one of the studies it was found that inoculation of PGPR alone or along with AM like *Glomus intraradices* or *G. mosseae* resulted in the better nutrient uptake and improvement in normal physiological processes in *Lactuca sativa* under stress conditions. The same plant treated with *P. mendocina* increased shoot biomass under salt stress (Kohler and Caravaca, 2010).

Combination of AMF and N_2-fixing bacteria helped the legume plants in overcoming drought stress (Aliasgharzad *et al.,* 2006). Effect of *A.brasilense* along with AMF can be seen in other crops such as tomato, maize and cassava (German *et al.,* 2000; Casanovas *et al.,* 2002; Creus *et al.,* 2005). *A. brasilense* and AMF combination improved plant tolerance to various abiotic stresses (Joe *et al.,* 2009). The additive effect of *Pseudomonas putida* or *Bacillus megaterium* and AMF was effective in alleviating drought stress (Marulanda *et al.,* 2009).

Photosynthetic efficiency and the antioxidative response of rice plants subjected to drought stress were found to increase after inoculation of AMF (Ruiz-Sanchez *et al.,* 2010). The beneficial effects of mycorrhizae have also been reported under both the drought and saline conditions (Aroca *et al.,* 2013).

Biofertilizers decompose organic matter and help in mineralization in soil. Heavy metals such as cadmium, lead, mercury from hospital and factory waste accumulate in the soil and enter plants through roots (Gill *et al.,* 2012). *Azospirillium* spp, *Phosphobacteria* sp. and *Glucanacetobacter* sp. isolated from rhizosphere of rice field and mangroves were found to be more tolerant to heavy metal specially iron (Gill *et al.,* 2012; Samuel and Muthukkaruppan, 2011).

b. Biostimulants

Agricultural biostimulants (plant biostimulants) include diverse substances and microorganisms that enhance plant growth. Jardin (2015) proposed the definition of biostimulant as 'A plant biostimulant is any substance or microorganism applied to plants with the aim to enhance nutrition efficiency, abiotic stress tolerance and/or crop quality traits, regardless of its nutrients content'. By extension, plant biostimulants also designate commercial products containing mixtures of such substances and/or microorganisms. This definition supports the nature, modes of action and types of effects of biostimulants on crop and horticultural plants (du Jardin, 2015). Biostimulants include humic and fulvic acids, protein hydrolysates and other N-containing compounds, seaweed extracts, inorganic compounds, beneficial fungi and beneficial bacteria. This review highlighted on the role of biostimulants for sustainable agriculture.

Humic and fulvic acids

Humic substances are extracted from naturally humified organic matter (e.g. from peat or volcanic soils), from composts and vermicomposts, or from mineral deposits (leonardite, an oxidation form of lignite). Thus, they are natural constituents of the soil organic matter, resulting from the decomposition of plant, animal and microbial residues, but also from the metabolic activity of soil microbes using these substrates. These heterogeneous compounds are categorized as humic acids and fulvic acids on the basis of their molecular weights and solubility into humins (du Jardin, 2012). Improvement in soil fertility, root nutrient uptake and nutrition was observed by the action of humic substances via different mechanisms as in case of hydroponically-grown maize seedlings with stress response modulation (Olivares *et al.,* 2015; Schiavon *et al.,* 2010).

Protein hydrolysates and other N-containing compounds

Amino-acids and peptides mixtures are obtained by chemical and enzymatic protein hydrolysis from agroindustrial by-products, from both plant sources (crop residues) and animal wastes (e.g. collagen, epithelial tissues) (du Jardin, 2012; Calvo *et al.,* 2014; Halpern *et al.,* 2015). Betaines, polyamines and 'non-protein amino acids' are some nitrogenous molecules diversified in higher plants (Vranova *et al.,* 2011). Particularly, glycine betaine is a amino acid derivative with eminent anti-stress properties (Chen and Murata, 2011).These compounds play multiple roles of biostimulants for plant growth (Calvo *et al.,* 2014; duJardin, 2012, Halpern *et al.,*2015). Direct effects on plants include modulation of N uptake and assimilation by the regulation of enzymes and structural genes involved in N assimilation along with the signalling pathway of N acquisition in roots. Also, they regulate the enzymes of TCA cycle contributing to the cross talk between C and N metabolisms. Hormonal activities are also reported in complex protein and tissue hydrolysates (Colla *et al.,* 2014).

Indirect effects on plant nutrition and growth are also important in the agricultural practice when protein hydrolysates are applied to plants and soils. Protein hydrolysates are known to increase microbial biomass and activity, soil respiration and, overall, soil fertility. Chelating and complexing activities of specific amino acids and peptides are deemed to contribute to nutrients availability and acquisition by roots. Several commercial products obtained from protein hydrolysates of plant and animal origins have been placed on the market. Variable, but in many cases significant improvements in yield and quality traits have been reported in agricultural and horticultural crops (Calvo *et al.,* 2014). The safety of hydrolyzed proteins of animal origin was recently assessed and no genotoxicity, ecotoxicity or phytotoxicty was reported on the basis of bioassays using yeasts and plants as test organisms (Corte *et al.*, 2014).

Seaweed extracts as biostimulants of plant growth and development

Seaweed extracts act as biostimulants, enhancing seed germination and establishment, improving plant growth, yield, flower set and fruit production, increasing resistance to biotic and abiotic stresses, and improving postharvest shelf life (Mancuso *et al*., 2006; Norrie and Keathley 2006; Hong *et al*., 2007; Rayorath *et al*., 2008; Khan *et al*., 2009; Craigie 2011; Mattner *et al*. 2013). Most commercial seaweed extracts are made from brown seaweeds, including *Ascophyllum nodosum*, *Fucus*, *Laminaria*, *Sargassum*, and *Turbinaria* sp. (Hong *et al*., 2007; Sharma *et al*., 2012). Extracts are active as biostimulants at low concentrations (diluted at 1:1,000 or more), suggesting that the effects observed are likely distinct from those associated with a direct nutritional function (Crouch and van Staden 1993, Khan *et al*., 2009). Seaweed extracts are a complex mixture of components that may vary according to the seaweed source, the season of collection, and the extraction process used (Khan *et al*., 2009; Rioux *et al*., 2009; Sharma *et al*., 2012; Shekhar *et al*., 2012). They contain a wide range of organic and mineral components including unique and complex polysaccharides not present in terrestrial plants such as laminarin, fucoidan and alginates, and plant hormones (Sivasankari *et al*., 2006; Rioux *et al*., 2007; Khan *et al*., 2009).

The foliar application of seaweed extract leads to enhanced root development in a variety of species, including maize (Jeannin *et al*., 1991), tomato (Crouch and van Staden 1992), A*Rabi*dopsis (Rayorath *et al*., 2008), grape (Mancuso *et al*., 2006; Mugnai *et al*., 2008), strawberry (Alam *et al*., 2013), winter rapeseed (Jannin *et al*., 2013), Norway spruce (*Picea abies*) (Slávik 2005), and lodgepole pine (*Pinus contorta*) (MacDonald *et al*., 2012). Increases in lateral root formation (Vernieri *et al*., 2005), total root volume (Slávik 2005; Mancuso *et al*., 2006), and root length (Zodape *et al*., 2011) have been observed and attributed to the presence of phytohormones such as auxins and cytokinins in seaweed extracts (Khan *et al*., 2011a, 2011b). Seaweed extract application also stimulated mineral nutrient uptake in plants such as lettuce (Crouch *et al*., 1990), grape (Mancuso *et al*., 2006), soybean (Rathore *et al*., 2009), tomato (Zodape *et al*., 2011), and winter rapeseed (Jannin *et al*., 2013) with increased accumulation of both macro- (N, P, K, Ca, S) and micro-nutrients (Mg, Zn, Mn, Fe) reported (Crouch *et al*. 1990, Mancuso *et al*., 2006, Rathore *et al*., 2009; Zodape *et al*., 2011) (Fig. 2).

Indirect stimulation of root growth may also occur via enhancement of associated soil microorganisms by seaweed extracts. Root colonization and *in vitro* hyphal growth of AMF were improved in the presence of extracts of brown algae (Kuwada *et al*., 1999). (Alam *et al*., 2013) showed that seaweed extract increased microbial diversity and activity in the rhizosphere of strawberry, while (Khan *et al*., 2012; 2013) reported that seaweed extract stimulated alfalfa growth and root nodulation by improving the attachment of *Sinorhizobium meliloti* to root hairs. Enhancement of root growth and nutrient and water uptake efficiency may also increase above ground plant growth and yield as well as resistance to abiotic and biotic stresses (Khan *et al*., 2009).

There are numerous reports of beneficial effects of seaweed extracts on shoot growth and crop yield (reviewed by Verkleij 1992; Stirk and van Staden 2006; Khan *et al*., 2009; Craigie 2011). Recent studies have shown enhanced growth and yield in agricultural and horticultural crops such as wheat (Kumar and Sahoo 2011), winter rapeseed (Jannin *et al*., 2013), apple (*Malus domestica*) (Basak 2008), strawberry (Alam *et al*., 2013), tomato (Zodape *et al*., 2011), spinach (Fan *et al*., 2013), okra (Zodape *et al*., 2008), olive (*Olea europaea*) (Chouliaras *et al*., 2009), broccoli (Mattner *et al*., 2013), and geranium (*Pelargonium* sp) (Krajnc *et al*., 2012). Root and shoot growth of the model plant A*Rabi*dopsis was also enhanced by treatment with algal extracts (Rayorath *et al*., 2008). Leaf chlorophyll content was increased following seaweed extract application in a number of studies (Blunden *et al*., 1997; Mancuso *et al*., 2006; Sivasankari *et al*., 2006; Spinelli *et al*., 2010; Fan *et al*., 2013; Jannin *et al*., 2013). This increase appeared to be associated with a reduction in chlorophyll degradation (Blunden *et al*., 1997) and delay in senescence rather than a net increase in photosynthesis rate (Jannin *et al*., 2013).

Recently, it was found that the seed treatment with the supercritical extracts of Baltic seaweeds (*Enteromorpha* sp. and *Cladophora* sp.) and *Spirulina* sp., showed improved sprout and root development in wheat (Michalak *et al.,*2016; Dmytryk *et al.,*2015).

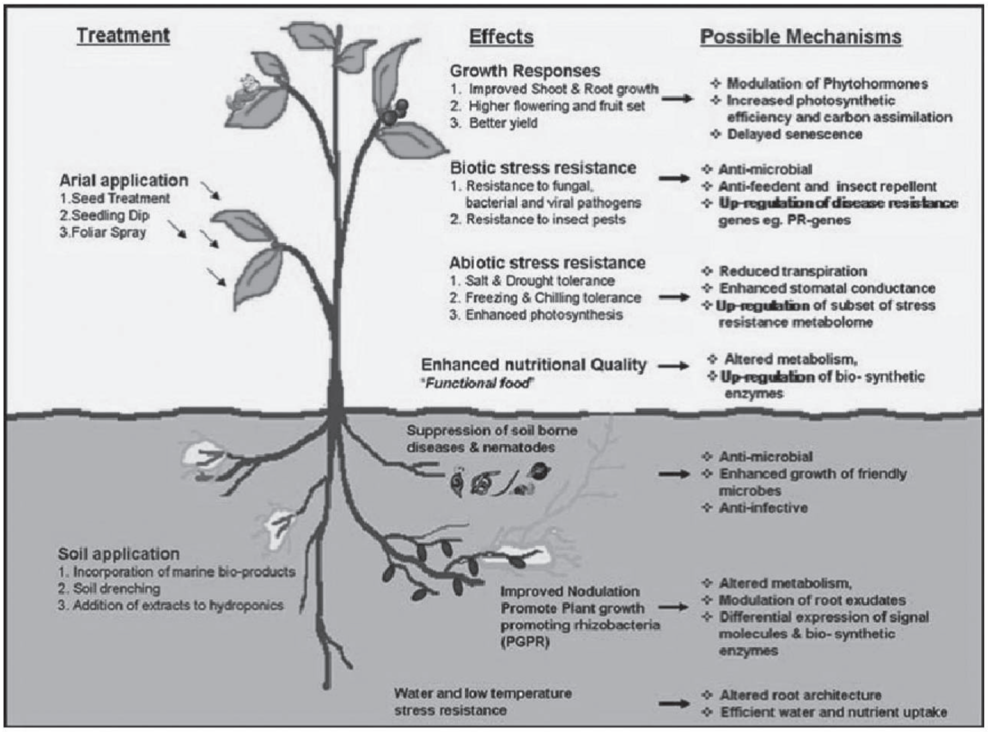

Fig. 2: Schematic representation of physiological effects elicited by seaweed extracts and possible mechanism(s) of bioactivity (*Source*: Khan *et al.,* 2009)

Inorganic compounds

Chemical elements that promote plant growth and essential to particular taxa but are not required by all plants are called beneficial elements (Pilon-Smits *et al.,* 2009). The five main beneficial elements are Al, Co, Na, Se and Si, present in soils and in plants as insoluble, inorganic salts like amorphous silica ($SiO_2.nH_2O$) in graminaceaous species. Many effects of beneficial elements are reported by the scientific literature, which promote plant growth, the quality of plant products and tolerance to abiotic stress. This includes cell wall rigidification, osmoregulation, reduced transpiration by crystal deposits, thermal regulation via radiation reflection, enzyme activity by co-factors, plant nutrition via interactions with other elements during uptake and mobility, antioxidant protection, interactions with symbionts, pathogen and herbivore response, protection against heavy metals toxicity, plant hormone synthesis and signalling (Pilon-Smits *et al*., 2009).

Role of microorganisms as biostimulants

Beneficial fungi

Fungi establish the interaction with plant roots in different ways, from mutualistic symbioses (i.e. when both organisms live in direct contact with each other and establish mutually beneficial relationships) to parasitism (Behie and Bidochka, 2014). Since the evolution, plants and fungi have co-evolved as mutualism- parasitism continuum (Bonfante and Genre, 2010; Johnson and Graham, 2013). Mycorrhizal fungi are a heterogeneous group of taxa which establish symbioses with over 90 % of all plant species. Growing demand for the use of mycorrhiza to promote sustainable agriculture is due to the benefits of the symbioses to nutrition efficiency (for both macronutrients, especially P, and micronutrients), water balance, biotic and abiotic stress protection of plants (Augé, 2001; Gianinazzi *et al.,* 2010; Hamel and Plenchette, 2007; Harrier and Watson, 2004; Siddiqui *et al.,* 2008; van der Heijden *et al*.,2004). Significantly the ecological and agricultural implications evidenced that the fungal conduits allow for interplant signalling (Johnson and Gilbert, 2015; Simard *et al.,* 2012). AMF form tripartite associations with plants and rhizobacteria which are relevant in practical field situations (Siddiqui *et al.,* 2008). The mycorrhizal associations adapted to the interaction with microorganisms showed more beneficial crop management practices and plant cultivars (Gianinazzi *et al*., 2010; Hamel and Plenchette, 2007; Plenchette *et al.,* 2005; Sheng *et al.,*2011). Recently, the fungal endophytes, like *Trichoderma* sp. (*Ascomycota*) and *Sebacinales* (*Basidiomycota*, with *Piriformospora indica* as model organism) are reported to transfer nutrients to their hosts (Behie and Bidochka, 2014). Many plant responses are induced by the mechanisms of nutrient transfer between fungal endosymbionts and their hosts including increased tolerance to abiotic stress, nutrient use efficiency, organ growth and morphogenesis (Colla *et al.,* 2015; Shoresh *et al.,*2010) establishing fungal endophytes as biostimulants.

Fungal symbionts can also improve plant productivity by various mechanisms including increased plant water-use efficiency maximized photosynthetic rate or increased production of metabolites such as the sugar trehalose or growth hormones such as GA and IAA (Herre *et al.,*2005; Khan *et al.,*2014; Marquez *et al.,*2007; Redman *et al.,*2002; Morsy *et al.,*2010; Contreras *et al.,*2014). In addition fungal symbionts can regulate a diverse set of plant genes. For example *ARabidopsis thaliana* colonized by *Piriformospora indica* showed faster and greater up-regulation of nine drought stress-related genes (Sherameti *et al.,*2008) and in *Theobroma cacao* colonized with *Trichoderma hamatum* the endophyte altered expression of 19 drought-responsive genes and promoted greater seedling growth when plants were exposed to drought (Bae *et al.,*2009).

Beneficial bacteria

Bacteria interacts with plants by many probable pathways (Ahmad *et al*., 2008): a continuum between mutualism and parasitism; bacterial niches extend from the soil to the interior of cells, with intermediate locations called the rhizosphere and the rhizoplane; transient or permanent associations; some bacteria being even vertically transmitted via the seed; functions influencing plant life cover participation to the biogeochemical cycles, supply of nutrients, increase in nutrient use efficiency, induction of disease resistance, enhancement of abiotic stress tolerance, modulation of morphogenesis by plant growth regulators. Such mutualistic endosymbionts of the type *Rhizobium* and mutualistic, rhizospheric PGPRs are regarded as biostimulants for agricultural use (Jardin, 2015). PGPRs are multifunctional influencing all aspects of plant life: nutrition and growth, morphogenesis and development, response to biotic and abiotic stress, interactions with other organisms in the agro ecosystems (Ahmad *et al.,* 2008; Babalola, 2010; Berendsen *et al*., 2012; Berg *et al.,* 2014; Bhattacharyya and Jha, 2012; Gaiero *et al.,* 2013; Philippot *et al.,*2013; Vacheron *et al*., 2013).

For example, bacterial symbionts also known as plant growth-promoting rhizobacteria, can enhance plant growth *via* a variety of mechanisms such as improved nutrient solubilization and uptake (Sharma *et al.,* 2013), N_2 fixation (Setten *et al.,* 2013; Boddey and Dobereiner, 1995), production of volatile organic compounds (Ryu *et al.,* 2003) and modification of plant hormonal status (Talboys *et al.,* 2014; Borriss, 2015).

Han *et al*. (2006) also showed that the combined treatment of *Bacillus megaterium* var. *phosphaticum* and *B. mucilaginosus* increased the availability of P and K in soil, and thus increasing the uptake and plant growth of pepper and cucumber. Sarma *et al*., (2009) reported that a combination of bioinocculents, namely, two Fluorescent *pseudomonas* strains, increased *Vigna mungo* yield by 300 % in comparison to the control crop. These results indicated that a combination of beneficial microorganisms might increase the nutritional assimilation of plant and total N in soil.

Effective Microorganisms (EM)

The concept of EM was reported to consist of mixed cultures of beneficial and naturally-occurring microorganisms that can be applied to increase the microbial diversity of soils and plant (Higa, 1991; Higa and Wididana, 1991).

EM consists of a wide variety or multiculture of effective, beneficial and nonpathogenic microorganisms coexisting together. Essentially it is a combination of aerobic and anaerobic species commonly found in all ecosystems. EM contains about 80 species of microorganisms which are able to purify and revive nature. The main species involved are normally the *Lactobacillus plantarum, L. casei* and *Streptoccus lactis* (lactic acid bacteria), *Rhodopseudomonas palustrus* and *Rhodobacter spaeroides*, (photosynthetic bacteria), *Saccharomyces cerevisiae* and *Candida utilis* (yeasts), *Streptomyces albus* and *S. griseus* (actinomycetes), and *Aspergillus* *oryzae*, *Penicillium* sp. and *Mucor hiemalis* (fermenting fungi) . All of those are mutually compatible with one another and can coexist in liquid culture (Renuka and Parameswari, 2012).

EM are claimed to enhance microbial turnover in soil and thus known to increase soil macronutrients resulting in crop quality and yield. Some of these microorganisms produce bioactive substances such as vitamins, hormones, enzymes, antioxidants and antibiotics that can directly or indirectly enhance plant growth and protection (Higa and Parr, 1994; Renuka and Parameswari, 2012).

LAB, as a member of useful organism, beneficial for agriculture and a bacteria stimulating plant growth, is one safe -and edible microorganism ubiquitously found in natural environment. It has played a unique advantage in agri-product cultivation and its quality and safety. Recently the studies were reviewed representing the roles of LAB in promoting plant growth, adjusting and controlling plant diseases, and improving quality of plant products. The application of LAB in agricultural products improves crop quality and edible safety, so as to improve the people's health level (Gao *et al.,* 2014). For sustainable natural farming EM serves as biostimulant encouraging growth and maturity in plants.

Probiotics in agriculture

The study of plants for managing plant health through the manipulation of some probiotic organisms were reported (Picard *et al.,* 2008). Specific microbial groups present in plant rhizosphere may have evolved to strategically stimulate plant-specific stimulation and support particular microbial groups capable of producing antibiotics as a defence against diseases caused by soil-borne pathogens (Weller *et al.,* 2002). Diseases caused by soil-borne fungal pathogens result in loss of more than $150 million production annually in cereal crops in Australia (Gupta, 2012). Currently, attention to bacterial biostimulants is growing and PGPR inoculants are now regarded as some kind of plant 'probiotics', i.e. efficient contributors to plant nutrition and immunity (Berendsen *et al.,* 2012). Berg (2009) has reported several advantages of using plant probiotics over chemical pesticides and fertilizers including: more safe, reduced environmental damage, less risk to human health, much more targeted activity, effective in small quantities, multiply themselves but are controlled by the plant as well as by the indigenous microbial populations, decompose more quickly than conventional chemical pesticides, reduced resistance development due to several mechanisms, and can be also used in conventional or integrated pest management systems.

Plant growth promotion can be achieved by the direct interaction between beneficial microbes and their host plant and also indirectly due to their antagonistic activity against plant pathogens. Several model organisms for plant growth promotion and plant disease inhibition are well-studied including: the bacterial genera *Azospirillum* (Perrig *et al.,*2007; Cassán *et al.,*2009), *Rhizobium* (Long, 2001), *Serratia* (De Vleesschauwer and Hofte, 2007), *Bacillus (*Bai *et al.,*2002; Kloepper *et al.,*2004*)*, *Pseudomonas (*Preston, 2004; Zhao *et al.,*2003*)*, *Stenotrophomonas (*Ryan *et al.,*2009*)*, and *Streptomyces (*Schrey and Tarkka, 2008*)* and the fungal genera *Ampelomyces*, *Coniothyrium* and *Trichoderma* (Hartmann *et al.,*2004*)*.Several mechanisms are involved in the probiotics-plant interaction. It is important to specify the mechanism and to colonize plant habitats for successful application. Steps of colonization include recognition, adherence, invasion, colonization and growth, and several strategies to establish interactions. Plant roots initiate crosstalk with soil microbes by producing signals that are recognized by the microbes, which in turn produce signals that initiate colonization (Compant *et al.,*2010; Bais *et al.,*2006). Colonizing bacteria can penetrate the plant roots or move to aerial plant parts causing a decreasing in bacterial density in comparison to rhizosphere or root colonizing populations (Compant *et al.,*2010). Furthermore, in the processes of plant growth, probiotic bacteria can influence the hormonal balance of the plant whereas phytohormones can be synthesized by the plant themselves and also by their associated microorganisms (Berg, 2009).

c. Biopesticides

Biopesticides or biological pesticides are microbial bioproducts based on pathogenic microorganisms specific to a target pest offering an ecofriendly alternative to chemical pesticides. They pose less threat to the environment and to human health. The most commonly used biopesticides are living organisms, which are pathogenic for the pest of interest. These include biofungicides

(*Trichoderma*), bioherbicides (*Phytopthora*) and bioinsecticides (*Bacillus thuringiensis, B. sphaericus*). A biopesticide is an effective solution to pest attacks which encompasses a broad array of microbial pesticides, biochemicals derived from micro-organisms and other natural sources, and processes involving the genetic incorporation of DNA into agricultural commodities that confer protection against pest damage (Gupta and Dikshit, 2010).

Microbial pesticides

Biopesticides derived from fungi, bacteria and viruses and also some other compounds produced directly from these microbes such as metabolites are main microbial pest control agents (Van Lenteren, 2012). The organisms used in microbial insecticides are essentially nontoxic and nonpathogenic to wildlife, humans, and other organisms not closely related to the target pest offering great safety. As their residues present no hazards to humans or other animals, microbial insecticides can be applied even when a crop is almost ready for harvest. They also enhance the root and plant growth by way of encouraging the beneficial soil microflora. By this way they take a part in the increase of the crop yield.

More than 3000 kinds of microbes are reported to cause diseases in insects. Over 100 bacteria have been identified as insect pathogens, among which *Bacillus thuringiensis* Berliner (Bt) has got the maximum importance as microbial control agent globally. So far, more than 1000 insect species viruses have been isolated such as nuclear polyhedrosis virus (NPV) infested 525 insects worldwide. Over 800 species of entomopathogenic fungi are reported as biocontrol agents (Koul, 2011).

Bacterial pesticides

The bacteria used as biopesticides include crystalliferous spore formers (such as *Bacillus thuringiensis*); obligate pathogens (such as *Bacillus popilliae*); potential pathogens (such as *Serratia marcesens*); and facultative pathogens (such as *Pseudomonas aeruginosa*). Out of these four, the spore formers have been most widely adopted for commercial use because of their safety and effectiveness. The most commonly used bacteria are *B. thuringiensis* (Bt) and *Bacillus sphaericus.*

B. thuringiensis is a specific, safe and effective tool for insect control (Roh *et al.,* 2007). It is a Gram-positive, spore-forming bacterium, with nearly 100 subspecies and varieties divided into 70 serotypes (Schnepf *et al.,* 1998). It is primarily a pathogen of l*epidopterous* pests like American bollworm in cotton and stem borers in rice. When ingested by pest larvae, Bt releases toxins which damage the mid gut of the pest, eventually killing it. Main sources for the production of Bt preparations are the strains of the subspecies *kurstaki, galeriae and dendrolimus* (Gupta and Dikshit, 2010) which are also widely used as biopesticides (Table 1). The insecticidal property of *B. thuringiensis* resides in the Cry family of crystalline proteins that are produced in the parasporal crystals and are encoded by the cry genes. The Cry proteins are globular molecules (65-145 kDa, depending on the strain) with three structural domains. Cry proteins are responsible for feeding cessation and death of the target pest (Whalon and Wingerd, 2003; Rodrigo-Simon *et al.,* 2008). These bacteria are mass-produced through either solid or liquid fermentation.

B. sphaericus is a Gram-positive strict aerobic bacterium, which produces round spores in a swollen club-like terminal or subterminal sporangium. These bacteria produce an intracellular protein toxin (5511-1) and a parasporal crystalline toxin at the time of sporulation. The mosquito-larvicidal binary toxin produced by *B. Sphaericus* is composed of BinB and BinA, 51.4 and 41.9 kDa, respectively (Park *et al.,* 2009; 2010b). *Bacillus sphaericus*-based products are commonly used for mosquito control.

PGPR as Biocontrol Agents

PGPR produce substances that also protect them against various diseases. PGPR may protect plants against pathogens by direct antagonistic interactions between the biocontrol agent and the pathogen, as well as by induction of host resistance. For biocontrol of soil-borne plant pathogens, siderophore-producing PGPR are used widely through seed, soil or root system. PGPR that indirectly enhance plant growth via suppression of phytopathogens do so by a variety of mechanisms. These include: siderophores producing ability that chelate iron, making it unavailable to pathogens; the capacity to synthesize anti-fungal metabolites such as antibiotics, fungal

Table 1: A summary of microbial insecticides

Pathogen	Host Range	Uses And Comments
Bacteria		
*Bacillus thuringiensis*var. *kurstaki* (*Bt*)	caterpillars (larvaeof moths andbutterflies)	Effective for foliage-feeding caterpillars (and Indian meal moth in stored grain). Deactivated rapidly in sunlight; apply in the evening or on overcast days and direct some spray to lower surfaces or leaves.Does not cycle extensively in the environment.
*Bacillus thuringiensis*var. israelensis (*Bt*)	larvae of *Aedes* and *Psorophora*mosquitoes, blackflies, and fungus gnats	Effective against larvae only. Active only if ingested.*Culex* and *Anopheles* mosquitoes are not controlled at normal application rates. Does not cycle extensively in the environment.
*Bacillus thuringiensis*var. *tenebrinos*	larvae of Coloradopotato beetle, elmleaf beetle adults	Effective against Colorado potato beetle larvae and the elm leaf beetle. Like other *Bt*s, it must be ingested. It is subject to breakdown in ultraviolet light and does not cycle extensively in the environment.
*Bacillus thuringiensis*var. *Aizawai*	wax mothcaterpillars	Used only for control of moth infestations in honeybee hives.
Bacillus popilliae and*Bacillus lentimorbus*	larvae (grubs) ofJapanese beetle	The main Illinois lawn grub (the annual white grub,*Cyclocephala* sp.) Is NOT susceptible to milky spore disease.
Bacillus sphaericus	larvae of *Culex,Psorophora,* and*Culiseta* mosquitos, larvae of some *Aedes* spp.	Active only if ingested, for use against *Culex,Psorophora,* and *Culiseta* species; also effective against *Aedes vexans.* Remains effective instagnant or turbid water
Fungi		
Beauveria bassiana	aphids, fungusgnats, mealy bugs,mites, thrips,whiteflies	Effective against several pests. High moisture requirements, lack of storage longevity, and competition with other soil microorganisms are problems that remain to be solved.
Lagenidium giganteum	larvae of most pestmosquito species	Effective against larvae of most pest mosquito species; remains infective in the environment through dry periods. A main drawback is itsinability to survive high summer time temperatures
Viruses		
Gypsy moth nuclearplyhedrosis (NPV)	Virusgypsy mothcaterpillars	All of the viral insecticides used for control of forestpests are produced
Codling mothgranulosis virus (GV)	codling mothcaterpillars	Commercially produced and marketed briefly, but no longer registered or available. Future reregistration is possible. Subject to rapid breakdown in ultraviolet light.

cell wall-lysing enzymes, or hydrogen cyanide, which suppress the growth of fungal pathogens (Bhattacharyya and Jha, 2012); nutrient competition with pathogen or specific niches on the root; and to induce systemic resistance (Sharma *et al.,* 2003).

Among the various PGPRs identified, *Pseudomonas fluorescens* is one of the most extensively studied rhizobacteria, because of itsantagonistic action against several plant pathogens. Banana bunchytop virus (BBTV) is the fatal virus severelyaffecting the yield of banana (*Musa* sp.) crop in Western Ghats,Tamil Nadu, India. It has been demonstrated that application of *P. fluorescens* strain significantly reduced the BBTV incidencein hill banana under greenhouse and field conditions (Raman, 2012). DifferentPGPR species as biocontrol agents against various plant diseases are given in Table 2.

PGPR as Biological Fungicides

PGPR and bacterial endophytes play a vital role in the management of various fungal diseases.

Bacillus subtilis, *Pseudomonas chlororaphis*, endophytic *P. fluorescens* inhibit the growth of stem blight pathogen *Corynespora casiicola*. The seed treatment and soil application of *P. fluorescens* reduce root rot of black gram caused by *Macrophomina phaseolina*. Seed and foliar application of *P. fluorescens* reduce sheath blight of rice. *B. subtilis* in peat supplemented with chitin or chitin-containing materials show better control of *Aspergillus niger* and *Fusarium udum* in groundnut and pigeon pea, respectively. Strains of *Burkholderia cepacia* have been shown to have biocontrol of *Fusarium* spp. (Podile and Kishore, 2007).

Table 2: PGPR as biocontrol agents against various plant diseases.

PGPR	Disease resistance
Bacillus pumilus, *Kluyvera cryocrescens*, *B. amyloliquefaciens* and *B. Subtilus*	Cucumber Mosaic Cucumovirus (CMV) of tomato (*Lycopersicon esculentum*)
B. amyloliquefaciens, *B. subtilis* and *B. pumilus*	Tomato mottle virus
B. pumilus	Bacterial wilt disease in cucumber (*Cucumis sativus*), Blue mold disease of tobacco (*Nicotiana*)
Pseudomonas fluorescens	Sheath blight disease and leaf folder insect in rice (*Oryza sativa*), Reduce the Banana Bunchy Top Virus (BBTV) incidence, Saline resistance in groundnut (*Arachis hypogea*)
B . subtilis and B. pumilus	Downy mildew in pearl millet (*Pennisetum glaucum*)
B. subtilis	CMV in cucumber
B. cereus	Foliar diseases of tomato
Bacillus spp.	Blight of bell pepper (*Capsicum annuum*), Blight of squash
Burkholderia	Maize (*Zea mays*) rot
B. subtilis	Soil borne pathogen of cucumber and pepper (*Piper)*
Bacillus sp. and *Azospirillum*	Rice blast
Fluorescent *Pseudomonas* spp.	Rice sheath rot (*Sarocladium oryzae*)

Fungal Biopesticides

An important group of microbial pest management organisms include the pathogenic fungi (Khachatourians, 2009) that grow in both aquatic as well as terrestrial habitats and when exclusively associated with insects are known as entomopathogenic fungi. These are obligate or facultative, commensals or symbionts of insects. The pathogenic action depends on contact and they infect and kill sucking insect pests such as aphids, thrips, mealy bugs, whiteflies, scale insects, mosquitoes and all types of mites (Barbara and Clewes, 2003; Pineda *et al.,* 2007). Entomopathogenic fungi are promising microbial biopesticides that have a multiplicity of mechanisms for pathogenesis. They belong to 12 classes within six phyla and belong to four major groups; Laboulbeniales, Pyrenomycetes, Hyphomycetes and Zygomycetes. Some of the most widely used species *include Beauveria bassiana, Metarhizium anisopilae, Nomuraea rileyi, Paecilomyces farinosus* and *Verticillium lecanii*.

These fungi attack the host via the integument or gut epithelium and establish their conidia in the joints and the integument. Some species such as *B. bassiana* (Table 1) and *M. anisipoliae* cause muscardine insect disease and after killing the host, cadavers become mummified or covered by mycelial growth (Miranpuri and Khachatourians, 1995). About 50 such compounds have been reported as active against various insect species belonging to *Lepidoptera*, *Homoptera*, *Coleoptera*, *Orthoptera* and mites. The most active toxins are actinomycin A, cycloheximide and novobiocin (Dowd, 2002). Spinosyns are commercially available biopesticidal compounds that were originally isolated from the actinomycete *Saccharopolyspora spinosa* and are active against dipterans, hymenopterans, siphonaterans and thysanopterans but are less active against coleopterans, aphids and nematodes (Sparks *et al.,* 1999).

Viral Biopesticides

Insect-infecting viruses have been isolated, mostly from *Lepidoptera* followed by *Hymenoptera*, *Coleoptera*, *Diptera* and *Orthoptera* (Khachatourians, 2009). The viruses used for insect control are the DNA-containing baculoviruses (BVs), Nucleopolyhedrosis viruses (NPVs), granuloviruses (GVs), acoviruses, iridoviruses, parvoviruses, polydnaviruses, and poxviruses and the RNA-containing reoviruses, cytoplasmic polyhedrosis viruses, nodaviruses, picrona-like viruses and tetraviruses. However, the main categories used in pest management have been NPVs and GVs. These viruses are widely used for control of vegetable and field crop pests globally, and are effective against plant-chewing insects (Table1). Their use has had a substantial impact in forest habitats against gypsy moths, pine sawflies, Douglas fir tussock moths and pine caterpillars.

The mechanism of viral pathogenesis is through replication of the virus in the nuclei or in the cytoplasm of target cells. At the late phase of viral protein expression, virions assemble to synthesize the 29 kDa occlusion body protein resulting in the occlusion of numerous virions (of NPVs) to develop hundreds of polyhedra and thousands of granules *per* cell by the infected nuclei. These can create enzootics, deplete the pest populations, and ultimately create a significant impact on the economic threshold of the pest (Khachatourians, 2009). Many NPVs are used on over 100,000 ha annually (Yang *et al.,* 2012). For soybean insect pest (*Anticarsia gemmatalis*), AgMNPV (Yang *et al.,* 2012) and for cotton bollworm, *H. Armigera*,combination of HaMNPV with endosulfan has provided significant results (Siddique *et al.,* 2010; Mir *et al.,* 2010; Elamathi *et al.,* 2012).

In Indian agriculture, biopesticides are employed to achieve great success in bio-control resulting in increased crop yield (Kalra and Khanuja, 2007). Some of the examples include, Control of diamondback moths by *Bacillus thuringiensis*; Control of mango hoppers and mealy bugs and coffee pod borer by *Beauveria*; Control of *Helicoverpa* on cotton, pigeon-pea, and tomato by *Bacillus thuringiensis*; Control of white fly on cotton by neem products; Control of *Helicoverpa* on gram by NPV; Control of sugarcane borers by *Trichogramma* and Control of rots and wilts in various crops by *Trichoderma*-based products.

Studies on Effects of Some Microbial Bio-products on Crops

Eco-friendly agricultural system has emerged as an important priority area globally in view of the growing demand for safe and healthy food and long term soil-environmental sustainability and concerns on environmental pollution associated with indiscriminate use of agrochemicals.Microbial bioproducts have emerged as supplements to mineral fertilizers and hold a promise to develop superior quality crop yield. They offer an economical and eco-friendly option by the management of beneficial microorganisms leading to establish the commercial trends around the world. The production of microbial bioproducts and their commercialization is focused on the creation and support of sustainable agriculture. The increasing concern about the environment and socio- economic impact of chemical agriculture has led many farmers and consumers to seek alternative practices for agricultural sustainability and marketability.

There are many reports on the studies of the effect of microbial products on agricultural and horticulture crops practiced by field experimentation. The review describes some of them to focus the role of microbial bioproducts for suatainable agriculture.

- The effect of biofertilizers application on growth and yield of tomato plants was studied (Ramakrishnan and Selvakumar, 2012). Seeds of tomato were sown in sand beds in size 5×1m2 under shade net condition to raise the seedlings. Twenty day old seedlings were transplanted into field until the fruit ripening period. After transplanting, seedlings of tomato were treated with *Azotobacter*, *Azospirillum* and combination of both. In all the treatments, *Azotobacter* with *Azospirillum* treated plants showed significantly maximum yield over control. The overall results suggested the improvement of plant mineral concentration through nitrogen fixation enhancing the fruit production in tomato plants (Ramakrishnan and Selvakumar, 2012).
- Arunkumar *et al..,* (2015) studied the evaluation of growth promoting effects of extracts squeezed from the fresh thallus of two seaweeds (Red-*Gracilaria corticata* var.*corticata* and brown- seaweed *Sargassum wightii*) on the seedling of chilly under polyhouse condition. The red seaweed extract of *Gracilaria corticata* var. *corticata* contained high content of calcium & magnesium and the brown seaweed extract of *Sargassum wightii* contained high amount of K & sulphate at slightly alkaline pH were significantly promoted the growth of chilly. Seedlings received full dose of both seaweed extracts and 50 % recommended dose of N, P and K (RDF) + 50 % extracts showed more growth than plants applied with both extracts separately in addition to RDF. This result demonstrated that the application of seaweed extracts have the potential on reducing 50 % fertilizer application concluding their important application for organic agriculture as organic fertilizer or biostimulant (Arunkumar *et al.,* 2015).
- A field experiment was carried out to study the combined effect of fertigation and consortium of biofertilizers on the accumulation of secondary and micronutrients in banana cv Robusta (AAA) (Senthilkumar *et al.,* 2014).

The results indicated that the combination of fertigation and consortium of biofertilizers (*Azospirillum*, phosphate solubilizing bacteria and AMF mixed in equal proportions) significantly enhanced the secondary and micronutrient accumulation in the leaves, pseudostem and fruits at harvest. Among the treatments, 100% and 75% RDF through fertigation with the combination of consortium of biofertilizers, recorded significantly higher secondary and micronutrients in the plant parts analysed with higher contents of calcium, magnesium, sulphur in the order of Ca>Mg>S and micronutrient contents in the order of Mn>Fe>Zn in the leaves, psuedostem and fruits (Senthilkumar *et al.,* 2014).

- The field study was carried out during 2010-2012 to find out the effect of integration of bio-fertilizers with organic manures and inorganic fertilizers on growth, yield and quality of strawberry (*Fragaria* × *ananassa* Duch.) cv. Festival (Hazarika *et al.,* 2015). The growth, yield and quality of strawberry fruits were significantly influenced by integration of bio-fertilizers, organic manure and inorganic fertilizers. The maximum growth in terms of plant height, spread and number of crowns/plant were observed in the treatment consisting of 75% RDF + vermicompost + *Azospirillum* + PSB + 50 ppm GA3+ 50 ppm BA. The yield attributing characters like number of runners/plant, berry set per cent, berry weight, number of berries/plant and yield/ha were found to be influenced by combined use of organic, inorganic and biological sources of nutrients (Hazarika *et al.,* 2015).
- The field studies were conducted to develop a protocol for application of commercially manufactured biostimulant (Brand name: Plantozyme) from bacterial extract and seaweed extract.

Plantozyme

Plantozyme is an innovative microbial product derived from specific strains of naturally occurring microorganisms and special type of seaweeds. A stable formulation containing bacterial extract and seaweed extract make plantozyme a safe and novel product for improving plant growth and yields in a natural way. The major constraint with the bacterial culture based bioproducts is the nativity of the bacterial strain used in the manufacture. The strain isolated from a particular place may not be able to complete the native flora of a totally different geographical area. Therefore the bacteria used in the manufacture of bioproduct may not show good results in a soil different from the native soil even though it proves to be very good in the laboratory studies. Plantozyme has been designed and developed precisely to overcome these constraints and aimed at achieving 'Sustainable Agriculture'.

Besides the role of seaweed extract as biostimulant enhancing seed germination; improving soil fertility, plant growth, yield; increasing resistance to biotic and abiotic stresses (Khan *et al*., 2009; Craigie 2011; Mattner *et al*., 2013), bacterial extract performs the additional significant role in the plantozyme biostimulant. To overcome the limitations of the live bacterial cultures based bioproducts, a novel concept of bacterial extracts has been successfully developed. Commercially, plantozyme is manufactured using specific bacteria and seaweed extracts under controlled fermentation conditions resulting in the stable formulation of bacterial extract and seaweed extract for agricultural applications. The plantozyme is based on seaweed extract bioproduct technology developed by Govt. Of India Laboratory under Council of Scientific and Industrial Research (CSIR) viz: National Institute of Oceanography (NIO).

Effect of plantozyme on various crops

Effect of plantozyme on a variety of crops such as Banana, Grapes, Soybean, Bengal gram, Chilli, Cotton, Sugarcane, Wheat, Paddy, Sorghum etc. were studied at different agriculture research centres in India. Moreover, the effect of plantozyme on lot of horticulture crops like papaya, mango, citrus, strawberry, apple, pineapple, vegetables, tomato, onion etc. was also studied and currently the trials are undertaken on various farms. Some of the studies of the effect of plantozyme were described.

a. Banana

India is the largest producer of banana (*Musa paradisiaca L.)*, contributing 19.71% of the global production with a total production of 19.19 M tones from 0.565 M ha. The major banana growing areas are: Tamil Nadu, Maharashtra, Andhra Pradesh, Gujarat, Kerala, Karnataka, West Bengal and Orissa. Tamil Nadu has the largest area while Maharashtra is second largest producer with highest productivity level.

Judicious nutrient management is often regarded as one of the important aspects to increase the productivity of fruit crops particularly banana. Efficient and rational use of the fertilizers is imperative not only for obtaining more yields *per* unit area on a sustainable basis, but also to ensure safe food and to conserve the environment. Banana generally requires high amount of mineral nutrients for propergrowth and production. Sea weed based bioregulators are widely used in the recent years to increase the nutrient use efficiency in various agricultural and horticultural crops.

- The studies of growth and development of *Basrai* banana during 2000-2001 were carried out by IIHR under the project of All India Coordinated Research Project and ICAR ad hoc schemes on Tropical Fruits, for two seasons in clay loamy soil were reported at Gujarat Agricultural University, Gandevi, India (Reddy *et al.,* 2001). Plantozyme was applied as sucker dip/foliar spray resulting into the improvement of the yield of Basrai banana under Gandevi conditions (58.24 t/ha as against 50.39 t/ha in control).
- Jeyakumar and Kumar (2002) studied bio-regulating efficiency of the plantozyme in banana cv. *Dwarf Cavendish* at Tamilnadu Agricultural University, Coimbtore, India and reported that the foliar application of 0.2% plantozyme at 6^{th} and 8^{th} month after planting in addition to RDF had significant influence on morphological characters, especially pseudostem height and girth; important physiological and biochemical parameters viz., chlorophyll content, NRase and IAA oxidase activity. Besides improving the leaf nutrients status, higher cell wall plasticity and dry matter accumulation was observed resulting in better yield (Jeyakumar and Kumar, 2002; Balamohan *et al.,* 2007). The higher LAI (Leaf Area Index, 3.37) due to plantozyme enabled the plant to make more effective use of solar energy during photosynthesis. The increase in leaf area could be due to the osmotic uptake of water facilitated by K. The higher N (2.07% increase over control) and K (3.92% increase over control) status in plants due to plantozyme favoured the plants to have more dry matter production by influencing net photosynthesis, transpiration and activities of enzymes such as NRase, 9.63 ìg NO^2/g/h and IAA oxidase, 0.77 ìg auxin/g/h (Jeyakumar *et al.,* 2007).
- The physiological and biochemical responses of the ratoon crop of '*Dwarf Cavendish*' (AAA) to biological derivatives plantozyme and biozyme were assessed during the year 2002-2003.The experiments conducted had seven treatments, including the control (RDF), soil drenched with plantozyme 0.2% at the time of setting the suckers, 10 gram of granular plantozyme *per* plant 2 and 4 months after setting, foliar spray of plantozyme 0.2% 6 and 8 months after setting, and exactly the same treatments of biozyme. The physiological and biochemical changes and agronomic performance of the plants were recorded at shooting (Jeyakumar *et al.,* 2004). Plants treated with foliar spray of plantozyme 0.2% showed higher net photosynthesis and stomatal conductance in the third youngest leaf. The increased net photosynthesis indicates more dry matter production well evidenced through improved pseudostem height and girth with low light transmission ratio. 0.2% plantozyme improved the leaf N and K considerably. Moreover, plantozyme 0.2% resulted in higher sugar content and TSS due to efficient translocation of available photosynthates to fruits and hydrolysis of complex polysaccharides into simple sugars (Jeyakumar *et al.,* 2004).

b. Grapes

The grape is the most important crop grown in the world. Mostly it was grown for making wines and preparation of raisin and then as a table fresh fruit. While in India, it is mainly grown for table use. Total area under grapes in India is about 40,000 ha, distributed mainly in Maharashtra, Karnataka, Andhra Pradesh and Tamil Nadu.

Recent years, unfavourable weather in major grapes growing areas has been an important constrain for Indian table grape industry. ICAR - National Research Centre for Grapes, Pune (established in January 1997) has undertaken the mission oriented research to address the issues related to grape production and processing in India.

- Several studies regarding input use efficiency-optimization of nutrient and water requirement of grapevine in different soil regions were conducted. For improving bud break and grape quality, ICAR recommended the plantozyme in Thompson seedless grapes in the annual report (2014-15) (Sawant *et al.,* 2015).Studies on bio-efficacy of plantozyme were evaluated for their effect on growth in Thompson Seedless grapes. Application of plantozyme as foliar spray (2.5 ml/L) significantly influenced all the berry parameters while the application as drip (2.5 ml/L) recorded significantly higher bunch weight, berry length, berry diameter and yield in Thompson Seedless grapes (Sawant *et al.,*2015).
- Considering the biostimulant quality of plantozyme, multi-location trials were conducted to study bio-efficacy of plantozyme in grapes by National Research Centre for Grapes, Pune (NRC) (2010-11, 2012-13). The experiments were applied to study the effect of plantozyme on vegetative growth, photosynthetic parameters, quality and yield of Thompson Seedless grapes (Ramteke, 2013).

The field experiments were conducted on Thompson Seedless grafted on Dog Ridge rootstosk planted at Nashik (Ugaon Khed, Niphad), (Pimpalgoan) and Pune (NRC) by completely randomized designing. Standard cultural practices were applied and replicated three times. Amazing results were observed at all the three places mentioned above. Out of all the treatments given the significantly highest yield was recorded as 19.01 ± 2.40 kg/vine over the control 14.29 ± 2.21 kg/vine by the treatment, 'RDF + Plantozyme Granules (PG) at 50 g/vine immediately after pruning + Plantozyme Liquid (PL)/ planto drip @ 2.5ml/vine at 21 days and 50 days after pruning + spraying of PL @ 2ml/ L at 30 and 55 days after pruning'. Remarkably improved results were observed in no. of Berries / Bunch (103.3 ± 7.6), Bunch weight (410.5 ± 36.3 g), 50 berry weight (199.30 ± 5.98 g), Berry length (29.1 ± 0.4 mm), Berry Diameter (16.4 ± 0.2 mm), Skin Thickness (26.7 ± 2.0 ìm), Total Soluble Solids (21.0 ± 0.6 ^{0}B), Acidity (0.8 ± 0.0 g/L) etc. quality and yield parameters. Effect of plantozyme on morphological parameters like shoot length, leaf area with improved leaf size and petiole length was proved better. Also, photosynthetic parameters such as photosynthesis rate, stomatal conductance, Transpiration rate, vapour pressure deficiate and diffusive resistance were recorded perfectly suitable for grape cultivation. From the three location studies, it was concluded that the plantozyme has a potential to increase morphological parameters, rate of photosynthesis, quality and yield components of grapes (Ramteke, 2013).

b. Sugarcane

Sugarcane (*Saccharum officinarum L.)* is the main sources of sugar in India and holds a prominent position as a cash crop. India is the world's largest consumer and the second largest producer of sugar, topped only by Brazil. Nearly 2.8 lakh farmers have been cultivating sugarcane in the vast area of 4.4 lakh acres and over 11 crore people are directly or indirectly dependent on the sugar industry in the country. Sugarcane is able to grow over a prolonged season. Under warm humid conditions, it can continue its growth, unless terminated by flowering.

- Study of the effect of plantozyme on growth and yield of sugarcane on 2 varieties, CoM 0265 and Co 86032 (2013-2014) was conducted at Central Sugarcane Research Station, Padegaon, Tal. Phaltan, Dist. Satara. Significant effect on germination per cent, tillering ratio and total dry matter was recorded in this study. Sugarcane yield as well as juice quality improvement was observed with considerably highest % of commercial cane sugar (CCS). The plantozyme treatment, sett dipping of plantozyme (2ml/L) for 15 min. + spraying of plantozyme @ 3 ml/L at 45 and 65 days after planting + soil application of 50 Kg planto granules / acre with basal RDF + drenching of 2.5 L plantozyme /acre at the time of earthing up either through irrigation system or by Knapsack sprayer without nozzle in addition to significantly increased the cane and CCS yield by 12.85% for variety CoM 0265 and 15.25% over control (Pawar *et al.,* 2014).

d. Chilli

Chilli (Capsicum annum L., Capsicum frutescens L.) is reported to be a native of South America and is widely distributed in all tropical and sub tropical countries including India. It was first introduced in India by Portuguese towards the end of 15th Century. Now it is grown all over the world except in colder parts.

Acharya N. G. Ranga Agricultural University conducted the plantozyme trials on chillis at Regional agricultural research station, Lam during *Kharif* 2004-05. The effect of plantozyme on growth and yield parameters in chillies were evaluated. Among the different treatments given (3 replications of randomised block design), the most suitable treatment was of RDF with soil application of planto granules @16kg/acre and foliar spray @ 2ml/L at 45, 75 and 90 days after transplanting. All the results of chilli treatment (plant height, 112.7 cm; no. of pods *per* plant, 189.8; LAI, 2.06; 100 pod weight, 74.20 g; dry chilli yield, 5592 kg/ha) were found significantly superior (Reddy and Bharathi, 2005).

e. Soybean

The Soybean (*Glycine max*) is an irrigated summer growing oilseed crop whose grain in Australia has traditionally been used for oil extraction and the meal used in the stockfeed industries. More recently soybeans have become a popular culinary grain used in the making of Asian foodstuffs such as milk and tofu.Effect of plantozyme on soybean was studied at Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, India. Significant results were found exploiting the PGPR activity of plantozyme in soybean (variety JS 335). Application of plantozyme (RDF + soil application @16 Kg PG + 2 foliar spray @ 2ml/L PL) showed increase in grain yield by 23%, reduction in chemical fertilizer consumption up to 20%, increased soil fertility. Application of plantozyme showed remarkable increase in no. of nodules (88.50, 45 days/plant) and improved N uptake efficiency by 39% (Anon, 1998).

f. Cotton

Cotton (*Gossypium sp.*) is one of the most important commercial crops playing a key role in economics. In India cotton is cultivated in 9 million hectares in varied agro-climatic conditions across nine major States.

Evaluation of plantozyme in cotton was studied by University of Agricultural Sciences, Dharwad at Agricultural Research Station, Dharwad (*Kharif,* 1999-2000, 2000-2001), India. Different parameters of cotton cultivation were evaluated including Days to 50% boll opening, Plant height (cm), Sympodia/ plant, Boll weight (g), Fruiting points/plant, No. of bolls /plant and seed cotton yield by using treatment schedule of randomised block design (3 replications). Application of plantozyme showed significantly increased seed cotton yield (13.09 q/ha; 21.69% increase over control) when sprayed 2ml/L at 60 days after sowing. Plant height (133.1 cm), no. of sympodia /Plant (21.9), Boll weight (3.92 g /boll, 19.87 % increase over control) as well as maximum no. of bolls /plant, maximum of 95.0 fruiting points /plants were reported radically better concluding the plantozyme as perfect suitable biostimulant for cotton cultivation (Patil, 2001).

g. Wheat

Wheat (*Triticum spp.*) occupies the prime position among the food crops in the world. In India, it is the second important food crop being next to rice and contributes to the total foodgrain production of the country to the extent of about 25%. Wheat has played a very vital role in stabilizing the foodgrain production in the country over the past few years.

Effect of plantozyme on wheat was studied under the project entitled 'Bio-efficacy studies of plantozyme bio product in rice and wheat' by Kumar *et al.,* (2015) at G. B. Pant University of Agriculture & Technology, Pantnagar India. 10 different treatments were applied including PG, PL and varying combinations of both, PG and PL.

Plant height, tillers *per* square meter were significantly influenced by PL and PG both at the treatment of PG (@ 75 kg/ha) + PL 3 sprays (@ 1500 ml/ha) at 60days, 90days and at harvest stage of wheat crop, which was significantly higher than control and alone application of granule and liquid formulations. At 90 days of crop growth the maximum SPAD (Soil and Plant analyser development) reading was found in PG (@ 75 kg/ ha) + PL 3 sprays (@ 1500 ml/ha), which was significantly higher than the other treatments. The similar results were also noticed in case of green seeker reading, cholorophyll content in leaves, yield contributing characters like spikes/ square metre, grains/spike, 1000 grain weight as well as grain yield and straw yield both were found maximum at PG (@ 75 kg/ha) + PL 3 sprays (@ 1500 ml/ha depicting the remarkable increase in the yield by 26% over control (Kumar *et al.,* 2015).

h. Sorghum

Sorghum (*Sorghum vulgare* Pers.) is an important crop of the dryland regions in India. It is cultivated in *Rabi* (October-March) (winter) season mainly for food purposes and in *Kharif* (July – October) season for food, feed and fodder uses. In addition, it has immense potential as a high biomass and biofuel crop.

Crop management studies involving tillage, INM (Integrated Nutrient Management) and efficacy of plantozyme were conducted during *Rabi* 2013-14 at different AICSIP (All India Coordinated Sorghum Improvement Project, Hyderabad) centres (Rahuri, Dharwad). A field experiment to study the efficacy of PL and PG was conducted on productivity of rainfed *Rabi* sorghum during *Rabi* 2012-13. Treatments include PG @ 20 kg/ ha as soil application, PL @ 2 ml/L water foliar spraying at 35 days after sowing (DAS), PL @ 2 ml/L water sprayed at 60 DAS, PL @ 2 ml /L water sprayed at 35 and 60 DAS, PL @ 2 ml/L water as seed treatment and RDF (60:30:30 kg/ ha NPK) alone replicated four times in a randomized block design. Results revealed that application of these compounds along with RDF improved the grain yield of *Rabi* sorghum as compared to RDF alone. Foliar spraying of plantozyme @ 2 ml/L water at 35 and 60 DAS significantly increased the grain yield (1570 kg/ ha) of *Rabi* sorghum compared to RDF alone (1178 kg/ ha) (Rajendrakumar *et al.,* 2014).

Moreover, the effect of plantozyme on various agriculture and horticulture crops was studied in detail at different Agricultural Research Centres and found superior results for each crop. The plantozyme thus, appeared as an efficient microbial bioproduct establishing the suatainable agriculture with quality crop yield in cost effective and eco-friendly way. Consequently the plantozyme has a potential to me*et al*l the challenges like reduction in chemical fertilizers, environment protection, soil health maintenance, quality crop yield establishing the disease resistant plant.

Conclusion

Microbial bioproducts can help to solve the problem of feeding an increasing global population at a time when agriculture is facing various environmental stresses. It is important to realise the useful aspects of microbial bioproducts and their implementation to modern agricultural practices. The lack of awareness regarding improved protocols of a range of bioproducts applied to the field is one of the few reasons why many useful microbial bioproducts are still beyond the knowledge of ecologists and agriculturists. The success of the science related to microbial bioproducts depends on the inventions of innovative strategies related to their functions and properrelevance to the agriculture. The major challenge in this area of agricultural research lies in the fact that along with the production and commercialization of various microbial bioproducts and their beneficial properties it is essential to analyse the actual mechanism of functioning and application of microbial bioproducts for their efficacy towards exploitation in sustainable agriculture. A diverse range of commercial microbial bioproducts have been found but their consistent use in fields is yet to be fully realised. New knowledge on soil microbial diversity can lead to the discovery of new generation microbial bioproducts following the exploitation of perfect combination of microbial bioproducts in the field. The performance of the microbial bioproducts depends on the potential of the microorganisms added or mixed cultures or microbial extracts along with seaweed extracts as well as their accuracy and stability in the field application. With the overall conclusion, the plantozyme has a potential to me*et al*l the challenges like reduction in chemical fertilizers, environment protection, soil health maintenance and above all, to protect our farmers interests and his life, ultimately to ensure the food security to the nation in the coming centuries. Moreover, the plantozyme as well as many other efficient microbial products should be applied in the fields with the perfect agricultural technique fulfilling the role of microbial bioproducts in sustainable agriculture.To become successful venture this microbial bioproduct technology must reach to the hands of the farmers. Therefore some more efforts are put to fully exploit the role of microbial bioproducts in the farmers' field by means of extension activities like field demonstration, farmers' fair and training programme.

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Diversification of Temperate Fruits in Western Himalayas: Alternate to Climate Change

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Variation in climatic conditions and short term abrasions in weather parameters has raised levels of uncertainty, vulnerability and risk of investments in horticulture. Horticultural production and horticultural science are both intimately involved with the debate and the policy shifts that are occurring around the factors that are closely associated with climate change. Aside from greenhouse crops, where knowledge about plant responses to environmental factors are generally well defined, our knowledge about the responses of field crops in general and perennial crops in particular is very poorly developed. Improved understanding of the consequences of inadequate winter chilling, and the means to counter that, are critical to the continued growth and survival of many temperate perennial crops – and yet our current knowledge is quite inadequate to deal with the changes that are occurring. The same can be said for knowledge about climatic factors and the development of maturity of different fruit crops. In the face of warmer temperatures due to climate change, winter chill requirements will become harder to meet in many important temperate-fruit and nut-producing areas. There is large scope for diversification of temperate fruits which can fit in to changing climatic situations and can tolerate biotic and abiotic stress under fragile Himalayan ecosystem. The identification of new species, their characterization, conservation and sustainable utilization is the key to improve agricultural productivity and sustainability, therefore contributing to national development, food security and poverty alleviation. Future fruits like black berries, Blue berries, sour cherry, raspberries, persimmon, rose hips, Chinese jujube, cape gooseberries, Red currants, kiwi fruit, nectarines, olive, apricot and un tapped nuts like hazel nut, chest nut having nutraceutical, ecological and economical importance special attention in respect of introduction, collection, evaluation, production technology, sustainable exploitation. Majority of these future fruits contain phytochemicals of nutraceutical importance. These phytochemicals, either alone and/or in combination, have tremendous therapeutic potential.

Introduction

The identification of new species, their characterization, conservation and sustainable utilization is the key to improve agricultural productivity and sustainability, therefore contributing to national development, food security and poverty alleviation. Variation in climatic conditions and short term abrasions in weather parameters has raised levels of uncertainty, vulnerability and risk of investments in horticulture. In the face of warmer temperatures due to climate change, winter chill requirements will become harder to meet in many important temperate-fruit and nut-producing areas. Aside from greenhouse crops, where knowledge about plant responses to environmental factors are generally well defined, our knowledge about the responses of field crops in general and perennial crops in particular are very poorly developed. In western Himalayas (WH), 80% people depend upon agriculture and allied activities. Geographically, Jammu and Kashmir, Himachal Pradesh and Uttarakhand which comprises the western Himalayas are located at Latitude 28 43-37 06 N and Longitude 73 26 – 81 02 E, and altitude varies from 300 to

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7800 m MSL and is known for greater diversity of species of *Malus, Pyrus, Prunes, Vitis, Ribes, Rubus, Fragaria,* etc. In North West Himalayan region, most of the area consists of difficult hilly terrain of different types (low, mid and high) which are unfit for cultivation of high input demanding crops. Such lands can easily be put to use for growing with low input in order to diversify the present day horticulture, and to meet the demands of increasing population, nutritional security and fast depletion of natural resources as well as the growing and changing human needs in the region. These untapped fruits are nature's wonderful gift to the mankind; indeed, they are life-enhancing medicines packed with vitamins, minerals, anti-oxidants and many phyto-nutrients (Plant derived micronutrients). Therefore it becomes possible to exploit the untapped potential of the region through location specific horticulture and subsequently expanding the area under lesser known horticultural crops through adoption of modern scientific viable technologies. Underexploited horticultural crops have a vast potential for production of value added products' with high therapeutic, medicinal values and antioxidant properties have high export potential.

Important Features of Important Minor and Future Temperate Fruit Crops

Berries

Berries are considered soft fruit and include botanically different types of fruits such as blackberries, blueberries, strawberries, cranberries, gooseberries and currants and raspberries. These types are used as desserts as well as in processing. They are canned, frozen or made into jams, jellies or preserves. The most important vitamin in berries is vitamin C. Berries are also regarded as good source of â-carotene, thiamin, riboflavin and nicotinic acid. Anthocyanin is a major pigment in berries.

(i) Blackberries (*Rubus fruticosus)*

Sweet, succulent blackberries are summer delicacies in the northern temperate regions. They are a small perennial shrubs belonging to the vast *Rosaceae* family of bush berries, in the genus: *Rubus*. Depending upon cultivar type, blackberry bush can be classified into erect, semi-erect, and trailing types.

(ii) Blueberries (*Vaccinium sps.)*

Sweet, juicy blueberries are rich in natural pro-anthocyanin pigments and anti-oxidants. Botanically, it is a deciduous shrub belonging within the family of *Ericaceae*, in the genus, *Vaccinium.* Broadly, *vaccinium* species are classified according to their growth habit as high-bush and low-bush berries. High-bush blueberry (*Vaccinium corymbosum*) is a highly branched, erect deciduous shrub with rich foliage. It grows up to 10-12 feet tall and bears clusters of small, cream-white flowers during spring, which subsequently develop into tiny berries after about two months. Low-bush blueberry (*Vaccinium angustifolium*) is a short, erect plant that grows about one-two feet in height and spread through underground rhizomes.

(iii) Black currants (*Ribes nigrum*)

Black currants are one of very popular, summer season berries. Indeed, they are incredibly rich in several valuable health benefiting phyto-nutrients, and anti-oxidants that are vital for our health. Is a small shrub belonging to the family of *Grossulariaceae*, in the genus; *Ribes.* The currant plant is a fast growing, deciduous, small shrub reaching about 5-6 ft in height. Each currant berry has a size of about 1 cm in diameter, very dark purple, almost black with a glossy skin, and a persistent calyx at its apex.

(iv) Cranberries (*Vaccinium macrocarpon*)

Unique, wild and natural by habitat, cranberries are rich in phyto-nutrients (naturally derived plant compounds), particularly pro anthocyanidin and antioxidants, which are essential for all-round wellness. This berry-plant is described as an evergreen dwarf, creeping shrub or a low-lying trailing vine, belonging in the family of *Ericaceae,* in the genus: Vaccinium, and subgenus: *Oxycoccos.* The fruit is small, round, red color berry.

(v) Raspberry (*Rubus idaeus*)

Wonderfully delicious, bright-red raspberry is among the most popular berries to relish! They are rich sources of health promoting plant-derived chemicals, minerals, and vitamins that are essential for optimum health. Botanically, raspberry is a small shrub belonging to the family *Rosaceae*, in the genus: *Rubus*. Several sub-species of raspberries exist. The most popular commercial cultivar in practice is red-raspberry.

(vi) Gooseberries (*Ribes uva-crispa* L.)

Gooseberries are small, round to oval berries of European origin. They grow in the wild all over the temperate climates of Europe, North America, and Siberia. Botanically, they related very closely to currants, and belong to the same family of *Grossulariaceae,* in the genus, *Ribes*. Packed with pigment antioxidant polyphenolics and vitamins, the berries come in different color, flavor, and shapes.

(vii) Cape gooseberry (*Physalis peruviana*),

Cape gooseberry, a short cycled annual crop grown for edible fruits, is rich in vitamin A, B, C and is a rich source of carotene, phosphorus and iron, and also contains vitamin P and polyphenols. It can be eaten raw, as dessert and appetizer and can also be used in making appealing value added products. Due to its wide range of versatile adaptation and use for table purpose and processing it has good prospects for expansion as a new diversified cash crop in temperate regions.

(vii) Strawberries (*Fragaria X ananassa*).

Delicious, rich-red, sweet, yet gently tangy strawberries are among the most popular berries. These berries are native to Europe, however, nowadays cultivated in many temperate regions all over the world as an important commercial crop. Botanically, the plant is a low-growing runner (creeper) belonging to the family of *Rosaceae*, in the genus: *Fragaria.* Strawberry is a small, low-lying, spreading shrub. It bears small white flowers which eventually develop into small conical, light green, immature fruits. They turn red up on maturity with each berry featuring red pulp with tiny, yellow color seeds piercing through its surface from inside.

Kiwi fruit (*Actinidia chinensis*)

Kiwi fruit, also known as *Chinese gooseberry,* is one of the delicious fruits with full of promising health promoting phyto-chemicals, vitamins and minerals. This widely recognized, wonderfully unique fruit is native to eastern Chinese "Shaanxi" province. And for the same reason, this exotic fruit is recognized as the national fruit of China. Kiwi fruit plant is a semitropical, deciduous, large woody vine belonging within the family of *Actinidiaceae* in the Genus, *Actinidia*. During each season which lasts from September until November, the kiwi vine bears numerous oval shaped, fuzzy, brown colored fruits. Each kiwi berry measures approximately a large size hen's egg, and weighs up to 125 g. internally; its flesh is soft, juicy, emerald green with rows of tiny, black, edible seeds.

Quince fruit (*Cydonia oblonga*).

Quince fruit is a member in the *Rosaceae* family of pome-fruits. Quince is rarely eaten raw but used in cooking where just a small section of this fruit would impart the whole recipe with a pleasant fruity aroma. Botanically, quince is the only fruiting tree in the genus: Cydonia. Quinces are medium sized semi-tropical deciduous trees, growing to about 10 to 15 feet in height. Pink-white flowers appear during the late spring and early summer, which develop into

Table 1: Chemical Composition of Berries

Constituent	Blackberries (*Rubus sp.*)	Cranberries (*Vaccinium Sp.*)	Gooseberries (*Ribes Sp.*)	Raspberries (*Rubus sp.*)	Strawberries (*Fragaria sp.*)
TSS (%)	15.2	13.0	11.1	13.9	10.2
Total sugars (%)	4.3	3.5	4.6	1.57-5.34	5.0
Acidity (%)	0.68-1.84	2.90-3.17	1.21-2.91	0.74-3.62	0.52-2.26
Ascorbic acid (mg/100 g)	20	11-33	20-50	19-38	89
Carotene (mg/100 g)	0.1-0.59	0.02-0.58	0.18	0.05-0.08	0.15
Thiamine (mg/100 g)	0.03	0.03	-	0.02-0.03	0.03
Riboflavin (mg/100 g)	0.034	0.02	0.024-0.03	0.03-0.09	0.027
Nicotinic acid (mg/100 g)	0.40	0.10	0.30	0.40-0.9	0.6
Minerals (%)	0.5	0.20	0.40	0.5	0.5
Phosphorus (mg/100 g)	23.9	11.2	19.0	22	23
Potassium (mg/100 g)	208	119	170	168	161
Sodium (mg/100 g)	3.7	1.8	1.2	1.0	1.5
Calcium (mg/100 g)	63.3	14.7	18.5	22	22
Magnesium (mg/100) g)	29.5	8.4	8.6	-	11.7

golden color pear-shaped fruits. The fruit is larger than average apple and bumpy; and its fuzzy surface is smooth. The quince fruit weighs about 250-750 g. Raw quince has intense fruity smell, and together with its bright yellow color instantly attracts the fruit lover's attention. However, raw fruits, even after ripen, generally astringent and tart in taste. Excellent for making quality marmalade and candies

Persimmon (*Diospyros virginiana*).

Persimmon fruit is a golden yellow, round or oval, flavorful, smooth textured delicacy from far East Asian origin. Its sweet, delicious flesh is packed with several health promoting nutrients such as vitamins, minerals, and anti-oxidants vital for optimum health. Botanically, persimmons belong to the family of *Ebenaceae*, in the genus: *Diospyros*. Persimmons are either multi-trunked or single-stemmed deciduous trees, which may grow up to 25 ft in height. The color of the fruit varies from light yellow-orange to dark orange-red. The entire fruit is edible except for the seed and calyx.

(xi) Chinese *ber* (*Ziziphus jujuba* Mill.)

Chinese *ber w*as originated in central and southern China. It requires a small amount of chilling during winter to set this fruit, however, it can withstand in wide range of temperature (below freezing to 34^{o}C). Average fruit weight varies 4 - 14 g with 16-21 percent total soluble solids .The ripened fruit can be stored at room temperature for 2 to 3 weeks or may be dried on candied jujube can be eaten like dry apricot.

Pecan nut *(Carya illinoensis Koch)*

Are classified in family Jugalandaceae is called as 'Queen of nuts'. It has a native of southern east United States of America. Fruit mature in September –October months. Alternate fruit bearing is more pronounced in pecan nuts. Hundred gram of Kernel is containing 71g fat, 92g protien, 14.6g carbohydrates and 2.3g fiber. Fruit also contain calcium, phosphorus, potash, iron, manganese and vitamin A.

Tree tomato (*Cyphomandra betacea*)

Fruit belongs to family Solonaceae. It is a native of Peru and extensively cultivated in the whole Andern region. It is a self pollinated plant. Its occurrences in India is noticed in mid hilly area of Uttaranchal and Himachal Pradesh. Fruits are of medium size (80-100g) green before maturity, and fully ripned fruit is red with purplish strips.

Hazelnuts or Filbert (*Corylus* spp.)

Nut belongs to the family Betulaceae. The common hazelnuts are classified as *Corylus* a*mericana*, the beaked hazelnut as *Corylus cornuta,* the European filbert as *Corylus avellana pontica* and the cobnut as *Corylus avellana granis*. The giant filbert is classified as *Corylus maxima*. In India, Hazel nut (*C. Colurna*) is known as "Winri", "Wiri", "Warrawi", "Wuriya" in Kashmir, Thangi , Thangoli in Pangi (Chamba, HP), "Bhutia badam" in Garhwal and Kapasi in Kumaon region of Uttarnchal Pradesh .The plants are usually 2-3 m tall , each plant has separate male flowers borne in catkins and female flower borne in clusters.

Sea buckthorn (*Hippophae* spp.)

Llocally called "Ames", "Chharma", "Dhurchuk", "Gartsak" and "Sarlais" is one of the wild resources in the higher Himalayas. It belongs to the family Elaegnaceae and genus *Hippophae,* grows abundantly in higher Himalayas and other countries like China, Russia and Mongolia. It is deciduous thorny shrub or small tree of 9- 12 m height above the ground with profuse branching and has a life span of 100-150 years. It grow naturally on the river side's and sun facing slopes in part of Ladakh, Chamba, Kinnuar , Lahul- Spiti, Kullu in Himachal Pradesh at an elevation of 7000 to 12,000 feet. The fruits are orange –yellow in colour and contain 90-95 percent yellow coloured sour juice. The fruits of sea buckthorn is rich in protein, fat, carbohydrates, calcium, phosphorus and 116mg/ 100g iron. The seed oil is also rich in vitamins K and E, corotenoides, flavonoides, steroids, linoleic and linolenic acid. Oil extracted from seeds, pulp, tender branches and leaves is used for making various life saving medicines and drugs.

Processing and product diversification of berries and other untapped temperate fruits

Berries and other untapped and underutilized temperate fruit crops are used as desserts as well as in processing. They are canned, frozen or made into jams, jellies or preserves. The juices are used in beverages and ice-cream (Table 2).

Future fruits and Nutraceutical

The term nutraceuticals, is derived from the words "nutrition" and "pharmaceutical", is a food or food product that provides health and medical benefits, including the prevention and treatment of disease. A nutraceutical is demonstrated to have a physiological benefit or provide protection against phytochemicals, sustain or promote health and occur at the intersection of food and pharmaceutical industries. Majority of untapped fruits of future importance, such as strawberry, blackberry, blue berry, currants, crane berry, gooseberry, rosehips, kiwi, lingon berry, red currant, rasp berry, sour cherry, apricot, peach etc contain phytochemicals of nutraceutical importance. These phytochemicals, either alone and/or in combination, have tremendous therapeutic potential.

Table 2: Processing and medicinal Value of Untapped fruits of Western Himalayan Regions.

S. No.	Name Of Fruit	Products Prepared	Medicinal Value
1.	Blackberries	Juice, Wine, Jam, Syrup,	Diarrhoea, gout, arthritis
2.	Blueberries	Jams, juices, syrups and baked products. Confectionery and beverages.	Antiseptics, Diuretics, Anti-inflammatory, and Ant carcinogenic.
3.	Cranberries	Concentrate, Sweetened dried, Frozen, Sliced cranberries, puree, cranberry puree concentrate, sauce, jams, jellies	Antiseptics, Diuretics, Anti-inflammatory, Ant hy perglycemic and Ant carcinogenic.
4.	Gooseberries	Jam, Jelly, Juice, Sauce, Cupcakes	Appetizing, tonic, diuretic, laxative, Anti inflam-mations, enlargement of the spleen and abdomi-nal troubles.
5.	Raspberries	Candy Jellies, Jam, Canned, ingredient in the preparation of sauces, candies, yogurts, ice creams and infusions.	Antiseptics, Diuretics, Anti-inflammatory, Ant hy perglycemic and Ant carcinogenic.
6.	Strawberries	juice, nectar, wine, Puree, wine	Anti oxidant, Anti Cancer, For healthy Immune system
7.	Pineapple guava	Juice, Salad, Sauce, Eaten Raw, Used as dessert fruit, Slices, Candies, Preserves, Jellies, Marmalade,	Therapeutic mechanisms against cancer, bacte rial infections, inflammation and pain.
8.	Chinese ber	Eaten as a snack, or with tea, canned, jujube tea, juice, vinegar, pickles, wine.	Antifungal, antibacterial, antinuclear, anti-inflam matory, sedative, antispastic, antifertility/contra-ception, hypotensive and Antinephritic, cardiotonic, antioxidant, immune stimulant, and
9.	Japanese persimmon	Eaten raw, Dried, fresh, cooked,	Stomach ailments and diarrhoea, Fever, Blood pressure, Cough, prevents heart attack,
10.	Currants	Jam, Jelly, eaten raw,	Kidney diseases and menstrual and menopausal problems, enhancer to assist women in becoming pregnant,
11.	Medlar	Eaten fresh, Salad, Pie, jam, jelly and chutney.	Ingredient for cough drops, soothe the digestive and respiratory systems
12.	Quince	Jam, Jelly, Quince pudding, Murabah, Wine, Brandy, Cider	Treat sore throat and to relieve cough, relieves intestinal discomfort. remedy for pneumonia and lung disease
13.	Pecan nut	Eaten fresh, used in sweet deserts, savory dishes,	Lower the risk of gall stones, reduce high choles-terol,
14.	Husk tomato	Eaten raw, Salads, jams, jellies, dried, pie.	Used as a remedy for abscesses, coughs, fe-vers and sore throats
15.	Hazelnut	To make pralines, chocolates, paste, hazelnut butter,	Anti cancer medication
16.	Seabuckthorn	Juice, Syrup, Skin cream, pie, jam, lotions, liquors, juice as baby food, beer,	Treatment for inflammatory disorders, Cancer pre vention, effective in bone marrow,

Table 3: Fruits a source of antioxidant polyphenols.

Polyphenols	Sources
Flavonoids (Anthocyanidins): Cyanidin 3-glycosides, Malvidin, Delphinidin, Pelargonidin	Blue berries, black berries, cranberry, raspberry, black currant, black grape, straw-berries, cherries, plums, pomegranate, juice, red wine
Flavonoid glycosides: Rutin, Hesperidin, Naringin	Orange, orange juice, lemon, grapefruit, tangerine juice
Flavanones: Naringenin, Eriodictyol, Hesperetin	Grapes, citrus fruits and their juices, tangerine juice, peppermint
Flavanols: Morin, Procyanidins Prodelphinidins, Catechin, Epicatechin and their gallates	Apricots, apples, grapes, peaches, pears, plums, raisins, berries, cherries, red wine
Anthoxanthins (Flavonols): Myricetin, Fisetin, Quercetin, Kaempferol, Isorhamnetin	Cherry, tomatoes, spinach, celery, onions, peppers, sweet potato, lettuce, broccoli, kale, buckwheat, beans, apples, apricots, grapes, plums, berries, currants, cherries, juices, ginkgo biloba, red wine, tea, cocoa
Phenolic acids: Caffeic acid, Chlorogenic acid, Ferulic acid, p-coumaric acid, Sinapic acid, Ellagic acid,Gallic acid	Lemon, peach, cider, Strawberry, raspberry grape juice, pomegranate juice bluberry, cranberry, pear, cherry, cherry juice, apple, apple juice, orange, grapefruit
Tannins: Catechin, Epicatechin polymers, Ellagitannins, Proanthocyanidins, Tannic acids	Pomegranate, walnuts, peach, olive, plum, chick pea, peas, grape seeds and skin, apple juice, strawberries, raspberries, blackberry, lentils, haricot bean, red wine, immature fruits

Future Perspectives

To strengthen the work on genetic improvement following strategies would be requiring for effective implementation and to achieve goals.

1. Systematic planning for explorations for minor temperate fruit including wild texa particularly for those crops, whose economic importance is known for commercial exploitation.
2. Need based introduction of new crops, new varieties with specific traits.
3. Mostly minor temperate fruit crops are hardly and resilient, once established in field gene bank then agronomic practices should be developed considering the climatic condition suited to them.
4. Priority should be to conserve the material in field gene bank and protocol should also be developed for *in vitro* conservation and cryopreservation as well.
5. *In situ* conversation by the various government agencies and policy planners to protect the ecological niches, where large variability is existing e. g. hazelnut in pang , dry type apricot in Leh and Ladakh and Kinnuar chilgoza in Kinnuar , and walnut in Jammu and Kashmir.
6. Molecular characterization of underutilized temperate fruits will provide the information on identification of use full genes and other molecular markers, which will help in genetic improvement work.

There is need to investigate value addition useful for products and processing, neutraceutical, ornamental and other potential applications.

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Climate Resilient Horticultural Crops of Future

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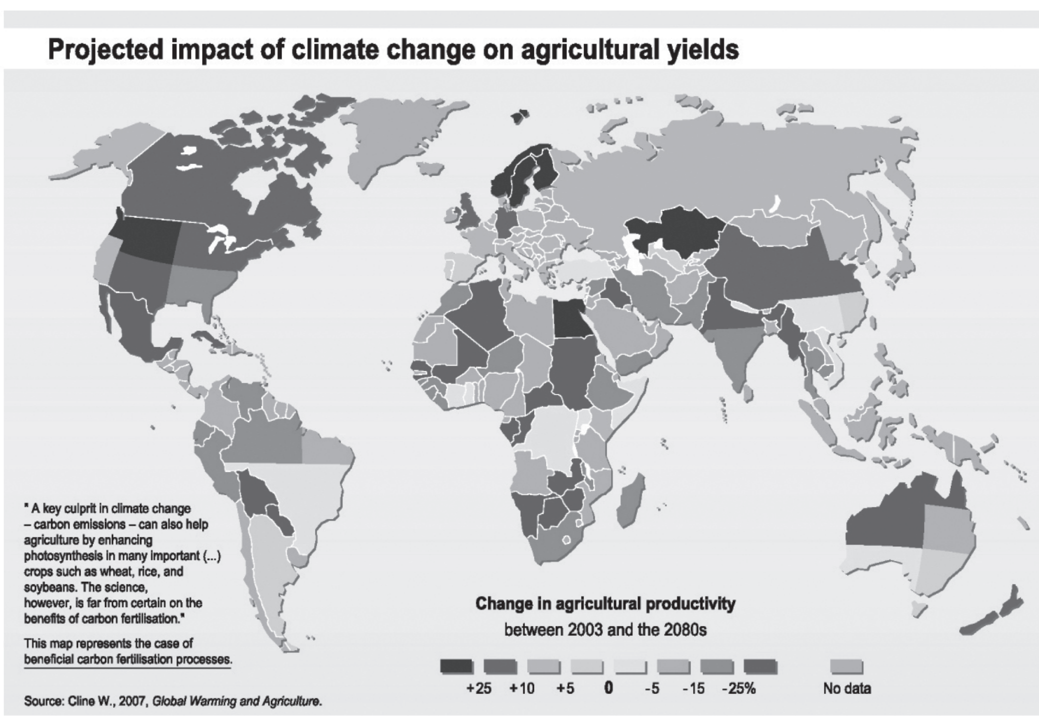
Climate resilient agriculture (CRA) representsa whole-system approach to food, feed, fuel and fibre production that sustains the health of soils, ecosystems and people.CRA encompasses adaptation and mitigation strategies and the effective use of biodiversity at all levels- genes, species and ecosystems for man essential pre-requisite for sustainable development in the face of changing climate. Climate change and its variability have major impacts on the Indian agriculture. Long term changes in shifting weather patterns resulted in changing climate. Effect on agricultural productivity through high and low temperature regimes, increased rainfall variability, and rising sea levels which potentially deteriorate coastal freshwater reserves and increased flooding has been witnessed. Yields of irrigated crops across regions are negatively affected, both due to increased temperature and changes in water availability. Rainfall variability and reduction in number of rainy days are the factors which affect the rainfed agriculture the most (Venkateswarlu and Shanker, 2012).The fourth IPCC report on global and regional impacts of projected climate change on agriculture showed significant decline in production. Shortening of growing period that have negative impact on reproduction and grain filling are particularly due to terminal heat stress and decreased water availability.



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The Indian agriculture production system has a daunting task of having to feed 17.5% of the global population with only 2.4% of land and 4% of water at its disposal. The type and impact of climate change will vary depending on the degree of change in climate, geographical region and type of production system. The key influences of climate change are changes in productivity with references to quantity and quality of crops. Climate change threatens to modify both the envelopes that characterize different crop production systems, and the associated yield variability and production and financial risk.

The recurrent drought and desertification threaten seriously the livelihood of over 1.2 billion people who depend on land for most of their needs. Human activities like fossil fuels combustion, production of synthetic chemicals, biomass burning, deforestation, excess use of chemical fertilizers and pesticides change the chemical composition of atmosphere, thereby enhancing green house effect. The frequent eruption of volcanoes in different parts of the globe recent time is one of the predominant factors to change the chemical composition of the atmosphere. The present growth rate of GHE is 1% in CH4, 0.4-0.5% in CO_2 and 0.2-0.3% in N_2O as per the Intergovernmental Panel on Climate Change (IPCC, 2007). In contrast, the ozone friendly substitutes for Chlorofluorocarbons (CFCs), Hydrofluorocarbons (HFCs), Hydro-chlorofluorocarbons (HCFCs) and Perfluorocarbons (PFCs) are also powerful greenhouse gases that contribute to global warming. The IPCC (2006) projected the rate of warming for the 21st century to be between 0.8 and 4.4°C at various stabilized CO_2 levels in atmosphere.

Effect of CO_2 on Crops

Global warming and climate change refer to an increase in average global temperatures. Natural events and human activities are believed to be contributing to an increase in average global temperatures. This is caused primarily by increases in greenhouse gases such as Carbon dioxide (CO_2).It increases the frequency and intensity of some types of extreme weather. For example, warming is causing more rain to fall in heavy downpours. There are also longer dry periods between rainfalls. This, coupled with more evaporation due to higher temperatures, intensifies drought.However, increasein CO_2 concentration can cause CO_2 fertilization and it has been shown to increase crop growth, dry matter production and yield in specific regions although this effect is related to frequency of water stress or changes in climatic factors such as temperature or rainfall, and nutrient status. Most crops grown under enriched CO_2 environment show increased growth and yield as enhanced CO_2 affects the growth and physiology of crops, enhanced photosynthesis and water use efficiency. Differences in physiology of C3 and C4 plants make C4 plants more photosynthetically efficient than C3, especially when the level of CO_2 is high.

Impact of Climate Change on Crops

Climate plays a major role in deciding the crop habitat, while crop habit depends on genotype and phenotype. It has direct impact on agriculture and horticulture. Two major parameters of climate change that has far reaching implications are more erratic rainfall patterns and unpredictable high temperature spells will consequently reduce crop

Year	Extreme event	Impact
2002	Cold wave	Extensive damage to horticulture crops in Punjab (Hoshiarpur),vegetable crops in Rajasthan and mustard in Haryana
2003	Heat wave	Estimated loss of 6 million tonnes in wheat from north India
2006	Floods	Extensive damage to field crops in Rajasthan and Andhra Pradesh
2009	Cyclone 'Aila'	Coastal flooding of agricultural areas in West Bengal, Odishaand excess rainfall in north and north eastern states
2010	Cyclone 'Laila'	Flooding in coastal areas of Andhra Pradesh
2012	Cyclone 'Nilam'	Flooding in coastal areas of Andhra Pradesh
2013	Cyclone 'Phailin'	Extensive damage to horticulture and paddy in Odisha andAndhra Pradesh
2014	Unseasonal rainsand hailstorm	Damage to horticultural crops in Maharashtra, Karnataka,Madhya Pradesh etc.
	Cyclone 'Hud-hud'	Extensive damage to horticulture and paddy in Odisha, AndhraPradesh and damage to several field crops in Chhattisgarhand Uttar Pradesh due to unseasonal rainfall
2015	Unseasonal rains	Extensive damage to *Rabi* crops in Maharashtra, Telangana,Andhra Pradesh, Madhya Pradesh, Punjab, Rajasthan andwestern Uttar Pradesh

productivity.In addition, climate change and CO2 are likely to alter important interactions between horticultural plants and pollinators, insects, diseases, and weeds (IPCC 2007). Commercial production of horticultural plants particularly grown under open field conditions will be severely affected. The table below depicts some of the agricultural loss due to the occurrence of extreme weather in the recent years.

The crop phenology like fleshing, flowering, fruit development and harvest time are sensitive to vagaries in weather and differ from crop to crop. The phonological events undergo several abiotic and biotic stresses or environmental stresses as seen in the case of cashew flowering during the process of crop growth and development. The effect of environmental stress on phenology could adversely affect final yield in the same year or the following year depending upon type of crop in the case of plantation crops.

The major effects on crops are as listed below:

(i) *Changes in physiology*::Due to high temperature physiological disorder of horticultural crops will be more pronounced. Increase in temperature has caused loss of vigour, fruit bearing ability, reduction in size of fruits, less juice content, low colour, reduced shelf life and increasing attack of pests resulting low production and quality of apples. Another direct effect in crops such as rice, wheat, sunflower etc., is on reproduction, pollination and fertilization processes, which are highly sensitive to temperature.

(ii) *Changes in crop season*:The major effect on crop is due to shortening of crop duration which is related to the thermal environment. Increase in temperature will also hasten crop maturity. In mango, unusual or very early flowering is experienced in recent years.

(iii) *Incidence of pest and diseases*: The indirect influences being the inadequate rainfall and effect of increase in temperature on pest and disease incidence. In guava, there is severe increase in pests and diseases due to climate change. Fruit fly in guava is becoming alarming due to hot and humid conditions.

(iv) *Reduced productivity*: Temperature limits the range and production of many crops. In annual crops, the shortening of crop duration may vary from 2-3 weeks, thus, adversely impacting productivity. Abnormal high temperature during winter cause poor flowering, irregularity in flowering duration, pattern of flowering and poor yield due to non-availability of sufficient chilling hours during winter months, for e.g., crops like peach, plum, pear which requires low chilling temperature reported decline in productivity.

Climate Change and Food Security: Climate change will affect all four dimensions of food security: food availability, food accessibility, food utilization and food systems stability. It will have an impact on human health, livelihood assets, food production and distribution channels, as well as changing purchasing power and market flows. Kumar *et al* (2009) also find that with current production trends, meeting future demand for food grains through domestic production will be difficult. The table listed below represents the demand projection for agricultural commodities towards 2011 and 2020.

Commodity	Projected demand (MT)		Required growth rate to matchdemand (%/year)	
	2011-12	2020-21	2011-12	2020-21
Rice	105	122	2.06	1.71
Wheat	79	84	0.95	0.73
Total cereals	232	273	2.21	1.84
Pulses	20	24	2.35	1.96
Total foodgrains	252	297	2.21	1.85
Milk and milk products	113.0	140.72	3.18	2.76
Egg	62.0	82.68	6.09	4.48
Meat	8.6	11.40	5.03	4.06
Fish	8.6	11.86	4.39	3.95
Edible oilseed 40% Import dependence	31.8	39.06	2.87	2.55
Vegetables	109.0	128.22	2.51	2.12
Fresh Fruits	67	85.98	3.46	3.06
Sugar and gur	35.50	40.55	3.87	2.55

Climate challenge will increase the risk of reduced crop productivity associated with heat and drought stress. Negative impacts in average crop and pasture yield will likely be clearly visible by 2030. For example, in parts of Brazil, rice and wheat yields are could decline by 14%, according to their forecast. The world needs to produce at least 50% more food by 2050, but climate change could cut crop yields by more than 25% (World Bank, 2016).The Intergovernmental Panel on Climate Change (IPCC) report of 2007 echoed similar concerns on wheat yield: a 0.5°C rise in winter temperature is likely to reduce wheat yield by 0.45 tonnes per hectare in India. Acute water shortage conditions, together with thermal stress, will affect rice productivity even more severely. These evidences supports the need for considerable investment in adaptation and mitigation actions toward a 'climate-smart food system' that is more resilient to climate change influences on food security.

Hence to mitigate the effects, some of the recommended crop management adaptations are as follows:

- Cultivar adjustment (e.g., developing new crop varieties that are tolerant to drought, heat and salt via breeding or genetic modification)
- Planting date adjustment
- Combined planting date and cultivar adjustment
- Irrigation optimization
- Fertilizer optimization

The 4th and 5th IPCC reports clearly outlined the global and regional impactsof projected climate change on agriculture, water resources, natural ecosystems and food security. Although, climate change impacts are being witnessed world over, thecountries in which larger population is dependent on agriculture, such as India, aremore vulnerable. The risks are likely to be experienced more by small and marginalfarmers of rainfed and other risk prone regions with poor coping mechanisms. However, adaptation to climate change can increase the yields by 13-19% in different scenarios thereby increasing the overall production by about 20%. Therefore certain crops are being developed by various innovative technologies as ***future crops*** to meet the food security in upcoming years.

Future Crops

Among 80,000 reported about 30,000 plants are found edible in nature and almost 7,000 plants are cultivated by mankind at one time or another, of which 158 plants are grown by man at some point of time. Among these, 30 crops provide world's food and only 10 crops supply 75% of the world's food requirement. This dangerously narrow level of food base prompts to widen the base of grains, vegetables, fruits, spices, industrial crops, medicinal plants, mushrooms, plantation crops, pulses, fiber crops, oil seeds and aromatic plants. The emphasis so far was more on terrestrial plants, forest plants and lesser on lower plants like lichens, micro algae, fungi and bryophytes. These are lower plants are not much explored for edible use expect by Chinese and Japanese. However, to meet the ever widening gap between the demand and supply for food, halophytes like marine microalgae (SCPs), marine macro algae (seaweeds), mangroves and sea grasses (marine flowering plants) inhabiting saline, coastal and marine ecosystems are to be explored as alternative sources of food, cattle feed, manure, fuel, medicines and other therapeutically important products. Another category of crops are the pseudo cereals, as the name indicates these are not exactly cereals but they are nutritionally very similar to cereals. These are very versatile crops and have high adaptability to wide range of environments. For e.g. amaranth can be grown from sea level to as high as 3000m asl while buckwheat is grown at the highest limit of crop production.Edible chasmophytes are yet other varieties of wild plant species that offers a different diet and also contributes to house hold food security. These plants are good supplements of protein, carbohydrates, sodium and potassium and may probably draw the attention of many biochemist, pharmacologist and food processing industries in near future (Tardio*et al.,* 2006; Saiwan*et al.,* 2007; Thomas *et al.,* 2010).

Vegetables

(i) *Vegetable mustard green*:It is one of the most common leafy vegetables of North eastern region. Vegetable mustard is a winter season leafy vegetable, but being grown around the year except heavy rainfall period. It is a cruciferous leafy vegetable related to cauliflower, cabbage, brussel sprouts, broccoli, kale, kohl*Rabi*, Chinese cabbage, turnip and radish with the attendant phyto-chemical properties. The leaves are rich source of dietary fibres, proteins, vitamins, minerals, antioxidant phyto chemicals (Flavonoids, indoles, sulforaphane, lutein and Zeaxanthin).

(ii) *Tomato*:Analysis of climate trends in tomato-growing locations suggests that temperatures are rising and the severity and frequency of above-optimal temperature episodes will increase in the coming decades (Bell *et al.*, 2000). Vegetative and reproductive processes in tomatoes are strongly modified by temperature alone or in conjunction with other environmental factors (AbdallaandVerkerk 1968). High temperature stress disrupts the biochemical reactions fundamental for normal cell function in plants. It primarily affects the photosynthetic functions of higher plants (Weis & Berry 1988). High temperatures can cause significant losses in tomato productivity due to reduced fruit set, and smaller and lower quality fruits (Stevens andRudich 1978). Hazral *et al*., (2007) summarized the symptoms causing fruit set failure at high temperatures in tomato; this includes bud drop, abnormal flower development, poor pollen production, dehiscence, and viability, ovule abortion and poor viability, reduced carbohydrate availability, and other reproductive abnormalities. In addition, significant inhibition of photosynthesis occurs at temperatures above optimum, resulting in considerable loss of potential productivity.Until now, the scientific information on the effect of environmental stresses on vegetables is overwhelmingly on tomato. And some of the varieties of tomato developed with resistance to environmental stressors are listed in the table below.

Environmental stressors	Resistant varieties of tomato
Heat Stress	ArkaMeghali, ArkaVikas, VC11-3-1-8, VC 11-2-5, Divisoria-2,Tamu Chico III, PI289309
Cold stress	LA-1777 (*Solanum habrochaites*) from AVRDC, Taiwan, and Lycopersiconhirsutum LA3921 and LA3925, both *Solanum habrochaites* from AVRDC
Drought resistant	ArkaMeghali, ArkaVikas, Pearson tomato, Early Girl tomato, Super Roma tomato, Golden Nugget tomato
Under delayed monsoon	JT-3, Paiyur-1

The cultivated tomato genotype (*Solanum lycopersicum,* earlier known as *Lycopersicon esculentum* L.) displays limited growth and development at temperatures under 12ºC (Hu *et al*., 2006). At temperatures between 0 and 12ºC, plants are damaged by the chilling stress.Cold-resistant cultivars could be planted earlier in the season, leading to an early harvest. Unlike cultivated tomatoes, wild tomato species such as *S. habrochaites* S. Knapp & D.M. Spooner, *S. chilense* (Dunal) Reiche and *S. peruvianum* L., recover rapidly after exposure to sub- optimaltemperatures. These genotypes can be grown at high elevations where temperature remains low, below 10°C. Wild species have been used for constructing genetic maps and identifying genes ofagronomic importance. Through backcrosses and selection assisted by molecular markers, cold-resistant genes from wild species can be bred into cultivated tomato varieties (Goodstal *et al*., 2005).

(ii) *Carrot*: PusaRudhira is also nutritionally rich as compared to other carrot varieties. The variety was tested to have higher levels of carotenoid (7.41mg) and phenols (45.15 mg) per 100 g. The primary benefit of these substances lies in their antioxidant property that guards against certain types of cancer, apparently by limiting the abnormal growth of cells. In years to come, *Pusa Rudhira* is expected to cover more and more area and remain dominant variety.

(iii) *Cabbage*: Chinese cabbage lines (*Brassica rapa* subsp. *pekinensis* and *chinenesis*) adapted to hot and humid climate. There is another form called Chinese kale (*Brassica alboglabara)* which is a typical tropical crop and hot weather vegetable crop and does not resemble to more popular curly kale. In India, both smooth leaf and curly leaf kale are cultivated. Local cultivars like Khanyari green, GM dari, Siberian kale and many others are cultivated in the Kashmir valley. However, two lines develop at IARI regional station, Katrain and two lines developed at SKUAS&T, Shalimar, Jammu and Kashmir have recently been entered in AICRP (VC), trails for multi location testing for the first time.

(iv) *Pepper*: In pepper, high temperature exposure at the pre-anthesis stage did not affect pistil or stamen viability, but high post-pollination temperatures inhibited fruit set, suggesting that fertilization is sensitive to high temperature stress (Erickson & Markhart, 2002). Yildirim and Guvenc (2006) have reported that pepper genotypes Demre, Ilica 250, 11-B-14, BagciCarliston, Mini AciSivri, YalovaCarliston, and Yaglik 28 can be useful as sources of genes to develop pepper cultivars with improved germination under salt-stress. In Tunisia, pepper cultivar Beldi significantly out yielded than other test cultivars at high salt treatments.

(v) *Cassava (Manihot esculenta)*:It is a tropical root crop which grows well in warm and humid climates. It thrives well between 25 and 35°C but does not grow well below 15°C. Cassava is drought resistant once established and able to withstand dry spells for more than 3 months. For eg: Shri Sahya is a drought resistant variety.

(vi) *Yam (Dioscorea* species*)*:It is a tropical tuber crop hence requires warm sunny weather. The tubers are basically starch storage organs. It is an annual plant. The two cultivars of Yam are of the species D.alata and are found on Malo are resistant to anthracnose disesase. Although they are also found on other islands they are commonly known as the Malo yams. The 2 yams are known in the Malo language as Daekarai red and Daekarai white. Wild yam is a resilient crop. This species of strong yam tolerates drought as well as prolonged wet season. It also grows well in a wide range of soil fertility and conditions. Other resistant varieties developed are NDA-5, Gajendra (drought), Bidhan Kusum,Gajendra (delayed monsoon).

(vii) *Potato*:A study conducted in USA on the effect of climate change on potato showed that CO^2 enrichment increased tuber yield and biomass dry weight by 30% and 34%, respectively. Daily temperatures beyond the optimal temperature range (16 and 22°C) may result in reduced growth and in turn lower harvest index and tuber yield. However, with climate change, the prevailing temperature during tuber growth and development may likely be different, but the effect of this changes on yield whether positive or negative is uncertain. Also, positive yield response to increased temperature and longer growing seasons by heat loving crops such as sweet potato has been reported.

Fruits: For apple production, the most serious problem is the scab disease and the outbreak of premature leaf fall and infestation of red spider mite. Changes in climate can cause poor harvests or even crop failures. Excess of water and decreased snowfall during winter causes low chilling hours in cropping areas, and this could pose serious threats to apple production worldwide, particularly in India (Singh *et al*., 2010). In India and Nepal, traditional apple cultivation area is moving further up in elevation because of the warmer climate. York Imperial is a variety that has been developed to resist drought in Indian climatic conditions. Indian gooseberry or Aonla (Emblica officinalis L.) have adapted by reducing leaf area, thereby reducing the transpirational area. Pomegranate (Punciagranata L.) is fairly winter hardy and also drought tolerant. Aonla, being a hardy and drought tolerant subtropical tree, can be grown well under tropical conditions. Papaya (*Carica papaya* L.) has adapted well to both tropical and sub-tropical conditions, which is also the case with guava. Through pruning and cultural manipulations, grapes (*Vitis vinifera* L.), which are basically a temperate crop, are able to have their vines adapt well to the tropics. Pineapple (Ananascomosus L.), being a CAM (crassulacean acid metabolism) plant, has remarkable adaptability to different climatic regimes and has high water use efficiency. These crops and many other fruit crops viz., custard apple (*Annona squamosa* L.), jamun (*Syzygium* spp.), woodapple, bael (*Aegle marmelos* L.), avocado (*Persa americana* L.), passionfruit (*Passiflora edulis* L.) and karonda (*Carissa carandas* L.) could be considered as candidate crops under climate change conditions.

Conclusion

Climate change combined with increasing populations constitutes serious challenges to the food security of the planet, and can exacerbate poverty and malnutrition in developing nations. The increasing frequency of droughts, higher temperatures, floods and deteriorated soil health are predicted to limit agricultural productivity across the globe, but more so in tropical areas and in semi-arid and sub-humid dryland regions. Hence, certain high-yielding and tolerant varieties are developed to alleviate the devastating effects of climate change

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Honey Bees and Beekeeping :A Productive Factor for Enhancing Farmers' Income

N.M. KEJRIWAL

Physio-morphology of flowers *and* the physio-morphology of bees explain their complementary development in Nature and the biological systems. Our farming systems are also the outcome of this synchronous development. However, with the need of feeding the large and ever increasing population our farming systems adopted the use of inorganic inputs in the form of fertilizers and pesticides. Their use gave a boost in production of staple food but their blanket and excessive use caused very serious this way-

(1) The farming systems included N-P-K based fertilizers and bio-killer chemicals as pesticides dominated the crop growing schedules.

(2) They affected the Natural biotic interactions causing biotic imbalance unlike the bio-chemical (organic) activities of the soil, providing nutrients to plants and the essential activity of pollination in crop growing.

The physiology of the plants and the resultant values as food, have developed over the ages under the influence of Nature's synchronous interactions. Biochemical activities of the soil, insect-plant (flower) relationship of exchange of food for effecting the generative activity of pollination and boosting of the vitality in plants through cross mating (*cross pollination*) have been the basic factors of sustained development of vegetation and the Natural food-chain-efficiency. Orientation of farming systems on the use of inorganic inputs for achieving the boost in yields of food crops has been the need of time. But, it has to be reviewed and revised for undoing the ill effects, not only on human health but on the whole of bio-spectrum. This has forced a global organic movement and recognition for the services of this *best little friend of man*, the ***honey bees as the essential component of crop growing schedules.***

Studies and Recommendations

According to a study Indian Agriculture is losing Rs.10,000/- to Rs. 50,000/- per hectare yearly on account of lack of proper pollination. In India crops benefitted by insects' (*honey bees being the major*) pollination are grown on an area of about 50 million hectares. Even at the lower level of Rs10,000/- we are loosing at least Rs.500 billion (Rs.50,000 Crores) worth of Agriculture production. It is note-worthy that this 50 million ha. area comes under most needed over 80 crops like- pulses, oilseeds, spices, fruits, vegetables etc. For assured pollination of crops on this 50 m. ha. area we shall need 50 m. honey bee colonies capable of directly producing honey and other hive products worth over Rs. 200 billion (20,000 crores). We need to think over seriously and take care of this colossal loss.

The value of honey bee pollination to U.S. agriculture, as per Cornell University study, is more than $14 billion annually. Crops from nuts to vegetables and as diverse as alfalfa, apple, cantaloupe, cranberry, pumpkin, and sunflower, all require pollination by honey bees. For fruit and nut crops, pollination can be a grower's only real chance to increase yield. The extent of pollination dictates the maximum number of fruits. *Post- pollination inputs, whether growth regulators, pesticides, water,*

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or fertilizer, are actually designed to prevent losses and preserve quality rather than increase yield.

Recognising the dimensions of a "pollination crisis" and its links to biodiversity and human livelihoods, the "Convention on Biological Diversity" has made the conservation and sustainable use of pollinators a priority. At the Fifth Conference of Parties (COP V), (**FAO**) in 2000, an International Initiative for the "Conservation and Sustainable Use of Pollinators", known as the International Pollinator Initiative - IPI was established (COP decision V/5, section II)

National Commission on Agriculture - 1976

"The primary object of modern apiculture should be to secure higher crop yields, honey and beeswax will come as a byproduct." This introductory statement was made by non other, but the ***National Commission on Agriculture, 1976, a body constituted by the Govt. of India to recommend to the Govt. on increasing agricultural productivity***. This pointed statement supported by estimates and projections was made 41 years earlier a period equal to over 8 five-year-plans. The NCA-1976 projected the possible crop yield benefits and the need to develop beekeeping to provide 6 million bee colonies with an average of 10 bee colonies per village. The National Commission on Agriculture (1976) enumerated over 80 oilseeds, pulse, fodder and vegetable seeds, fruits and commercial crops which are directly benefited by honeybees' pollination. This complementary activity of honeybees is not only capable of enhancing the production of oilseeds and pulses which we are short of, but also the production of vegetables & fruits, commercial crops like coffee, nutritious fodder for cattle and various fiber crops, besides producing honey and the other product from bee hive as an extra gain.

The Indian Scenario

A TNAU Publication, "Pollination & Bee Flora" reveals the effect of bee pollination on crop as:

- It increases yield in terms of seed yield and fruit yield in many crops.
- It improves quality of fruits and seeds.
- Bee pollination increases oil content of seeds in sunflower.

Bee pollination is a must in some self incompatible crops for seed set.

The crops benefited by bee pollination are:

Fruits and nuts: Almond, apple, apricot, peach, strawberry, citrus and litchi

Vegetable and Vegetable seed crops: Cabbage, cauliflower, carrot, coriander, cucumber, melon, onion, pumpkin, radish and turnip.

Oil seed and Pulse crops: Sunflower, niger, rape seed, mustard, safflower, gingelly, pea, gram pigeon pea.

Forage seed crops: Lucerne, clover.

The publication specifically mentions the yield increase due to bee pollination in the following crops.

Crop	Per cent yield increase
Mustard	43
Sunflower	32-48
Cotton	17-19
Lucerne	112
Onion (seed) Apple	9344

Under a Tribal Sub Plan (TSP) programme in Kinnaur District of Himachal Pradesh the scientific intervention of managed pollination at community level in apple orchards spreading in an area of 110 ha resulted in an average enhancement of 19.44 per cent apple fruit yield. The average enhanced monetary income was observed as Rs. 17,496/- per family. A bulk of around 300 Kg honey was extracted till the end of January, 2016 from the current apiary of the Panchayat by migratory beekeeping and fetched an income of 12,000/-. A study on pollinators of Kiwifruit in Jammu revealed that the hive bees, A. *meliifera* and A. *cerana* are the most efficient and effective pollinators of this crop.

In a study conducted in Maharastra on farmers' fields by "Vidya School of Biotechnology", Baramati (District Pune) through Network Project under Ministry of Science & Technology, Government of India (*Beekeeping in India ; Contribution of VSBT*) the farmers found good results and encouraged others to start beekeeping in their fields for increase in crop production. The increase in different agricultural and horticultural crops by bee pollination ranged from 44 to 140 %. Brief of the results is presented below:-

VSBT fields locations wise % increase in yield by honey bee pollination

Sl.No.	Field location	Crop	% Increase inYield
1.	VSBT Field - A	Sunflower* (*Helianthus annus*)	56 %
2.	VSBT Field - B	Tur (*Cajanus cajan*)	64 %
3.	VSBT Field - C	Coconut (*Cocus nucifera*)	80 %
4.	VSBT Field - D	Jamun* (*Scizigium cuminie*)	75 %
5.	VSBT Field - E	Drumstick* (*Moringa oleifera*)	65%
6.	VSBT Field- A.1	Soyabean (*Glycine max*.)	44%
7.	Sansar	Pomgranate (*Punica granatum*)	66 %
8.	Patas Road Farm	Jamun* (*Scizigium cuminie*)	122 %
9.	Karhati	Tur (*Cajanus cajan*)	105 %
10.	Buldhana	Tur (*Cajanus cajan*)	110 %
11.	Supa	Tamarind* (*Tamarindus indicum)*	140 % Expected

INSECT POLLINATION MANUAL

Compiled and developed by the Department of Agricultural Entomology,University of Agricultural Sciences, Bangalore under the auspices of "Indian Council of Agricultural Research" the *Insect Pollination Manual* spells the need and procedures for taking advantage of the basic and essential input of POLLINATION. This manual speaks a lot of our apathy to needed management of farm inputs. It narrates- "*It is important to express the increased fruit set or yield of the target crop in terms of monetary benefit derived. For example, arabica coffee, though can set berries through self pollination, when bee visits are allowed the berry set will almost double. Which means if an hectare of coffee which has adequate bee population, produces*

Effect of Pollination on Fruit set / Pod formation / Yield / Quality : Abstract from AICRP(HB & P), ICAR

AICRP Center	Crop	Attribute	Results as per Attribute		% Increaseover P E.	
			O P	B P	P E	
PAU Ludhiana	Soft Pear	Fruit Set % of flowers	06.94	—	01.08	642
	Peach	—do—	52.65	—	33.36	157.82
Dr.YSPU Solan,	Cherry.	—do—	13.65	52.80	00	—
Medziphema,Nagaland.	Guava	Fruit Wt.(gm)-2 yr Av.	135.21	124.00	98.73	136.9; 125.6
		Yield Kg./Plant-2 yr Av	16.44	15.06	12.42	132.4; 121.3
		Quality-TSS% -2 yr Av	10.58	10.54	09.73	108.7; 108.3
		-Pectine % ,,	01.32	01.26	01.13	116.8; 111.5
Pusa, Bihar	Litchi(*Shahi*)	Fruit Set % of Flowers	03.00	02.70	02.11	142.18;127.96
	Sesamum	Yield Kg per Tree	118.40	115.20	90.20	131.26;127.71
		Quality – Fruit Wt. (g)	22.10	20.50	18.60	118.81;110.21
		Yield Qtl. Per ha.	05.20	04.90	04.60	113.04;106.52
		Oil Content (%)	47.30	46.20	45.60	103.72;101.31
Jammu, J & K	Cauliflower	Seed Yield – Qtl/ha.	06.07	05.24	02.94	206.46;178.23
	Coriander	Wt. of 1000 seeds (g)	06.15	04.99	03.06	200.98;163.07
		Seed Yield – Qtl/ha.	13.52	12.31	07.33	184.44;167.93
		Wt. of 1000 seeds (g)	06.84	05.39	04.09	167.24;131.78
Coimbatore,Tamil Nadu	Cottonhyd.	Seed Cotton Yield--Kg/ha.	1,903.5	1,620.0	1,378.5	138.08;117.52
Kota,Rajasthan	Mustard	Seed yield- % over PE	183.55	138.4%	—	— —
Jorhat, Assam	MangoCoriander	Yield per ha. (Qtl.)	68.5305.46	78.3707.47	58.1801.73	17.7; 34.73
		Yield Qtl per ha.				15.6; 431.79
Kalyani, W.B.	Onion	Seed Yield – Kg / ha.	518.2271	457.7276	05.9114	8668; 7644
		Germination (%)				507.14; 542.85

OP – Open Pollination – Includes Honey Bees, other bees and other Insects;
BP – Honey Bees Pollination – Includes *Apis cerana*(A.c.) and/or *A. mellifera*(A.m.);
PE – Pollinators Excluded.
Ref. – *AICRP(HB & P) Biennial Report (2013-2015) & Annual Report (2015-16).*

1000 kgs, at the rate of Rs. 3000 per bag of 40 kg, bees would be responsible for nearly Rs. 32,000/- of the total income from one hectare. Unfortunately we do not have such data for many of the common crops that are insect pollinated".

All India Coordinated Research Project on Honey Bee & Pollinators

Out of the recommendations of National Commission on Agriculture,1976 the "AICRP on Honey bee and Pollinators" was created by ICAR. Lot of scientific information on various aspects of honeybee and apiculture has been generated. However, this valuable knowledge could neither be utilized to update the INPUT TECHNOWLOGY, nor it could effectively trickle down to the user, the farmer and beekeeper. Some of the information on benefits of insect and honeybee pollination during the years 2013 to 2016 are tabulated below:-

Pollination Needs of Crops

Various pollination experiments conducted under "AICRP on Honey Bee and Pollinators" at AAU, Jorhat Centre revealed that there is substantial increase in crop yield from 44.34 per cent to 127.27 per cent in case of field crops like Sesamum, Rape seed & mustard, Niger, Buckwheat, pigeon pea etc. Again 57.14 per cent to 276.97 per cent yield increase in case of horticultural crops such as Assam lemon, litchi, guava and cucumber was recorded.

Potential for Direct Income for Farmer and Rural Folk

Employment for the rural youth and low investment occupation are the prerequisites for rural development. Beekeeping, ***besides crop yields enhancement*** is capable of increasing farmers' income as a befitting vocation providing income through direct production of at least 6 valuable FOOD and MEDICINAL products namely, Honey, Bees' wax, Edible bee collected pollen, Propolis, Royal Jelly and Bee Venom and by providing earning employment to rural (farmer) youth.

Standardization of pollination requirement of Crops

Crop	Area inlakh(ha)	Pollination requirement/ha	Yield(q/ha)	%increase inyield
Rapeseed &mustard	3.1	Five *Apis cerana* colonies/Two *Apis mellifera* colonies	12.25	127.27
Niger	0.35	Six *Apis cerana* colonies/Two *Apis mellifera* colonies	6.10	120.2
Buckwheat	0.42	Five *Apis cerana* colonies/Two *Apis mellifera* colonies	12.20	121.87
Pigeon pea	0.11	Five *Apis cerana* colonies/Two *Apis mellifera* colonies	12.0	59.61
Litchi	0.32	Five *Apis cerana* colonies/Two *Apis mellifera* colonies	66.7	123.27
Assam lemon	0.41	Five *Apis cerana* colonies/Two *Apis mellifera* colonies	50.8	57.14
Guava	0.10	Five *Apis cerana* colonies/Two *Apis mellifera* colonies	75.22	276.97
Cucumber	0.23	Five *Apis cerana* colonies/Two *Apis mellifera* colonies	75.97	240.36
Ridge gourd	0.32	One thousand *Xylocopa*bamboo nest	75.67	249.53
Sesamum	0.30	Five *Apis cerana* colonies/Two *Apis mellifera* colonies	7.45	44.34

Source: AICRP on Honey bees and Pollinators, AAU Jorhat Centre

Beekeeping: Cost – Benefit from Direct Produce

As is stated above beekeeping gives us six valuable products and income through bee colony multiplication activity. Following tables give the economics of beekeeping based on only honey, bees wax and nucleus bee colonies multiplication.

A 10 or 50 bee hive unit can be adopted by farmers as subsidiary vocation for direct additional income. A 10 bee hive unit can increase the income of a farmer family by about Rs. 50,000/- (Rs.49,600/-) and a 50 bee hive unit adds about Rs.2,56,000/- to the family income. This is the direct income while these bee colonies shall help increase the crop yields by their pollination service to the crops.. A 50 bee hive unit is regarded as an economically viable unit. Thus a 50-hive unit is an ideal vocation for land-less rural and tribal families.

This tiny insect, honey bee and modern scientific beekeeping helps the farmer by augmenting crop yields, by direct produce of honey and other bee products and as means of rural employment generation.. As an employment generating vocation it creates 4,68,000 man days on every 10,000 bee colonies in over 30 activities. Converting it into yearly jobs, it provides full years' (@ *200 days per year*) employment to 2340 persons.

Table 1: Cost of Setting up a "10- bee hives" & "50 bee Hives" Apiary

Particulars	For 10 honeybee hive APIARY		For 50 honeybee hive APIARY	
	Rate	Total Cost Rs.	Rate	Total Cost Rs.
1-Standard Bee hive with 2 half supers, complete with detaching bottom, a dummy & inner cover.	10 @ Rs.2,400/-	Rs. 24,000	50 @ Rs.2,400/-	Rs. 1,20, 000
2-Nucleus Bee Colonies – 6 to 8 frame size worker bees with young laying queen, brood & food store.	10 @ Rs.2,600/-	Rs. 26,000	50 @ Rs.2,600/-	Rs. 1,30, 000
3-Hive stands with metal bowl (4 with each) for ant - Proofing.	10 sets @ Rs. 600/-	Rs. 6,000	50 sets @ Rs.600/-	Rs. 30, 000
4-Protectives & Various Tools for Handling Honey Bees, Queens /Swarms etc.	1 set @ Rs.2,000/-	Rs. 2,000	3 sets @ Rs.2,000/-	Rs. 6, 000
5-Honey Extractor 4 frame size and extracting accessories (all made of S.S.) net etc.	1 set @ Rs.20,000/	Rs. 20,000	1 set @ Rs.20,000/-	Rs. 20, 000
Total	—	**Rs. 78,000**	—	**Rs. 3 ,06,000**

Table 2 : Yearly Cost of 10 & 50 Bee hives Apiaries

Particulars	**For 10 honeybee hive APIARY**		**For 50 honeybee hive APIARY**	
	Rate	**Total Cost Rs.**	**Rate**	**Total Cost Rs.**
1-Non-recurring Cost – 10% of Capital Cost	10%	Rs. 7,800/-	10%	Rs. 30,600/-
2-Comb Foundation Sheets - 12/colony	120 @ Rs.25/-	Rs. 3,000/-	600 @ Rs.25/-	Rs. 15,000/-
3-Sugar, Pollen Substitute, medicines etc.	----	Rs. !0,000/-	----	Rs. 50,000/-
4- Migration, Honey Extraction and Misc. Exp.	----	Rs.10,000/-	----	Rs. 50,000/-
Total	----	**Rs.30,800/-**	----	**Rs. 1,45,600/-**

Table 3: Cost – Benefit of 10 & 50 Bee Colony Apiaries

Produce /Benefit	Qty. & Value -10 honeybee hive APIARY		Qty. & Value - 50 honeybee hive APIARY	
	1st Year	2nd. Year	1st Year	2nd. Year
1-Honey :1st Yr20kg, 2nd Yr onwards -40kg @ Rs. 70/- per kg.	20*10=200kg @ Rs.70/- **Rs. 14,000/-**	40*10=400kg @ Rs.70/- **Rs. 28,000/-**	20*50=1000kg @ Rs.70/- **Rs. 70,000/-**	40*50=2000kg @ Rs.70/- **Rs.1,40,000/-**
2-Bees Wax:10 kg /50 bee colonies @ Rs. 200/- per kg	2 kg **Rs. 400/-**	2kg **Rs. 400/-**	10kg **Rs. 2,000/-**	10 kg **Rs. 2,000/-**
3- Nucleus Bee Colonies: Nil -1st Yr.; 2- 2nd Yr onwards @ Rs. 2,600/- each.	Nil	20 **Rs.52,000/-**	Nil	100 **Rs.2,60,000/-**
Total Produce (TP)	**Rs.14,400/-**	**Rs.80,400/-**	**Rs.72,000/-**	**Rs.4,02,000/-**
Value Enhanced(VE) -end of the 1st year @ 12 bee frames per colony @ Rs 300/-	12*10=120fr. Value@300/- **Rs. 36,000/-**	______	12*50=600fr. Value@300/- **Rs.1,80,000/-**	______
Earning (TP+VE)	**Rs, 50,400/-**	**Rs. 80,400/-**	**Rs.2,52,000/-**	**Rs. 4,02,000/-**
Yearly Cost	Rs. 30,800/-	Rs.30,800/-	Rs. 1,45,600/-	Rs. 1,45,600/-
Net Earning (NE)	**Rs. 19,600/-**	**Rs. 49,600/-**	**Rs. 1,06,400/-**	**Rs.2,56,400/-**
Investment -10% =	78,000-7800= **Rs. 70,200/-**		3,06,000-30,600= **Rs.2,75,400/-**	
Net Asset(NA=I+VE)	**Rs.1,06,200/-**	**Rs.1,06,200/-**	**Rs.4,55,400**	**Rs.4,55,400**
Gain %(NA+TP*100/I)	**154%**	**239%**	**172%**	**280%**

Table 4: Man Days Created by 10,000 Bee Colonies

Activity	Description	Man days
1. Apiary Management	Handling, care, security, migration, extraction of honey & wax, etc.: Average 1hr. per day per10 colonies	3,00,000
2 Manufacturing	Manufacturing equipment & appliances for 10,000 bee colonies	58,500
3. Multiplication of bee stock	Taking 5 bee packages & 10 queens per 10 bee colonies per year : 2 hrs. per day per 10 colonies for 100 days a year	1,00,000
4. Processing of honey and wax.	A conservative estimate of 4 persons Handing 100 kg honey & wax per day - total estimated production of only, 2,50,000 kgs from 10,000 bee colonies	9,500
	TOTAL	**4,68,000**

Means – Full year's (200 days per year) employment for 2340 persons,
Marketing and Service activities - Extra

Reference: Perspective in Indian Apiculture; Agro Botanica 1997-98; Page 34-37

Conclusion

The tiny insect, the HONEY BEE and the vocation it provides, the beekeeping benefits the farmer and rural people in three ways:-

1- Direct produce of the hives by adopting beekeeping as a family vocation. With 10 bee colonies apiary, as projected by the NCA, 1976 could additionally earn Rs. 49,600/- per annum. (Table 3, page 7 above)

2- As primary benefit of the working of the honey bees, the crop yields of important crops like pulses, oilseeds, fiber crops, fruits and seeds will enhance on an average of about Rs.10,000/- per hectare. This will not only benefit the farmer but also to the National Agricultural Produce.

3- At an average Employment generation of 2340 persons per year (200 days) wages earning of rural people (including farmers) will be added by about Rs. 9.36 Crores annually per 10,000 bee colonies.

Indeed to achieve this we will have to take serious note of the ***recommendations of*** "***National Commission on Agriculture, 1976***" and ***the FAO initiatives***. The forgoing narration and scientific sinformation leads us to the following ***Road Map***.

- Change in National Perception of Farm Inputs and recognizing and including

  "*Bees and Beekeeping*" in the schedule of inputs for crop growing. We can, at least take some lesions from developed countries and the FAO.

- Protection, Promotion and Production of Pollinators, including all *Apis* species.

- Cavity dwelling *Apis* species (*Apis cerana* and *Apis mellifera*) to be promoted as

  "***most economical managed pollinating agents***".

- Beekeeping to be promoted - as ***Managed Farm Input***; as ***Earning Vocation for Rural Youth*** and for ***direct Production of healthy Organic Food and Medicines***, *viz*., Honey, Bees' wax, Edible pollen, Propolis, Royal Jelly and Bee venom.

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Agricultural Waste Utilization for Enhancing Farm Income

N.C. PATEL*

Agriculture contributes nearly 20% of India's GDP and 11% of total exports, provides employment to more than 55% of the country's workforce and livelihood security to about 650 million people. The country is a net exporter of agricultural products for many years now. The livestock has very important role in Indian farming system. They not only provide milk and meat but also provide farm yard manures, wool, egg etc. Besides, they are extensively used in agriculture for draught purpose as well for transport purposes.The livestock are fed by both dry and green fodder. The dry fodder is usually in the form of crop straw/residuals of cereals, pulses, oilseeds after harvesting of the crop produced while in mountain/hilly regions grasses from permanent pastures and some forest areas are harvested, dried and stored for feeding during offseason (like winter) period. Livestock waste is major source of green house gas, pollution, pathogens and odour. 40 % of global methane is produced by agriculture and livestock byproducts followed by 18 % from waste disposal globally.The Ministry of Environment & Forests is the nodal Ministry of the Government of India for the protection of environment. The Government of India has approved the National Environment Policy 2006.

Much of the agricultural by-products are not used economically. Probably the most prominent example of this is rice straw, sugarcane bagasse, etc. They are burnt in the field, creating economic waste as well as environmental problems like air pollution, smog formation, loss of soil moisture etc. An integrated approach at the farmer's level is needed by which a closed system is pursued in order to make efficient use of agricultural produce and by-products. In view of the actual rising food prices, high population growth rate, and higher energy prices; efficiency and improvement of the whole production chain process becomes more important. In this context, the beneficial reuse of agricultural waste will be economically profitable for both the farmers and the industries. By doing so, it will add to the income of the farmers also. Improving the position of small farmers is expected to contribute to social stability in the communities.To manage waste agricultural biomass and to convert it into a material resource, considerable efforts are being made by many Governments and other entities. There are still major gaps to be filled, especially due to its "not insight and not in mind" phenomenon. There is a lack of awareness and capacity to divert most of the waste for

Invited as a Lead Speaker during National Seminar on "Technological changes & innovations in Agriculture for Enhancing Farmers' Income" held at Junagadh Agricultural University, Junagadh during 28-31 May, 2017. material and energy recovery. The large unused volume of biomass can be converted to an enormous amount of energy and raw materials. As raw materials and biomass wastes have attractive potentials for large-scale industries and community-level enterprises.The modern uses of biomass take the advantages of modern biomass conversion technologies (combustion, pyrolysis, gasification, fermentation, anaerobic digestion) for production of heat and electricity, liquid and gaseous transportation fuel, biogas for cooking etc. There is a huge potential for modern uses of biomass energy

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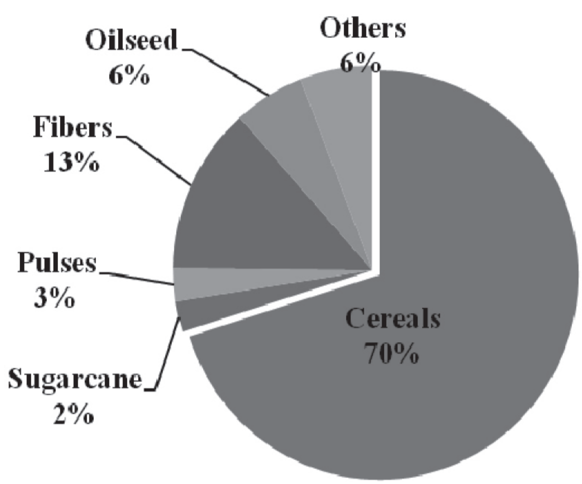
in rural India, especially in the cooking and lighting sectors. The common biomass feedstock for power generation in India includes sugarcane bagasse, rice husk, straw, cotton stalk, coconut shells, soya husk, coffee waste, jute wastes, groundnut shells, saw dust, *etc*.

Agricultural crops and their waste

Crop	Waste
Coconut	Fronds, husk, shell
Coffee	Hull, husk, ground
Corn	Cob, stover, stalks, leaves
Cotton	stalks
Nuts	Hulls
Peanuts	Shells
Rice	Hull/husk, straw, stalks
Sugarcane	Bagasse



Contribution of various crops in Residue generationin India

Among different crops, cereals generate 352 Mt residue followed by fibres (66 Mt), oilseed (29 Mt), pulses (13 Mt) and Contribution of various crops in Residue generationin India sugarcane (12 Mt). The cereal crops (rice, wheat, maize, millets) contribute 70% while rice crop alone contributes 34% of crop residues. Wheat ranks second with 22% of residues whereas fibre crops contribute 13% of residues generated from all crops. Among fibres, cotton generates maximum (53 Mt) with 11% of crop residues. Coconut ranks second among fibre crops with 12 Mt of residue generation. Sugarcane residues comprising tops and leaves generates 12 Mt i.e., 2% of crop residues in India.

(*Source:* MNRE report 2009)

Generation and surplus of crop residues in various states of India

States	Residue generation (Mt) (MNRE, 2009)	Residue surplus (Mt)(MNRE, 2009)
Andhra Pradesh	43.89	6.96
Arunachal Pradesh	0.4	0.07
Assam	11.43	2.34
Bihar	25.29	5.08
Chhattisgarh	11.25	2.12
Goa	0.57	0.14
Gujarat	28.73	8.9
Haryana	27.83	11.22
Himachal Pradesh	2.85	1.03
Jammu and Kashmir	1.59	0.28
Jharkhand	3.61	0.89
Karnataka	33.94	8.98
Kerala	9.74	5.07
Madhya Pradesh	33.18	10.22
Maharashtra	46.45	14.67
Manipur	0.9	0.11
Meghalaya	0.51	0.09
Mizoram	0.06	0.01
Nagaland	0.49	0.09
Orissa	20.07	3.68
Punjab	50.75	24.83
Rajasthan	29.32	8.52
Sikkim	0.15	0.02
Tamil Nadu	19.93	7.05
Tripura	0.04	0.02
Uttarakhand	2.86	0.63
Uttar Pradesh	59.97	13.53
West Bengal	35.93	4.29
India	501.76	140.84

Burning of Crop Residues in the Field

Increased mechanization, particularly use of combine, declining number of livestock, long period required for composting are some of the reasons for residues being burnt in field. Other reasons for intentional burning include clearing of fields, pest and pasture management. Burning traditionally provides a fast way to clear the agricultural field of residual biomass and facilitating further land preparation and planting. It also provides a fast way of controlling weeds, insects and diseases, both by eliminating them directly or by altering their natural habitat. However, this will ultimately results in loss of nutrient, impact on soil properties, emission of greenhouse gases, emission of other gases and aerosol etc. which pollutes the environment heavily. There are several options which can be practiced to manage residues in productive manner. Besides use as cattle feed, large amount of residues can be used for preparation of compost, generation of energy and production of biofuel and mushroom cultivation (www.nicra.iari.res).

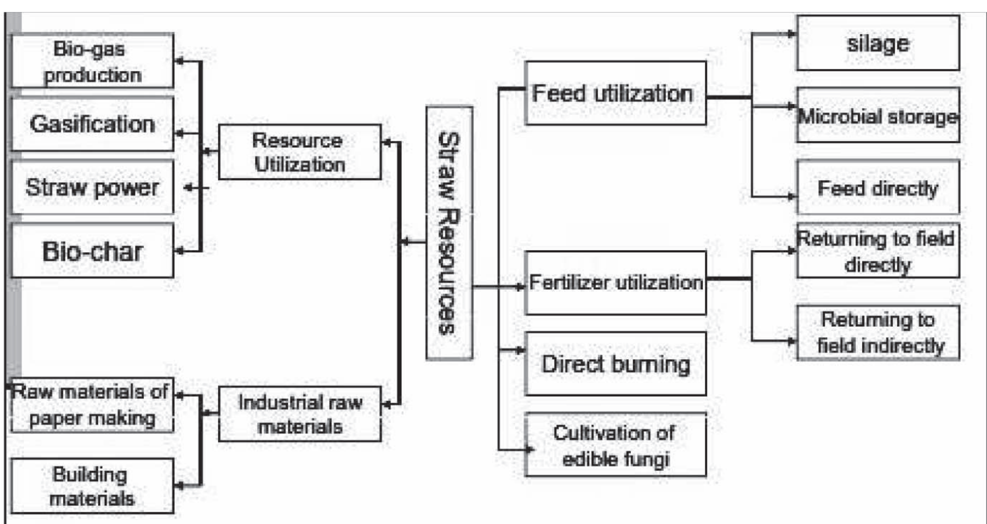
Composting of Residues for Manure

The residues can be composted by using it as animal bedding and then heaping in dung pit. Each kg of straw absorbs about 2-3 kg of urine from the animal shed. It can also be composted by alternative methods on the farm itself. The residues of rice from one hectare give about 3.2 tonnes of manure as rich in nutrients as farmyard manure (FYM). (Sidhu and Beri, 2008)

Biomass utilization

Biogas technology provides an alternative source of energy mainly from organic wastes. The feed materials for production of biogas such as animal and agricultural wastes are abundantly available in rural and semi-urban areas of country. These materials are still used for cooking food and heating homes in traditional processes which are highly energy inefficient and waste of important organic matter needed for sustainable agriculture. The technology has been widely used in rural areas for many years now to provide biogas for cooking and also for lighting using specially designed mantles. In recent years with advanced processes of bio-methanation, the technology is further being expanded as a solution to waste handling and mitigating environmental problems.Biogas is obtained in the process of biodegradation of organic materials under anaerobic conditions. Therefore, the bio-gas technology, i.e., production of methane gas from livestock waste under anaerobic condition is the best alternate source of energy from organic waste. Even not only animal but also agricultural waste can be utilized for this purpose. These are abundantly available in rural and semi-urban areas. It is used as fuel for cooking and lighting purposes. It can also be used in diesel engines to substitute diesel-oil up to 80 per cent. Biogas engines are also available in the market.

The left over decomposed slurry is a good source of manure for agricultural lands. An additional benefit is that the quantity of digested slurry is the same as that of the feedstock fed in a biogas plant. This slurry can be dried and sold as high quality compost. The nitrogen rich compost indirectly reduces the costs associated with use of fertilizers. It enriches the soil, improves its porosity, buffering capacity and ion exchange capacity and prevents nutrient depletion thus improving the crop quality. This means increased income for the farmer.Thus biogas plants help in total recycling of organic wastes in an environment-friendly manner.Its production typically varies from 0.8 to 1.6 m per adult unit per day. From 1 ton of manure with 20 % solid content, 20–25 cubic meter biogas can be produced with a total energy value of 100–125 kWh and the same can be utilized to generate 35–40 kWh of electricity and 55–75 kWh of heat energy.



Ways of utilization of straws resources

Mushroom Cultivation

Diversification in any farming system imparts sustainability. Mushrooms are one such component that not only impart diversification but also help in addressing the problems of quality food, health and environment related issues. One of the major areas that can contribute towards goal of conservation of natural resources as well as increased productivity is recycling of agro-wastes including agro-industrial waste. Utilising these wastes for growing mushrooms can enhance income and impart higher level of sustainability.Mushroom cultivation was first initiated through an in-situ training cum live demonstration in all the six Self Help Groups (SHGs) of Dhalai Districts along with the fifty-five beneficiaries in May 2008. The six SHGs were Abachanga, Khabaksha, Sharda, Pohor, Bodol, and Loknath. Till December 2010, 216 farmers have had started mushroom cultivation. Farmers produced 2062 kg of fresh oyster mushrooms at the expenditure cost of Rs. 46492; @Rs. 12 for a poly bag filling. The farmers sold fresh oyster mushrooms at Rs 80/kg to the local markets and earned Rs. 165045. The net profit resulted in Rs. 118509. Besides, increase in employment is registered to 1185 mandays. Mushrooms cultivation ensured enhancement of family income at cost of less investment. Waste materials easily deposed into food materials enriching with nutrition is the extra benefits at farmers' hand.

Vermi Compost Manure

Vermicomposting is a simple biotechnological process of composting, in which certain species of earthworms are used to enhance the process of waste conversion and produce a better end product. Vermicomposting differs from composting in several ways (Gandhi *et al*. 1997). In short, earthworms, through a type of biological alchemy, are capable of transforming garbage into 'gold' (Vermi Co 2001, Tara Crescent 2003).On one hand tropical soils are deficient in all necessary plant nutrients and on the other hand large quantities of such nutrients contained in domestic wastes and agricultural byproducts are wasted. It is estimated that in cities and rural areas of India nearly 700 million t organic waste is generated annually which is either burnt or land filled (Bhiday 1994). Such large quantities of organic wastes generated also pose a problem for safe disposal. Most of these organic residues are burnt currently or used as land fillings. Microorganisms and earthworms are important biological organisms helping nature to maintain nutrient flows from one system to another and also minimize environmental degradation. The earthworm population is about 8–10 times higher in uncultivated area. This clearly indicates that earthworm population decreases with soil degradation and thus can be used as a sensitive indicator of soil degradation. A simple biotechnological process, which could provide a 'win-win' solution to tackle the problem of safe disposal of waste as well as the most needed plant nutrients for sustainable productivity . (Wani 2002). Earthworms consume various organic wastes and reduce the volume by 40–60%. Each earthworm weighs about 0.5 to 0.6 g, eats waste equivalent to its body weight and produces cast equivalent to about 50% of the waste it consumes in a day. Vermicompost provides all nutrients in readily available form and also enhances uptake of nutrients by plants.

Earthworms serve as "nature's plowman" and form nature's gift to produce good humus, which is the most precious material to fulfill the nutritional needs of crops. The utilization of vermicompost results in several benefits to farmers, industries, environment and overall national economy Less reliance on purchased inputs of nutrients leading to lower cost of production • Increased soil productivity through improved soil quality • Better quantity and quality of crops • For landless people provides additional source of income generation.Number of farmers across the country have adopted the vermicompost technology and the knowledge imparted by the agricultural scientists working in the SAUs and KVKs. It has greatly benefitted the farmers especially for soil fertility management and organic farming.

Bagasse Fiber

Bagasse fiber bundles are unusually coarse and stiff material. It is used either as a fuel for the boilers by the sugar factory or as a raw material for the manufacture of pulp and paper products, various types of building boards, and certain chemicals. It is suitable for making non-woven products.

Ethanol from Crop Residues

The conversion of ligno-cellulosic biomass into bio-based alcohol production is of immense importance and is a researchable issue as ethanol can be either blended with gasoline as a fuel extender and octane-enhancing agent or used as a neat fuel in internal combustion engines. The theoretical estimates of ethanol production from different feedstock (corn grain, rice straw, wheat straw and bagasse) varies from 382 to 471 L t^{-1} of dry matter.

Gasification of Residues

Gasification is a thermo-chemical process in which gas is formed due to partial combustion of residues. The process breaks down biomass completely to yield energy rich gaseous products after initial pyrolysis. The main problem in biomass gasification for power generation is the cleaning of gas so that impurities are removed. The residues can be used in the gasifiers for the generation of producer gas. In some states gasifiers with more than 1MW capacity have been installed for generation of producer gas which is fed to the engines coupled to the alternators for electricity generation. One tonne of biomass can be used for generation of 300 kWh of electricity.

Fast Pyrolysis

Fast pyrolysis of crop residues requires the temperature of biomass to be raised to 400-500 ^{o}C within few seconds. This results in a remarkable change in the thermal disintegration process. About 75% of dry weight of biomass is converted into condensable vapours. If the condensate cools quickly within a couple of seconds, it yields a dark brown viscous liquid commonly called bio-oil. The calorific value of bio-oil varies 16-20 MJ kg^{-1}.

Biochar

Biochar is high carbon material produced from the slow pyrolysis (heating in the absence of oxygen) of biomass. It has got advantages in terms of its efficiency as an energy source, its use as a fertilizer when mixed with soil, its ability to stabilize as well as reduce emissions of harmful gases in the atmosphere. Biochar finds use in the release of energy-rich gases which are then used for producing liquid fuels or directly for power and/or heat generation. It can potentially play a major role in the long-term storage of carbon. Biochar increases the fertility, water retention capability of the soil as well as increasing the rate of mineral delivery to roots of the plants.Management of farm wastes in conservation agriculture is vital for long-term sustainability of Indian agriculture.

Problems in Adoption and Measures to be Undertaken

The central and state governments need to be more proactive in providing easy access to these technologies to the poor farmers. The policies and support of the government are decisive in persuading the farmers to adopt such technologies and to make a transition from wasteful traditional approaches to efficient resource utilization. The farmers are largely unaware of the possible ways in which farm and cattle wastes could be efficiently utilised. The government agencies and NGOs are major stakeholders in creating awareness in this respect.Moreover, many farmers find it difficult to bear the construction and operational costs of setting up the digester. This again requires the government to introduce incentives >ýlike soft loans?ý and subsidies to enhance the approachability of the technology and thus increase its market diffusion.Management of crop residues in conservation agriculture is vital for long-term sustainability of Indian agriculture. Burning of residues must be stopped improving soil health and reducing environment pollution.

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New Paradigm in Cold-chain Systems for Enhancing Farmers' Income

PAWANEXH KOHLI*

At its Independence and for a few decades thereafter, India was dependent on foreign aid to secure food for its citizens. In 1947, the country's population was about 335 million and many doubted if India could ever be self-sufficient to feed its masses. The subcontinent was made infamous due to frequent famines till the 1970s. However, by the start of 1980, having benefited from initiatives of the green revolution, the region transformed itself from a starving zone to become an exporter of food. The "Green Revolution" as was implemented all over the world, focused on increasing the yield, especially in developing countries, with the aim to cope with growing demand from an increasing population. The green revolution involved using agro technologies on the production side of the value cycle – improving quality of seeds including hybrids, promoting double cropping and the increased use of fertilizers, irrigation and farm mechanisation. Expanding the area under farms was also a thrust area and entire agenda was to produce more.

The farmer has responded robustly by producing ever more - as a result, with a population about four times in size since, today the concerns are no longer about production but about the enormous wasted surplus. Today in 2016, India's focus is shifting, from production, towards avoiding food loss in the post-harvest supply chain. The need today is to maximise our capability such that produce is delivered to consumers in quantity, with quality and safely. India today stands more concerned about nutrient value and the easy access to food, than merely about securing the production of food.

Agriculture Production in India

India's success with agriculture has manifested across all agrarian sectors. Food grain production stands close to 252 million tons and the country underwent a white revolution where milk production is in the range of 160 million litres per annum in 2016-17. In horticulture, once again surpassing all other agriculture sectors, in 2016, the production totalled 283 million tons. It is to note that horticulture utilises only 24 million hectares (approx. 15% of total area under agriculture), yet contributes the highest (almost 38%) to agricultural GNV/GDP. Horticulture, combined with produce from fisheries, dairy and livestock, captures almost 70% of agriculture's contribution to the national GDP, making these domains the prime drivers for rural wealth and economic productivity.

Compared with the production at the start of the 1960s, India now harvests 40 times as much tomato, 14 times more potato, 8 times more wheat, thrice as much in poultry and meat, 13 times more fish, 8 times more milk and almost 40 times more eggs. The scaling up of our food production far surpassed the growth in population (which grew about 2.8 times from approx. 460 million in 1961).

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Production figures - India (annual estimates 2015-16)

Horticulture	(million tons)	Livestock	(million tons)
Potato	44.8	Meat & Poultry	5.9
Onion	20.9	Fish	9.6
Tomato	18.4	Inland Fish	6.1
Mango	18.8	Marine Fish	3.5
Citrus	11.5	Butter& Ghee	5.4
Banana	29.1	Milk	160(million litres)
Brinjal	12.6	Egg	69731 million pcs
Aromatics, Cashew, Flowers, etc.	18.87	Field Crops	(million tons)
Spices	6.35	Pulses	17.1
Fruits	91.44	Rice	103.4
Vegetables	166.61	Wheat	94.0
Total Horticulture	283.36	Sugar cane	346.7

Data from MoAFW

Having almost 155 million hectares under agriculture, India's concerns today, are about empowering farmers with greater market connectivity to achieve greater value realisation. Producing food in sufficient quantity is no longer the immediate concern; instead now, apprehensions relate more to minimising post-harvest losses, securing of easy and affordable access to the food and in improving resource use and input management.

India has shifted gears to drive a change to bring its harvest to more gainful end-use, and to make its agriculture sustainable on both commercial and environmental terms.

Annotations & Learnings

Despite the robust performance of the farming community, in producing sufficient and surplus produce, there is a seemingly disassociated inflationary pressure on food items. In the last decade or so, food prices had started to lead inflation. This contradicts the higher production or the designs to increase farm yields. It is obvious that all was not well.

A major learning arises, that no matter how much food we harvest, if the associated market linkage or logistics mechanism is unable to cope with the flood of farm produce, the waste incurred nullifies any benefits that ought to accrue. This inefficiency in the post-harvest supply systems is a constraint, which creates inherent mismatch between supply and demand, with inflationary pressures. In effect, production alone is not sufficient to ensure reach of food to India's dispersed sub-continental footprint. The missing piece for achieving food security is the physical and effective market reach, in having a good food distribution mechanism.

In 2013, India was the first country to enact a rights based approach to Food Security. The legislation was not merely to make food available, but aimed at assuring affordable nutrition. The Food Security Act was in response to counter the rising cost of food and to assure nutrition at the right cost to the underprivileged. The primary concern for India today, is to bring its immense farm-gate production to gainful and effective end use - to reach the hands of consumers, regularly and efficiently. Every kilogram wasted due to poor post-harvest handling & logistics capabilities is also a loss multiplied in terms of resource wasted and in greenhouse gas emissions. Any loss on the supply side has an immediate ramification on farmers' income and inflation.It is opined, that with the presence of efficient logistics to link harvested produce with markets, the Food Security Act may not have been required. Post-harvest supply chain systems allow for streamlining the balancing of episodic supply and demand, providing horizontal integration of farmers with markets. Long-term supply stability is best achieved through developing dynamic logistics chains, designed as bridges that link the rural farm scape with high density population centres. Post-harvest market connectivity is the need of the hour.

A Fresh Look at Cold-chain

Horticulture and livestock produce are clearly established as future drivers of agriculture. The majority of the produce is perishable and therefore, the marketing range of the farmers is normally limited to a small radius from place of harvest. However, with cultivation practices having developed to produce in excess of local consumption demand, the limitation in selling radius of the farmer is leading to greater waste, more discards and a distressful environment. The answer is not to produce less, but to develop cold-chain systems that link the perishable produce with existing, ready, markets.In the past, cold storage was understood to be key to the cold-chain. All government subsidies had focused only on supporting the development of refrigerated warehouses. This was a misnomer as the cold store and its function varies depending on its positioning in the overall cold-chain and the type of produce it is intended to handle. It also required to be understood, that all fresh food is organic and will eventually perish, even within the confines of a cold store. Therefore, the main function of a food supply system is to reach the food to point of consumption, and not merely to store it. A cold store, merely delays the eventual loss, unless the produce can be marketed before it is discarded. A proper cold-chain buys time to use it fruitfully, by linking the produce with market, much before its final expiry.

This latter was not applied for various reasons in the Indian backdrop. Yet, the evidence has suggested a conceptual change is required, and this is why a paradigm shift in understanding cold-chain systems is required. Cold-chain needs to be looked upon afresh. In future, all modern post-harvest logistics will need to be designed to counter perishability while produce is in transit to market. The counter to perishability is not for the sake of science but for the sake of expanding market access. Ensuring the market access would result in improved throughput to consumers, matching value realisation and socio-economic growth for farmers.

Life Extension in Cold-chain

The loss of farm produce is most evident when dealing with fresh perishable produce. This format of produce is also categorised high value agriculture (HVA). Dairy output, meat products, fruits and vegetables are the typical food items under this category. Floriculture and medicinal plants are some non-food produce which also fall in the same category.Amongst these produce categories, all having an inherent constraint of perishability, the horticultural harvest is unique. The produce is living, breathing and highly temperature sensitive. For example, meat and fish is comparatively safe if rapidly chilled and retained as less than -18 °C (in fact, the colder the better), a temperature below which external microbial activity is largely rendered dormant. Conversely, in case of fruits & veggies, they will perish below a specific temperature point. These temperature points (chill injury temperature) is individual to each produce type (colder is not better).Even at the optimal temperatures, fresh horticulture produce type, needs added aspects of care and need to be kept in optimal humidity & with a continued supply of oxygen, to stay alive. While alive, the living tissue avoids the onslaught of decomposing influences; but with demise, decay will set in rapidly.

This extension to the produce life, has differing consequences for different produce types. The most common application is seen in crops like potato and apple, which have atypical holding periods. These produce types are observed to remain marketable over months, across seasons, when maintained in environmentally controlled conditions. When attaining a holding life of 6 to 8 months, seasonality in production can be countered, and produce owners can maintain inventory to offset variations in demand. Nevertheless, this advantage is denied to a vast majority of crop types with short holding periods (eg. capsicum, tomatoes, litchi, mango, banana, eggplant, lettuce, mushroom, plum, radish, spinach, strawberry, melons, etc.).The majority of fresh farm produce, will not gain more than a week to a few weeks only, a comparatively short period of holding. In the case of the majority, the time gained must be used to reach markets and not wasted in the confines of a store.

When we look at Food Loss & Waste with clarity, one unambiguous rationale stands out – we farm food with the sole aim to consume what is harvested; and deficit occurs when such gainful-end-use is not achieved. When food does not reach the consumers; or reaches in degraded condition, a loss of all associated inputs is suffered. Cold-chain, helps extend the life force in fruits and vegetables and thereby manages to extend the marketable or holding life of fresh farm produce. Cold-chain must be used gainfully, which means to take farmers produce to a point of value realisation.

Building Capacity in Cold-chain

The Government of India has been providing financial support to the private sector, since 1999, for the creation of cold-chains, for more than a decade and a half. This resulted in India having created an enviable capacity in refrigerated warehouses, approx. 135 million cubic metres of temperature controlled space (the largest refrigerated warehouse capacity in the world).

The common understanding had been that entry into a controlled temperature space would safeguard the produce and benefit both consumers and producers. However, maintaining inventory in cold stores only tended to defer the inevitable, and the pressure to reach markets to make the sale remained, irrespective. Whether the produce could last three weeks or thirty weeks, the perishable inventory needs to get within reach of consumers. This access by consumers should be about a week (or at least a few days) before it the produce perishes.

In certain limited cases, a time extension of a few months in cold stores (where possible), helped drip-feed the consumption over that period, spreading a fixed volume of transactions. In the case of crops that lasted only a short duration even in the cold-chain, the temporal shift was at times too minimal to even counter the harvest window off individual farms. A long stay in cold storage premises only tended to complicate the problem.Another aspect was that any excess in farm production, led to a glut and wasted produce. Any planned increase to farm level productivity, required a matching multiplier in consumption. This could of course happen by expanding the market reach of farmers/producers. In case of perishable produce, to capture a wider market radius brought about the need to offset inherent perishability, so as to reach across greater distances. This meant that the cold-chain needed to be applied for cross geography access, or distance arbitrage and not just for time-arbitrage or cross seasonal trading.

In 2011, a committee was set up under the central planning commission of India to evaluate the status of agrilogistics infrastructure. This committee, headed by Dr. Saumitra Chaudhuri, remarked that the past thrust on building cold stores had not borne the expected results, especially in case of vegetables and most fruits. There was some missing link in the overall equation and the supply chain needed strengthening. The missing link was concept clarity about the cold-chain and its varied applications. The gap in clarity between the stakeholders - equipment sellers, logisticians, farmers, researchers and policy makers needed to be bridged by core domain experts. The Government of India decided to establish an independent body, with intention to keep distanced from day-to-day government functioning, and tasked with bringing greater coherence to the nation's cold-chain assessments. February 2012 saw the formal birthing of National Centre for Cold-chain Development (NCCD). The centre was established with participation of domain experts from industry, invited to help fulfil the mandate. NCCD is required to focus on the horticulture sector, albeit keeping synergy with needs of other allied sectors.

NCCD has brought about a paradigm shift in the understanding and policy interventions on cold chain development. The concept understanding was on how cold-chain is a necessary logistics chain, which must be planned as an enabler that allows farmers to extend their reach to markets. The value from cold-chain, to farmers, is not from delaying a sales transaction, but arises from providing scope to multiply their sales transactions.

Cold-chain empowers farmers by enabling greater connectivity with multiple markets, by countering the limitations of perishability to expand their reach to consumers. When cold-chain is used as model to store and defer trade, it is not used to its full capability. In accordance, NCCD highlighted some key concept aspects, with associated changes to the supporting interventions by the government:

Food has one end-use, to be consumed: food loss or waste occurs when food is not consumed - or, when food perishes before it could reach the market within its normal saleable life cycle. Achievement metrics must measure gainful delivery of food, not mere production.

Food loss can be reduced: Only by ensuring that all the harvested produce reaches its intended end-use. This means that food delivery mechanisms must also aim to counter the perishable nature of food, to extend its saleable life cycle and thereby become accessible to more consumers. Cold-chain is the mechanism that does this.

Cold-chain does not preserve endlessly: It applies technology to merely stretch the marketable time of a perishable product, for a very finite duration. The time in hand should be fruitfully utilised and not wasted in-situ storage, especially when dealing with high perishable fresh produce.

Cold-chain buys time: Temporarily countering perishability. This allows produce owners more time to reach buyers, to expand their market footprint to realise greater economic value. In turn, this promotes gainful livelihood and justifies any efforts to increase production.

Saleable life extension: It is best utilised by moving to markets, reaching closer to the shelf and the consumers who complete the cycle. Food lost in the delivery chain is avoidable loss, and loss in hand of consumers is called waste.

Cold stores do not directly reduce food loss - Cold stores are only one piece in the cold-chain. All inventory has a time limitation, even grain perishes if left in storage - store only to buffer the supply, against demand. Supply chain intervention is best used to reach more shelves and increase access to more buyers. This logic applies to all products. The time matrix is determined by the saleable life span of the product and time taken to access markets.

Understand cold-chain as a bridge, not merely as a storage system. When used as a physical conduit to markets, cold-chain is **always successful** as it then expands the geographical reach of producers, and by reaching more consumers provides real cause to produce more at farms.

Without market access, all food will eventually perish, unused - lost even when stored within temperature controlled environs. Hence, cold-chain is a solution only when used to facilitate market access, to reach many more consumers.

Cold-chain needs to progress towards delivering fresh quality in quantity, well within the limited time span on offer. Mere presence of technology is not the end-all... any applied science must target an effective end-result.

Refrigeration brings intrinsic challenges in fresh produce care, which when not understood can make its application the premier cause for food loss. Cold-chain is not just about cooling, but includes specialised post-harvest handling in the supply chain of fresh produce. Cold-chain also helps to organise the business of agriculture.

Cold-chain needs multi-disciplinary skills akin to life care - knowledge of biology, physics, logistics and time management, not of refrigeration alone. Without feasible market links, in this sector the loss is large. Due to perishability, time, range and access to consumers is limited, and after a short period, all that remains unsold perishes. Luckily, some of the would-be-loss of fresh produce can be processed into food products.

Expanded market reach by producers, leads to a market driven increase in production. In addition, it feeds improved resource utilisation and greater productivity, both by area and by value realisation. Conceptual change in technology use and changed practises adds to valuable resource conservation. Production can surpass supply chain handling capabilities. Expanding food supply and reach to more markets is key to reducing loss & waste, making agriculture economically sustainable.

Inherent self-reliance of the rural community endorses near-farm employment opportunities. Benefits from creating near-farm-jobs in terms of value linked sustained employment, helps take agriculture from peasant mode to market linked livelihoods. Associated logistical links need to develop faster. India is on a path that takes a "System Approach" to post-harvest infrastructure investments and the practise of promoting private industry / entrepreneurs' investments in '*for agriculture'* infrastructure (both post-harvest and pre-harvest), as the preferred option.

Cold-chain is a logistics tool, a service that uses cooling and other techniques, and makes it feasible to access multiple markets, taking perishable produce where it could not normally have reached. Therefore, cold-chain is a key to multiplying income of farmers, to make agriculture more valuable. A future ready Cold-chain needs to be a thrust item in agriculture policy.

Conclusion

Till not too long ago, the normal practise for fresh food supply (that reached our homes), was quite simple and a matter of routine. Our cities adjoined lush fertile farmlands; these surrounding farmers would harvest their produce in the wee morning hours, and aggregators would rush it to the local wholesale centres. By the time the consumer upped to buy their daily basket, the local grocer or street vendor was ready with that day's fresh supply. This was a highly fragmented yet efficient food supply system that ensured that each morning's harvest was at tables well within 24 hours. There were those awkward vagaries of weather and unbalanced supply, but the consumer too was an understanding and pliable creature. Today, not only are those farmlands distanced very many kilometres away, entry into our cities has turned into bottlenecks and transit time is no longer directly related to distance. No more can the harvest reach the consumer within its natural life cycle. What now reaches the consumers' homes, was harvested a previous couple of days, or more ago! This extended in-transit time is compounded by the perpetually growing demand, wherefore an increase in handling volume adds to the delays. The produce life cycle needs to be extended, using the *cold-chain!*

There is no alternate, no substitution to the cold supply chain. This is the only logistics chain that intrinsically and directly impacts price realisation of its cargo, whether in the cold storages, distribution hubs or en-route in transport. It definitely demands a far higher standard of commitment from all its participant stakeholders and its benefits accrue all across the value chain it stitches. Its success is already palpable across your frequent dose of high value needs, from ice-cream to vaccines, it is innate to some of the processed food you consume. As global population increases, nutritional security comes to fore, and environment security becomes imperative, cold-chain will counter all these concerns. Cold-chain ensures that fresh whole produce reaches gainful end-use and therefore minimises the negative impact to our depleting natural resources. Cold-chain allows farmers to extend their market footprint, justifies efforts to produce more and brings overall growth to agriculture.

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Food Traceability and Food Safety for Enduring the Quality and Enhancing Farmers' Income

C.K. NARAYANA

When mankind was practicing subsistence farming, one knew about the source of food that he/she was consuming. They knew its grower and his farming practices, quality and safety of the produce. As a result of globalization, the distance that food travelled has increased and the producer / intermediaries became unknown. Ensuring the quality and safety along the supply chain has become a challenge. WHO said that "the globalization of food industry created new risks for consumers as the production chain has become very, very , long". Over the past 1 to 1 ½ decade there have been an increasing number of food alerts worldwide creating a genuine crisis of confidence among consumers. The significant ones among them have been BSE (Bovine Spongiform Encephalopathy), dioxin contamination, listeria, salmonella, camphylobacter. The biggest killer was Salmonella, which caused 52,000 deaths in 2010, followed by Ecoli (37,000) and norovirus (35,000).This crisis has led to multiple countermeasures, regulations and monitoring programmes for food safety and quality from both the public and the private sector, particularly in developed world.

The UN Radio announced that food borne illnesses takes a toll of 3,51,000 deaths a year across Africa alone. When food moves across the continents, the pathogens also move along with it ravaging the lives of innocent and hungry. Food safety has become a matter of international concern, more so after unprocessed and processed food took a centre stage in international trade. Prompt trace backs and recalls play a vital role in stopping the spread of food borne illnesses and deaths. In response to growing food safety issues, the laws, policies and standards regarding food safety and quality management have been developed for the food industry. Traceability has been found to be an important tool to comply with legislations and meet the food safety and quality requirements in food supply chain. Consumers also demand verifiable evidence of traceability as an important criterion of food quality and safety. The traceability system gives information on origin, processing, retailing and final destination of foodstuffs. The word **'food safety'** underwent several metamorphoses from mere absence of a pathogen to sustainability of environment, ecology and public health.

Currently in the United States, food industry traceability standards are governed under federal laws imposed in 2002, in the Bioterrorism Act, requiring "one-step-forward and one-step-back" accountability in the food supply chain. With the passage of the Food Safety Modernization Act of 2011, for the first time the US FDA had mandatory recall authority for food products and will be able to require full traceability and record keeping for designated high-risk foods.

Food safety and food quality are two important terms which describe aspects of food products and the reputations of the processors who produce food. Codex Alimentarious Commission defines food safety as an assurance that food will not cause harm to the consumer when it is prepared and/or eaten according to its intended use. Food safety refers to all hazards, whether chronic or acute, that may make food injurious to the health of the consumer. It is not negotiable and a global issue affecting billions of

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people who suffer from diseases caused by contaminated food. Both developed and developing countries share concerns over food safety as international food trade and cross-border movements of people and live animals increased.

In India, often quality is dealt in isolation with characteristic attributing to sensory acceptance, while the term encompasses the safety without being explicit. Quality is a prime criterion in gaining access to competitive markets. Post WTO, exports of food commodities to markets in developed nations by developing countries has grown several folds. The capacity of developing countries to access these markets depends on their ability to meet stringent food safety standards imposed by developed countries. These standards are stringent and go beyond traditional quality standards and demanding to pay close attention to the responsible use of agrochemicals, energy, water and waste, as well as social and environmental impact. These standards are significantly higher than those prevailing in developing countries. While defects in size, shape other visual parameters may result in consumer rejection and lower sales, food safety hazards may be hidden and go undetected until the product has been consumed. Since food safety hazards directly affect public health and economies, it takes precedence and higher weightage over other quality attributes.

Food quality and safety assurance, builds the consumer confidence in the product as well as brand. Fruits and vegetables pose higher safety risk of spoilage due to their perishable nature and if there are any distortions in the production and supply chain, the produce can go bad both in quality and safety. The aim of fruit and vegetable production is to deliver a safe and wholesome final product to the consumer. Nevertheless, fresh fruits and vegetables have recently been identified and confirmed as a significant source of pathogens and chemical contaminants that pose a potential threat to human health worldwide. In order to develop proper practices and methods of production, hazards and the risks that they may impose to consumer health have to be fully understood. An understanding of the agents/factors that affect fresh fruit and vegetable safety and quality makes it possible to develop practices to minimize potential negative impacts.

Quality is a prime criterion in gaining access to competitive markets. Apart from everything else, commercial markets require a stable supply and consistent quality in the produce they trade. Food safety is the most important component of quality, since a lack of product safety can result in serious injury, illness or even death for the consumer of the respective product. Quality might be defined differently since it is a term defined by consumers,

Class of attribute	Quality attribute	Measurement of quality attribute
External	Appearance (sight)	Visual evaluation of size, shape, gloss and colourMay be accompanied by visual guides and colorimeters.
	Feel (touch)	Manual evaluation of firmness and texture. May be accompanied by mechanical texture analysis
	Defects	Visual evaluation of absence of defects or deterioration of colour. May be accompanied by mechanical methods.
Internal	Odour	Mostly qualitative and subjective evaluation by smelling. May be accompanied by technical methods (gas chromatography).
	Taste	Oral tasting (sweetness, bitterness, sourness and saltiness, etc.) Technical quantification of taste compounds (e.g. chromatography) can also be done.
	Texture	Includes tenderness, firmness, crispness, crunchiness, chewiness, fibrousness which are measured by applying force to the produce;additionally, textural characteristics are evaluated as "mouthfeel".
Hidden	Wholesomeness	Wholesomeness is difficult to measure objectively; it can be described as "freshness" "produce integrity"; it also has a "sanitary" component meaning how clean / hygienic the product is.
	Nutritive value	Nutritive value is measured by the content of nutrients such as fat, carbohydrates, protein as well as essential vitamins, minerals and other substances that influence human well-being.
	Food Safety	Food safety can be measured via the examination of food items with regard to their pathogenic microbial load, content of chemical contaminants or presence of physical foreign matter in the produce.

buyers, food handlers or any other client based on subjective and objective measurement of the product. The ideal of proper product quality therefore also differs between countries and cultures and is difficult to define on an international level.

However, Food quality can be defined as “the totality of features and characteristics of a product that bear on its ability to satisfy stated or implied needs”. Food safety is the “Assurance that food will not cause harm to the consumer when it is prepared and/or consumed according to its intended use”. Both food safety and quality assurance (QA) should focus on the prevention of problems, since once safety or quality has been reduced it is difficult or impossible to restore. Also, implementing QA programmes should help ensure that problems experienced in the past do not affect the future product the same way.

Quality attributes of fresh fruits and vegetables can be classified into three classes according to the occurrence of product characteristics when they are encountered or consumed.

Despite of enough care, sometimes the produce may lose its quality and become unsafe to consume. In such cases it is essential to call back the consignment or product, and fix the problem to ensure that it does not recur. To identify where the safety risk has crept in, it is essential to track and trace the movement of the produce or product. A system put in place through a common agreement by all the stakeholders for this purpose is called ‘Traceability System’. As per ISO 9001:2000 Traceability is “the ability to trace the history, application or location of that which is under consideration”. In food products it is the ‘Ability to follow the movement of a food product through specific stages of production, processing and distribution along the supply chain’.Traceability can be defined as “a business process that enables trading partners to follow products as they move from field through to retail store or food service operator. Each Traceability Partner must be able to identify the direct source (supplier) and direct recipient (customer) of product”.

The topmost priority of traceability is to protect the consumer through faster and more precise identification of implicated product. There are external traceability or internal traceability process followed.

- **External Traceability** is the business processes that ***occur between trading partners*** and the information/data exchanged to execute traceability.
- **Internal Traceability** is the proprietary data and business processes a company uses ***within its own span of operations*** to execute traceability.

The new trends in the Food Traceability sector focus on improving the processes such as Food Track and Trace Ontology (FTTO) and Critical Tracking Point (CTE) combined within the TraceFood Framework, which can provide new advances for improving the efficiency and compatibility of the present traceability system.

There are three primary objectives in using traceability systems: i) improve supply management; ii) facilitate traceback for food safety and quality; and iii) differentiate and market foods with subtle or undetectable quality attributes. USDA Economic Research Service states that the benefits associated with these objectives include lower cost distribution systems, reduced recall expenses, and expanded sales of products with attributes that are difficult to discern. Not only just a way to improve food safety systems, traceability can also be seen as a strategic tool to improve the quality of raw materials, to improve inventory management and as a source of competitive advantages. From a consumer perspective, traceability helps to build trust, peace of mind, and increase confidence in the food system. For the growers, traceability is part of an overall cost-effective quality management system that can also assist in continuous improvement and minimization of the impact of safety hazards. It also facilitates in the rapid and effective recall of products, and the determination and settlement of liabilities. Traceability can be classified according to the activity or the direction in which information is recalled in the food chain. Depending on the activity in the food chain, three different types of traceability can be distinguished. Those are: back traceability or suppliers’ traceability; internal traceability or process traceability; and forward traceability or client traceability.

GS1 Global Traceability Standard (GTS)

GS1 standards make traceability systems possible on a global scale no matter how many companies are involved or how many borders are crossed as food and food ingredients travel from one end of the supply chain all the way to the consumer. GS1 is a not-for-profit standards organisation with member affiliates in over 100 countries dedicated to the design and implementation of global standards for use in the supply chain. These standards provide a framework that allows products, services and information about them to move efficiently and securely for the benefit of businesses and the improvement of people's lives, everyday, everywhere. Together with local/national produce trade associations they are important resources that are able to help the company understand the most effective way to implement traceability with the trading partners. They can also help the company to connect with technology providers that serve the produce industry.

The implementation guidelines for GS1 has been developed and shared with all the member countries. The GS1 Global Traceability Standard defines the essential pieces of information that have to be collected, recorded and shared to ensure one step up, one step down traceability. The standard is applicable to companies of all size and geography.While the GS1 Global Traceability Standard may be implemented independently from any specific technology, best business practices require adoption of bar coding on cases and/or pallets. Businesses are further encouraged to adopt electronic messaging to exchange essential business information.

The Implementation Guide for Traceability of Fresh Fruits and Vegetables provides a guide for fresh produce growers, packers, exporters/importers and distributors. Individual organisations may perform any combinations of these roles. The guide has been developed following an organised and thorough process, the Global Standard Management Process (GSMP). The standard defines the globally accepted method for uniquely identifying:

- Trading parties (your supplier, your own company, your customer..etc)
- Trading locations (can be any physical location such as a warehouse, packing line, storage facility, receiving dock or store)
- The products your company uses or creates
- The Logistics units your company receives or ships
- Inbound and outbound shipments

For each of the actors, fundamental questions were covered such as how a company is identified uniquely, how a company identifies its products in the supply chain, what traceability information is needed...etc, as well as best practices and business scenarios. For better understanding of the process few important guidelines from the GS1 are reproduced below for illustration.

Guidelines for Growers

What is the essential information that growers should record to enable an efficient traceability?

Capturing Production Inputs

To enable traceability, growers must maintain records of essential information related to the production of the product (e.g. crop protection materials including date of application, seed information, fertilizers, packaging material, harvesting crew, and water source). This information is critical to the company's body of **internal traceability** information.

Additionally to assist packers in assigning batch / lot at the pack house, growers should include on their Logistic Unit (crate / bag / basket) tag/label, in human-readable format, all relevant grower/harvest information. The information included should enable the creation of a meaningful batch / lot and could include the harvest crew, field or plot of harvest, date of harvest, etc.

To ensure that the traceability link is maintained, the following data must be recorded and shared. This represents the minimum data set required to ensure traceability between you (grower) and your trading partners.

Logistic Unit identification (SSCC)

- Commodity name and, where applicable, variety name
- Receiver Identification (GLN)
- Shipping from location identification (i.e. GLN of shipping location)
- Shipping to location identification (i.e. GLN of receiving location/trading partner)
- Shipping Date

- Grower records details related to growing/production (e.g. field, seeds, details of production inputs)
- Additional grower information (e.g. harvest crew, date of harvest) to enable batch / lot assignment by the trading partner (packer)
- Sender Identification (GLN)

*Who are the trading parties?:*For example, ABC Farms grow, harvests, and transports raw product to other companies (pack houses and/or cooperatives) which, in turn, receive, sort, grade and pack raw product received in bulk from ABC Farms into "finished product" configurations.

*What needs to be traced?:*ABC Farms is responsible for recording and maintaining information that will enable batch / Lot assignment during the packing process. ABC Farms are also responsible for providing this information to its trading partners as product is delivered.

*How do they accomplish this?:*ABC Farms harvests their product and transports the raw product in bins or field boxes to their trading partners. As product is harvested, ABC records information related to each day's activity based on commodity, harvest date, field being harvested (i.e. Ranch/Plot, Unit/Block) and harvesting crew. A human-readable "field tag" is generally applied to the bin or field boxes as they are filled. The "field tag'' generally includes information as outlined above. To enable greater granularity during the batch / lot assignment, additional information could include specifics on the actual truck load of raw product being transported to their trading partner.

Guidelines for Packers/Re-packers

Growers deliver product in bulk using various containers or logistics units for transport. Common examples of logistics units include bags, bins and trailers. Each Logistic Unit must be individually traceable. For this reason, each Logistic Unit carries a tag or label that shows a unique identification number. This is a GS1 Serial Shipping Container Code (SSCC) number and is assigned by the Grower. Use of the SSCC number ensures not only distinct identification from any of the Grower's other shipping containers but also guarantees uniqueness across all growing companies providing product. The tag or label provides other important information including:

- Commodity name and, where applicable, variety name
- Additional grower/harvest information
- The grower's unique company identification (GLN)

Product sourced from other packers is identified using the GS1 Global Trade Item Number (GTIN). The assignment of GTINs for each product traded (i.e. all product configurations) is the responsibility of the brand owner and must be recorded in the re-packer's internal systems prior to being re-packed and traded. Use of the GS1 GTIN ensures unique product identification across all of the supplier's product configurations. Traceability is accomplished by associating each GTIN with its batch / lot. GTIN and batch / Lot information is shown on individual case labels.

How Does my Company Identify Products in the Supply Chain?

The best practice is to assign a GS1 Global Trade Item Number (GTIN) for each traded item.

What is a Global Trade Item Number?

A Global Trade Item Number (GTIN) is a standardized and globally unique way to identify items traded in the supply chain. Where there is a requirement to accurately order, invoice, price or receive your product, the GTIN is the basic enabler. The GTIN provides a common language to support multiple business practices, including traceability.

Guidelines for Case Labels

Case labels provide a means to identify product to other trading partners. The label shows the product identification (i.e. the GTIN) and associated batch / lot in an easy-to-read human readable form and should also, as a best practice, provide case information using GS1- compliant bar codes. This ensures cases can be identified quickly and accurately at any subsequent point in the supply chain, anywhere in the world. Case bar codes (i.e. symbols) conform to a symbology called GS1-128. Your local GS1 Member Organisation can help your company understand how to produce GS1-128 bar codes and provide guidance on label placement.

For Distributors/Traders

Distributors/traders must capture product information from their supplier companies. These products are identified using a GS1 Global Trade Item Number (GTIN). The assignment of GTINs for each product traded (i.e. all product configurations) is the responsibility of the brand owner and must be recorded in the distributor/ trader's internal systems prior to product being traded. Use of the GS1 GTIN ensures unique product identification across all of a supplier's product configurations and uniqueness across all sources of supply.

Traceability is accomplished by associating each GTIN with its batch / lot. GTIN and batch/lot information is displayed on individual case labels. This information will need to be captured, stored, and communicated to the food service operator/ retailer.

Distributors/traders may also need to capture information about inbound logistics units, these are typically pallets. Pallets are identified at the time that they are created by the packer and are individually identified using a GS1 Serial Shipping Container Code (SSCC). This number is assigned by the packer/ shipper and appears on individual Logistic Unit labels. The pallet label provides other important information that must be collected and recorded. To enable traceability, distributor/traders must also maintain records of other product inputs (e.g. packaging material) for their own use. This information is equally critical to a company's body of internal traceability information.

The best business practice is to assign a GS1 Global Location Number (GLN) to your company and then share that number with suppliers and customers. Like the GTIN, a GLN is based on your GS1 Company Prefix Number, thus ensuring global uniqueness. GLN's can be allocated either by a GS1 Member Organisation or by your company using your GS1 Company Prefix. Individual GLN's can be assigned to represent your company as well as any individual trading subsidiaries. GLN's can also be used to identify important production, storage, shipping or receiving locations in your company. Where distributors/traders simply re-sell product from their packer/re-packer suppliers (i.e. products are **not** re-configured into other traded units), they must use the GS1 GTINs assigned by the packer/ re-packer suppliers to inbound products. Where distributors re-configure product from suppliers, the best practice is to assign a new GS1 GTIN for each new product.

Food Service Operators/ Retail Stores

Ensure unique product identification across all of a supplier's product configuration and uniqueness across all sources of supply chain. Food Service operators and retail stores must capture product information from their supplier companies. These products are identified using a GS1 Global Trade Item Number (GTIN). The assignment of GTINs for each product traded (i.e. all product configurations) is the responsibility of the brand owner and must be recorded in the foodservice operator/retailer's internal systems prior to product being traded. Use of the GS1 GTIN ensures unique product identification across all of a supplier's product configurations and uniqueness across all sources of supply. When the trading relationship requires that the inbound product is traceable, this is accomplished by associating each GTIN with its batch / lot. GTIN and batch / lot information is displayed on individual case labels.Food service operators and retail stores may also need to capture information about in-bound logistics units, these are typically pallets. Pallets are identified at the time that they are created by the supplier and are individually identified using a GS1 Serial Shipping Container Code (SSCC). This number is assigned by the supplier/ shipper and appears on individual Logistic Unit labels. The pallet label provides other important information that must be collected and recorded.

Foodservice operators and retail stores may also need to capture information about out-bound shipments to stores, these are typically cases. Cases are identified at the time that they are created by the supplier and are individually identified using GTIN and batch / lot. This number is assigned by the supplier/shipper or the retailer/foodservice operator and appears on individual case labels. The case label provides a reference that can be traced to the original source. Each order that is shipped to a store should have the linkage between the order, GTIN, batch / lot, and quantity shipped. The retailer/foodservice operator may also create new logistics units and this information must be captured as well.

To enable traceability, foodservice operators/ retail stores must also maintain records of other product inputs (e.g. packaging material) for their own use. This information is equally critical to your company's body of internal traceability information.

Technological Advancements in Traceability System

Recording, transmission and sharing of information pertaining to the quality and safety among all the stakeholder in the supply chain is key in the whole tracing and tracking system. Recent developments in technology make these tasks easily achievable. Some of these include: advanced data handling systems based on RFID and a Wireless Sensor Network (WSN), a location tracking system like Global Positioning System (GPS) and decision support system using intelligent software agents etc. An intelligent container system using a combination of RFID, sensor networks, and software agents to trace fruit transports, demonstrating an effective use of RFID technology in fruit logistics are being proposed. System have been developed where a temperature-managed traceability system for frozen and chilled food during storage and transportation are used. The system integrates RFID with GPS, mobile communication with Time Temperature Tolerance (TTT) theory that automate the tasks, like daily work routines, and cross- communicate information flow between the manager, the driver, the stakeholders and insecurities about arrival time. Real-time monitoring and decision support system, with a combination of existing technologies such as RFID,WSN, GPS and rule-based decisions to improve the delivery system for perishable products are being developed in Hong Kong. Based on the mathematical models, and data from the RFID and sensor network, the quality of the goods can be predicted by the forecast module.The traceability system will become a basic minimum requirement for any kind of production system – food or non-food in future. Creating an awareness and providing enabling environment for implementation of Traceability system is an essential part of planning and execution of developmental activities aimed at building competitive advantage among our farmers and traders.

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Converting Horticultural Waste to Wealth for Increasing Farmers' Income and Employment Generation

NEELIMA GARG*

Agriculture is one of the main drivers of country's economic growth with social justice. Our agriculture did extremely well and it was on the ascendancy till the mid nineties but after that the growth slowed down. Since 1996-97 the growth rate of agricultural GDP has been, on an average, 1.75 % per year in contrast with the rate of 4% that is required. On the other hand the farmer has been facing rising input costs, declining returns from the inputs, uncertain market, increasing role of market in agriculture and blurring of distinction between the domestic market and the international market. To assist the farmer in these changing contexts new strategies and innovative solutions are urgently required which in turn will require technological support. Hence, the agricultural research system which generates technologies, has to conduct the business of agricultural research in an innovative way.

In India, more than 350 million people are malnourished. According to FAO prediction agricultural productivity in the world will sustain the growing population in 2030, but millions of people in developing country will starve. By 2025, 83% global Population of 8.5 billion will exist in developing world. The question arises 'can we provide food, nutrition, health care, fuel and fibre to growing population'? Optimistically, through the science led development, challenges of future can be addressed. India is going through economic and social transformation from agriculture-based economy to products-and-services-based economy which finally aims at knowledge-based economy. Transformation is important to enable economies to progress. One of the best ways to achieve this is to promote entrepreneurship in the agricultural sector. Entrepreneurs act as major building blocks of the economy anywhere in the world today. Agribusiness incubation is the only way to solve the many and diverse challenges faced by entrepreneurs. Parameters of success are farmers and their growth. Agricultural transformation is about giving, enabling and empowering our fellow farmers.

Fortunately, India is self sufficient in primary agriculture (grains, sugarcane, fruits, vegetable and milk, etc.) with improved production of various commodities viz. cereals (4 times), milk (4 times), horticulture (8 times) and Fish (9 times). But declining factor productivity is driving farmers away from farm. There is a declining share of agriculture in the national GDP (from 31% to 18.34% at present) while the number of people depending on it remains the same. Secondary agriculture can reverse this trend and add two to three-fold value to primary agriculture. Horticulture provides best options for improving farmers' lively hood. India ushered into an era of Golden Revolution during 11th Five Year Plan with unprecedented increase in area expansion, productivity and production. India harvested 223.089 million tonnes of horticultural produce from 20.876 million hectares of land. The major crops contributing to it are fruits and vegetables (approx 204 million tonnes from 14.314 million hectares area). Horticulture accounts for 30 per cent of India's agricultural GDP from 8.5 per cent of cropped area. The constant research efforts by the scientists and the adoption by farmers have resulted in manifold

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increase in the productivity of several horticultural crops. Parallel with increase in area and productivity, the crop residue and post harvest waste also has grown proportionately.

Unfortunately, India, the world's second largest producer of fruits and vegetables, is throwing away fresh produce worth INR 133 billion every year because of the country's lack of adequate cold storage facilities and refrigerated transport. Fruit and vegetable wastes are generated in huge quantities in fruit and vegetable mandies (whole sale market) and constitute a source of nuisance in the area. According to Indian agricultural research data book, the losses in fruits and vegetables are to the tune of 30%. India wastes about Rs. 13,300 crore worth fruits and vegetables per year due to lack of adequate cold storage facilities, according to a report from Central Institute of Post-Harvest Engineering and Technology (CIPHET). Mandi waste (fruit and vegetable waste) is not utilized for any specific purpose. These also create problems in municipal landfills due to their high biodegradability and only fed by stray cattle. Though there is technology for making biogas but currently it is not being actually used at most of the places because of technical problems in maintenance of units. Due to lack of defined use of these waste the problem of environmental pollution is increasing.

Horticultural based farming systems and processing industries generate huge amounts of crop residues and processing wastes. Though the data on all the horticultural crop residues and wastes are not available, it is estimated that during mango processing approximately 32-45% of the weight of mangoes used goes as various forms of waste like peels, pulper waste and stones. Similarly in banana cultivation approximately 65% of biomass goes as field waste. Ripe banana peel waste constitutes to about 20% while 35-40% of peel waste is generated in banana (plantains) chips industry.

In general processing of fruits and vegetables produces two types of waste –

- Solid waste of peel/skin, seeds, stones etc
- Liquid waste of juice and wash waters.

In some fruits the discarded portion can be very high (e.g. mango 30-50%, banana 20%, pineapple 40-50% and orange 30-50%). These wastes are rich in organic constituents like, cellulose, starch pectin vitamins, minerals etc and posed serious health hazard problems due to high biological oxygen demand (BOD).

One way of managing the situation is to reduce the losses and the other is to utilize the available material for the production of value added products. The utilization of waste will not only economizes the cost of finished products but also reduce the pollution level. The waste could be used for the production of fertilizers, fuel and value added products through processing, extraction, hydrolysis or fermentation and as animal feed.

Fermented edible products

A number of beverages such as cider, beer, wine and brandy, and vinegar can be obtained from the fermentation of fruit wastes. Apple pomace has been utilized for the production of cider. Best quality of cider can be made by carbonating it. Good quality apple cider and brandy can also be produced by fermenting milled apple pulp. The possibility of making brandy from dried culled and surplus apples, grapes, oranges and other fruits have also been explored. Vinegar production by fermenting waste from pineapple and orange peel juice has been attempted successfully.

Candied peel

Peel from citrus fruits (orange, lemon, grapefruit) can be candied for use either in baked goods or as a snack food. In addition, shreds of peel are used in marmalades and the process to make these is similar to candying.

Single Cell Proteins

Single cell proteins can be produced from fruit waste such as grape and pine apple waste, potato peel, dried and pectin extracted apple pomace etc. by using *Trichoderma viride* and *Aspergillus niger*.

Animal Feed

The waste obtained from processing of fruits and vegetables is rich in fibre, which includes cellulose, hemi-cellulose, lignin and silica with poor quality of protein. Fermented potato waste, apple pomace and grape pomace have been successfully tried as animal feed. Waste from wineries, breweries and distilleries can be used for feeding livestock.

Alchohol

The waste from fruits and vegetable processing industries being polysaccharides (cellulose, hemi-cellulose and lignin) can be subjected to solid state fermentation for the production of ethanol, which has several uses. It can be used as a liquid fuel supplement and as a solvent in many industries. Process for production of ethanol from apple pomace, pear, cherry and orange waste has been developed.

Biogas Production

Bio-mass consisting of agricultural, forest, crop residues, solid and liquid wastes from industries, sewage and sludge can be utilized for production of biogas through microbial technology. Similarly, the waste from fruit and vegetable processing industries has been used for production of biogas. Biogas is produced by anaerobic digestion of fruit and vegetable wastes. Methanotropic bacteria like *Methanobacterium* and *Methanococus sp*. can utilize CO_2 from waste materials to produce methane. During this process, the complex polymers are first hydrolyzed into simple substances by acid forming bacteria and finally these are digested anaerobically by methanotropic bacteria and methane gas is liberated.

Organic Acids

These acids are produced through aerobic fermentation of sugars. Since they are produced in large amounts they could easily be extracted and purified from the fermented medium. Grape pomace when used as a source of fermentation, approximately 10% of citric acid could be produced. Important organic acids produced by fermentation are citric, acetic and lactic acids which could be used in many processing factories like confectionary, synthetic beverages, alcoholic beverages.

Enzymes

World trade in enzyme production is about 500 million US Dollars of which about 160 million US Dollars worth are consumed by food and detergent industry. Pectinases are widely used for beverage and juice clarification. The total market for enzymes in India is about 20 crores with a predicted growth rate of 20-30% annually. Except papain, which is produced in plenty, for majority of enzymes used by food processing industry, India is dependent on imports. Enzymes from microbial sources are preferred compared to plant or animal sources because enzyme production from former is relatively cheap and controllable. The enzyme production cost can further be reduced if negative value or cheap value substrates such as fruit processing industry waste are used. This will also help in solving fruit industry waste problem to some extent and will reduce the pollution problem. A wide variety of fruit processing wastes such as apple or grape pomace, banana skin, orange peel etc. have been used for production of various enzymes such as cellulases, amylases, and pectinases. Lot of research work has been conducted on pectinase production from apple pomace, lemon peel, orange finisher pulp. Recently, it has studied the potential of using apple pomace, cranberry pomace and strawberry pomace for pectinase production. Polygalacturonase yield after 40 days of fermentation were 29.4, 20.1 and 4.0 enzyme unit/g of strawberry, apple and grape pomace, respectively. A lipase with a unique specificity for unsaturated fatty acids was produced by *Geotrichum candidum* grown on sauerkraut brine. This enzyme is of industrial interest for the production of specialty chemicals from fats and oils. â-glucosidase was produced by *Aspergillus niger* grown on apple pomace.

Waste Utilization by Chemical Extraction

Some of the value added products like fibre, starch, pectin, oil, flavour and wax may be extracted from solid fruit wastes like peel, pomace etc. . These materials have many uses in cosmetic, food and pharmaceutical industries.

Fibre

It has been reported that processing waste such as peel, pomace etc generally contain up to 30% of fibre. It may be obtained by treating the waste with alkali followed by boiling with hydrogen peroxide in alcohol. The fibre is increased the nutritional value of confectionary products.

Starch

The starch content in the peel and pulp of most of the fruits and vegetables is very less (2-5% on dry wt. Basis). However, mango kernel contains up to 58% starch. The starch may be extracted from the powdered seeds or kernel by washing repeatedly with sulphur waster so that all the soluble materials may be washed away. The starch is then separated from the settled residue. It is used as the flour and also in the pharmaceutical industries for making many formulations.

Pectin

This is a gelling agent used in jams and some sweets found to a greater or lesser extent in most fruits. Commercially, pectin is extracted from citrus peel and apple pomace (the residue left after apple juice has been removed). Some other tropical fruits contain high levels of pectin, passion fruit being a notable example. The utilization of the 'shells' remaining after pulp removal offers possibilities for pectin extraction. Two different options for the combined recovery of pectin and phenolic compounds from mango peels, a by-product of industrial mango processing, were developed. After extraction of dried mango peels with diluted sulphuric acid, the phenolic compounds were adsorbed using a styrene–divinylbenzene copolymerisate resin, and pectin was obtained from the effluent by precipitation with ethanol. Phenolic compounds were recovered from the resin with methanol and the eluate was lyophilized.

Oils

The stones of some fruits (e.g. mango, apricot, peach) contain appreciable quantities of oil or fat, some of which have specialized markets for culinary or perfumery/toiletry applications. Palm kernel oil is well established as both cooking and industrial oil. In addition some seeds (e.g. grape, papaya and passion fruit) contain oil which has a much specialized market. The main problems are to identify the import/export agents, who would buy such products, producing the oil in sufficient quantities for them, meeting their very stringent quality standards and finally, obtaining the equipment needed to produce the oils at low cost.

Waste Water Utilization

The organic waste waters are treated in lagoons or stabilization ponds. Anaerobic ponds are primarily used to treat strong organic waste waters and are devoid of oxygen as a result of the high organic loading applied. Facultative ponds operate at lower organic loading and dissolved oxygen persists in the water column owing to the presence of algae. Maturation ponds are aerobic lagoons used as a polishing stage after facultative ponds in the treatment of waste waters containing faecal material and their principal function is pathogen removal. Aerated lagoons are basically activated sludge units without sludge recycle and operate at low mixed liquor suspended solids levels and relatively long retention times. Aerated ponds are varying shallow lagoons. Usually incorporating mechanical aeration and are designed to optimise the growth of algae.

Aerated Lagoons

The designs of aerated lagoons can be based on completely mixed reactor theory for BOD removal. Aerators in a completely mixed aerated lagoon provide enough energy to maintain the solids in suspension. The aerobic treatment of the waste includes activated sludge process but it has many limitations. These types of lagoons, due to high inputs, have specific use.

Anaerobic Ponds

The anaerobic treatment of the waste has proved to be ideally suited for treating food processing waste. Anaerobic ponds are varying cost effective for the removal of BOD when it is present in high concentration. Ambient temperature in hot climate conditions is conductive to the biochemical reactions which take place in the anaerobic ponds. Anaerobic digestion is brought about into two steps by two distinctive types of microorganisms in the same reactor. In the first stage, complex organic compounds are degraded, hydrolysed and converted into organic acids by acid forming bacteria. Methanogenic bacteria then convert it into methane and CO_2. The resulting sludge is well stabilized and could be disposed off as fertilizer. The anaerobic fermentation has many advantages like requirement of low energy, high loading, uniform quality and generation of biogas.

Relevance of Value Addition

Horticultural waste provides ample opportunities for value addition besides providing wealth from waste. Its effective utilization helps in reducing the cost of production of crops besides optimum utilization of biomass. The additional returns that it brings augment the income from farming activity besides providing opportunities for employment and capital formation. In the present context of increasing cost of inputs the farming activity becomes more viable only when the total biomass is effectively utilized per unit input. In the context of climate change and global warming, environment protection is a major concern. Utilization of horticultural residues and processing waste for in the development of high value products in the form of fuel, fibre, food and feed holds promise.

Future Strategies

According to Mr Peter Kenmore, Food and Agriculture Organization (FAO) representative in India, "The country is on the march towards attaining food security through innumerable innovations and interventions. Development in the agriculture sector should also emphasize off-farm job creation in the rural areas through more innovations'. The future strategies should be:

1. To give the agricultural research and technology development system an explicit development and business perspective through innovative models. In other words, the agricultural research system should be able to support agriculture as a business venture and also as a means of security of livelihood of the rural Indian while maintaining excellence in science.
2. To make the National Agricultural Research System a 'pluralistic' system where every Organisation having stake in agricultural research: public, private or civil society, has to play a role.
3. Working in well defined partnership groups with clear common goals and understanding on sharing responsibilities and benefits.
4. Funding through competition so that a wide choice of excellent innovative ideas come in from the stakeholders themselves.
5. Work with focus, plan and time frames.

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Diffusion of Horticultural Technologies and Knowledge for Doubling Income of Farmers

V.V. SADAMATE*

GDP Contribution of Agriculture is sliding down; however, still > 60% population depends on agriculture & allied sectors. There are over 135 million farm families, average size of farm holdings being 1.33 ha. Around 60% cropped area would continue to be rain fed, which demands innovative development strategies. Agricultural Extension is one of the crucial inputs to address these issues with focus on improving performance of existing extension models in operation. Good or bad, there exists an agricultural extension system for crops sector.However, in allied areas like horticulture, animal husbandry, dairy, poultry, fisheries, etc., it is either weak or missing.Enhanced research backstopping for extension and feedback based extension strategies is essential. Horticultural technology options for Agro-Climatic Zones, Sub-Zones & micro situations need to be systematically worked out & integrated into programme delivery mechanism.Future horticultural extension strategies should focus on technology mapping, R&D linkages & activating existing linkage forums. Follow-up by the field formations by themselves may not able to penetrate down the line, especially to the small and the marginal farmers, across the sectors, due mainly to inadequate numbers, their quality and limited outreach. Therefore, it would be better if the chains of extension agents, formal/informalare systematically promoted and used in horticultural extension. Operational flexibilities to the field formations are required enabling them to respond to the emerging local extension challenges, thus making extension operations accountable to the local horticultural situations. Extension Strategies must focus on producer aggregates at various levels & provide strong forward linkages.Farmer to Farmer Extension has been one of the most effective mechanisms, the question is how to promote, encourage & fund it.Farm women's presence is seen increasing in all the farm/ horticultural operations because of male migration to towns and cities, hence extension services need to be re-oriented to their horticultural technology dissemination needs. ICT has lots of scope for future extension strategies, however, content development and delivery for print and electronic media is equally crucial. Internet access needs to be improved by organizing Farmer Knowledge Groups (FNGs) in the villages facilitating improved arrangements for knowledge interpretation and sharing. Training co-ordination (segregated responsibility to the agency having comparative advantages), convergence and programme delivery, horti extension priority setting, horti extension for farmer in distress areas & PPPs in horti extension management, need to be streamlined. Future dissemination strategies must address yield potentials/ gaps and organize large number of FFSs / FOs & FPCs in potential areas. Identification of potential areas for export opportunities (for entrepreneur farmers), involving processing and export industries in such assessments, drawing strengths from international extension experiences & setting quality standards for extension services may form essential parameters of horti extension performance. Also, there is an urgent need for intensive research in extension approaches to look into their efficacy for horticultural extension needs. It is also pertinent to address the emerging climate change challenges in various micro level horti-eco situations. It may need special measures to orient field functionaries,

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farmers, farm women / farm youth for climate change adaptation with reference to horticultural crops / sector. Promotion of intensive extension work through various methods, linking farmers to the markets, promoting growers associations, focussed processing and value addition, encouraging cluster based approach, promoting low volume high value crops, etc. would enable farmers in doubling their farm incomes.

Agricultural and Horticultural Sectors Growth Scenario

Agricultural Growth: India with 1.25 billion people can boast of a robust Agriculture sector that accounts for 14% of GDP and having a share of about 11% in total exports. Agriculture is the principal source of livelihood for more than 58% of the population providing employment to 57.4% of work force in rural areas. It remains the main source of raw materials for a large number of industries and thus fundamental to the economy. Agricultural growth in the XIth plan has accelerated by 3.3% compared to 2.4% in the Xth Plan. However, its share in overall GDP has declined from 23.4% in IXth Plan to 19% in the Xth and to 14.2% at the end of XIth Plan without commensurate decreaseof number of people dependent on agriculture. The Crop sector has recorded an average growth of about 1.8 to 2%, recording increase in farm diversification from cereals. However, allied sectors such as Horticulture, Animal Husbandry and Fisheries have registered output growth of 4.5 to 6%.State wise growth trends (CSO) showed that despite usual explanations for low growth like changing climate, soil degradation, stress on water resources, technology slowdown and policy constraints, a few States seemed to have done exceedingly well, recording average annual growth of above 4% during the XIth Plan, though there are medium and slow performers too. Rapid growth of agriculture is critical to reduction of poverty and hunger and inclusiveness. Therefore, enhancing productivity, resource use efficiency, technology & innovations, sustainability & total factor productivity require serious attention. Other important issues like investments, market infrastructure, price incentives, convergence and programme delivery, agricultural diversification from cereals towards high value agricultural commodities requite adequate focus to achieve targeted agricultural growth of 4% for the XII th Plan period.

Crops/Horticulture::The current food grain production of over 271.98 MillionTs goes well with projected demands of same level by the end of XIIth Plan. However, major trend emerged during XIIth Plan was that the rice and wheat led to the rising of stocks and the shortfall in pulses and oilseeds led to imports. The projected demand for oilseeds by the end of XIIth plan is 59MTs as against the current production of 33.5 MTs; signifying that even in the best production scenario India remains deficit in oilseeds. The deficiency in terms of oilseeds is expected to rise to 20 to 24 MT of oilseeds. The figures for pulses for the same period are 27MTs as against the present production level of 22MTs. The projected demand figures for fruits, vegetables, milk and meat are 97, 161, 141 and 7 MTs as against the present production levels of 91.44, 166, 150 and 7 MTs respectively. The fish production is at 10.16 MTs at the current level (6.66 inland & 3.5 marine) with a projected demand in the range of 11 MTs by the end of XII th Plan. The shortfall in oilseed and pulses would need more diversification in agricultural production. In particular, the procurement policy needs to be revamped to include these crops as part of the PDS mechanism. Food stocking and distribution is a serious concern especially in the disadvantaged areas/groups. Further, India has very high levels of malnutrition due to several reasons, including poor calorie intake. The increased production of fruits, vegetables, milk, and fish and nutri-cereals offer enhanced scope for improved nutritional off take (Report of Ministry of Agriculture, 2016). Horticultureaccounts for about 30% of India's agricultural GDP from 13.08% of cropped area. It also provides about 37% of the total exports of agricultural commodities. India produces nearly 11% of the vegetables and 15% of the fruits of global output, yet its share in global exports of vegetables is only 1.7% and the fruits of meagre 0.5%.Thus, there is a vast scope for Indian Horticulture sector in export regime (Report of Planning Commission, 2011).

Agriculture and allied sectors- current concerns: Agriculture sector faces formidable challenges of shrinking land and water, adverse impact of climate change, skewed development, crisis in farm labour, stagnant productivity, increasing production costs, dwindling natural resources, market uncertainties and weak technology delivery systems across states and sectors. The major concerns revolve around are:

GDP Contribution of agriculture sector sliding down, still 60% population depends on agriculture.*Allied Sectors*are contributing significantly, and need adequate focus in terms of investments, development strategies and programme delivery.*Shrinking Land Holdings and Natural Resource Base*Predominance of small holders in Indian agriculture continues to rise. Average size of land in India has reduced to 1.30 hectareper farm holding. Small and marginal farmers now comprise of 83% of total land holdings and they occupy about 41% of area under all operational holdings (Report of DAC, 2011).

Deterioration of Natural Resource Base: Natural Resource base that sustains farming is under increasingly serious strain. Land, water, soil health and biodiversity resources are shrinking and deteriorating. Due to overexploitation, ground water levels are going down even in irrigated areas in several parts of the country. Continuing imbalance in use of fertilizer has adversely affected soil health. Thus, long term sustainability requires that land and water are used judiciously and efficiently.

Regional Imbalance: Present level of productivity of most of the crops and other sectors is significantly low as compared to what is attainable and also are being attained by some other countries. This production potential is believed to be very large, for example, in the eastern and central regions. Regional imbalances in growth and productivity are surprisingly high in rainfed conditions. Dryland areas that are home to a large section of marginalized areas and communities continue to be in disadvantageous position in terms of desired development interventions. Recent focuses on agricultural investment and infrastructure in some of the backward states and regions have shown significant promise in improving growth performance (Ramesh Chand,*et al*., 2012)

Input Use Efficiency & Water Use Efficiency: Present extension strategies are inadequately addressing these issues. Accordingly, the training and capacity building arrangements for the field .*Sustaining Food and Nutritional Security*India ranks at 67th as per Global Hunger Index (IFPRI) amongst 171 nations. Half of the Children (51%) are malnourished, over 55% married women suffer from anaemia and 30% adults suffer from protein –energy malnutrition. Food availability to BPL families and supply and distribution apparatus in disadvantaged areas along with food quality standards are basic concerns. Access to food and affordability of the impoverished families to harness the social entitlement are also issues that need greater attention to expand the income and livelihood options for such category of people. Horticulture, milk, poultry and nutri-cereals may provide an excellent opportunity on nutritional improvement; however, the awareness and reach are still limited. Malnutrition particularly with reference to essential minerals is a major problem, which can be addressed by inclusion of coarse cereals and millets in the NFSM and PDS, food fortification and propagation of nutrient-dense food. Farm women could play an important role in managing and sustaining house hold food security and extension services need that kind of orientation. xtension functionaries and farmers would need to be strengthened.

Rainfed Ffarming and its Sustainability: Nearly 60% cultivable area would continue to be rain fed - typically characterized by vulnerable natural resource base, inhabiting 40% population, giving 40% food grain output and sustaining about 60% of livestock. Watershed has been taken up as a key intervention for development of such areas. As against the target of 36.6 million ha the area covered under watershed is about 20 million ha so far, that indicates greater scope for resource conservation through WSD and thereby improving the productivity of dryland agriculture. Climate change and adaptation are dominant issues in farm sustainability. Better convergence and programme delivery below of the sub-district levels are urgently called for. Recent innovative programmes like NICRA & NMSA have demonstrated good potential that need to be mainstreamed into the future strategies. Technology transfer models adopted so far are yet to make any perceptible dent in rain fed areas. It calls for alternative thinking in policy framework and delivery mechanism involving farm women (Report of DAC, 2012).

The Agricultural Distress: It is reflected in some parts of the country needs to be addressed by alternate strategies as the normal programmatic formulations are yet to impact there. The focus would need to be on the conservation technologies, alternate crops and cropping patterns, crop diversification and alternate livelihood options and training of farm women in alternate livelihoods. *Farmer Empowerment & Market linkages*Market access, especially to the small and marginal producers has been a serious concern throughout and across various sectors.

Convergence with other GOI Programmes: Agriculture development programmes and related programmes of other departments like Rural Development, Panchayati Raj, Social Development etc generally operate in vertical silos, with very little or no horizontal convergence, especially at the block level and below. Hence, field level convergence is one of the major challenges existing today across the departments. The major task therefore would be to reorient the district and the block functionaries for the task and provide them opportunities for experience sharing across the departmental boundaries so as to obtain required coherence. The farmers and the farm women need required support for implementing programmes on convergence mode, especially below of the blocks and at the cluster level.

Re-orientating Farm Extension Services for Women in Agriculture : Foregoing text has adequately focused on Growth and development of Agriculture and allied sectors wherein farm women have been playing important role practically in all the field operations. Serious attention is needed to improve the access of farm women to the extension services, both public and private.Women's participation in agriculture has been going up due to a variety of socio-economic factors. Therefore, there is need for intensive capacity building and empowerment efforts for women and women groups at every level that includes re-orienting farm services to improve their access to credit, technology, inputs, markets and gender friendly mechanization. It may call for feminization of farm extension services enabling effective women extension workers for better participation and extension delivery. Farm women including women from weaker sections need to be given adequate representation in various programme management fora at all the levels. The ongoing programmes and schemes should ensure greater gender coverage through improved strategies, financial allocation and well defined extension strategies.

Efficacy of Programme Delivery & Extension Systems in disadvantaged areas: Programme delivery in hill and mountainous areas, far flung areas, tribal areas, naxal affected areas etc. is a real challenge. Perhaps it needs regionally differentiated extension strategies, with location specific approach.

Strategic Solutions for Agriculture and Horticulture Extension

Present Extension Models & Performance & Issues across the Sectors

Improving Roles &Performance of Extension Models in Operation: Several Extension models are in operation for dissemination of information such as ATMA Model, KVK model, PPP model, NGO model, Extension services provided by input support services providers, Extension services extended by co-operatives and Farmer Organizations, ICT Extension Modes, etc. There is need to improve performance of extension models in operation to their optimum levels with focus on R& D linkages, especially research backstopping, widening the sectoral and area coverage. Resource sharing, training coordination, convergence & programme delivery, improving penetration to the small & marginal producers would also need to be addressed by the respective models in their area of jurisdiction on supplementary and complementary mode.

Extension in Allied Areas : Good or bad there is Agricultural Extension System exists for Crops sector. However, in allied areas like horticulture, animal husbandry, dairy, poultry, fisheries etc, its either weak or missing , though the allied sectors are contributing significantly in agricultural growth .Hence, Extension needs to be re-oriented thoroughly (additional support from KVKs/ ATMAs), promoting Grower's Associations(in horticultural sector), use of milk cooperatives, fisher co-operatives, use of entrepreneurs, progressive farmers, etc could play an important role to cater to the extension needs of allied sectors.Empowerment of FarmersFarmers could be empowered by various methods like organizing them into SHGs, FOs, FPCs, Coops, Growers Groups etc, by providing training & capacity building and by making them partners in decision making and by providing role space in extension operations. There is need for re-orienting extension services to address extension needs of farm women and farm youths. It has been observed that the Farm Youths are taking interest in secondary agriculture (processing, value addition, etc.) and the extension may need to address this dimension too.

Promote Producer Aggregates (PPAs): Future Extension Strategies must focus on organizing producer aggregates at various levels. This would provide strong backward and forward linkages including market led extension strategies for enhanced income opportunities for the farmers. Such Farmer Aggregates would also provide adequate pressure on the R&D agencies making extension operations demand driven and participatory.

Farmer to Farmer Technology Dissemination

Farmer to Farmer Extension:This is one of the most effective methods of technology dissemination wherein the innovators and progressive farmers share the technological information with the fellow farmers; however, they need to be oriented on their roles and responsibilities. The Farmers Field Schools are being organized on the fields of such farmers where they become the host and the teacher for the technology in which they have already excelled or have had an unique experience and achievements. Now, the issue is how to promote, encourage & fund it under various programmes? One of the methods tried by the ATMAs and KVKs was to involve such farmer's innovations for validation by the research system and using these innovators as training resources & disseminators. FOs, FFSs are few such successful experiments wherein innovative farmers have been used to promote farmer to farmer extension.

Promoting Farmer Facilitators:There is a strong need for promoting informal sources of technology delivery like farmer friends, model farmers, contact farmers, Kisan Sahayyaks (farmer facilitators), etc. across the states/sectors, to enable faster technology transfer at the cutting edge levels. There are different models promoting farmer facilitators at the community levels. NGOs like Ramakrishna Mission have trained young boys and girls from the rural areas, built their capacities and used them as local farm volunteers. Every three months these young volunteers are brought back to the local KVKs for training and retraining. The Department of Agriculture, Andhra Pradesh have selected local practicing farmers as Model farmers (Adarsh Raytu) for technology transfer. Kisan Sahayyaks (Farmer facilitators) are used in the States of Uttar Pradesh, Bihar etc. In fisheries and in the animal husbandry sectors the states like West Bengal are promoting Matsya Mitras(Fish friends) and Prani Bandhus(Animal brothers). Uddayan Mitras are also being promoted in a few States. These facilitators would need to be properly selected and trained for the specific tasks in horticulture sector. They should be innovative, practicing farmers and should have acceptability of the community. So the selection process would need to be far fairer in selecting the farm facilitators. He /She needs to be oriented to handle community level extension advisories and therefore need periodic updating of their knowledge and skills. The field extension agencies like ATMAs, KVKs, NGOs, farmer organizations would need to promote the Farm Facilitators and use them at community levels. This sort of intervention is necessary especially if extension has to be location specific at the field, cluster and below of the block.The States could take a few pilots in selected blocks and promote farmer facilitators (FFs) and demonstrate how effectively they could take on extension and technology transfer functions at the community level. This would largely fill up the extension gaps at the community level especially in the remote areas, hill and mountain eco-systems and tribal areas where the public extension services are practically non- existing or remained very weak.

Intensification for Horti Farmers Field Schools (HFFSs): FFS is an effective extension tool, practiced widely, needs to be up-scaled as it provides an opportunity for farmer to farmer extension which has been found to be quite effective. The host farmer needs to be properly oriented about his roles and responsibilities and the technology that is being demonstrated on his field. The fellow farmers would have to have a faith and access to the host farmer, his competence and results that are being obtained on the farmers field schools.HFFS differs from demonstration since it has more emphasis on experimentation, science based learning, sharing of knowledge and skills in adoption of technologies. Up-scaling of HFFSs is a challenging task.

Management of Field Extension Activities: *a) Promote Chains of Extension Agents- Formal / Inform*: Field formations, by themselves are not able to penetrate down the line, especially to the small and the marginal farmers, and across the sectors and areas. This has resulted due mainly to inadequate numbers, their quality and limited outreach. Therefore, it would be better if extension services promote chains of extension agents, formal/informal for enhanced and appropriate coverage. Change Agents in Extension chains may include Progressive farmers, Entrepreneurs, the FOs, FPCs, Cooperatives, Local Self Government Agents, etc.

b) Field Formations May Supplement & Complement for Enhanced Coverage: Field formations of various extension streams would need to supplement and complement in selecting programme sites, identification of beneficiaries, joint diagnosis, problem solving, information support, training and capacity building of FFs, BTMs, ABTMs. Sharing of training resources, providing mentoring support to the block level formations (eg, RSKs of Karnataka & Krishi Bhavan's of Kerala) in the specialized areas, jointly promoting farmer to farmer extension etc may also be thought of. As above is far more applicable in case of KVK and ATMA in operations.

*c) Providing Operational Flexibilities (Top Down vs Bottom Up)*Flexibilities are required to be promoted to the field formations to respond to the emerging local extension challenges. Thus, making extension operations accountable to the local situations and farming communities and making extension to address allied sector extension needs effectively. Operational flexibilities may facilitate entering local MOU based PPPs which are essential to make the extension interventions effective at the local level.

d) Convergence and Programme Delivery: Programmatic Convergence down the line is essential for wider coverage to benefit from each other's strengths. Policies & instructions are necessary to drive it. Convergence appears to be most effective at the Block/Cluster level. Matrix mode / MOU approach is recommended to make it happen at the field level. Likewise, the programme delivery is crucial in disadvantaged areas, far flung areas, tribal areas, hill and mountainous areas, desert areas, etc. Hence, Extension Strategies need to be re-oriented and strengthened accordingly for convergence and programme delivery.

Priority Setting – Instruments

There are series of district level planning instruments available as follows:

- Comprehensive District Agricultural Plans (C-DAPs) under RKVY
- Strategic Research and Extension Plans(SREPs) under ATMA
- District Profiles (DPs) prepared under KVK Programme
- Detailed Project Reports (DPRs) developed under Watershed Projects
- Potential Liked Credit Plans (PLPs) developed by NABARD for the districts
- District Irrigation Plans (DIPs)) developed under PMKSY

The District/Block extension functionaries may scan these instruments for capturing the horticultural extension priorities & integrating in the convergence & programme delivery strategies.

Extension for Farmer Distress / Challenged Areas: Farmer distress and challenged areas need clear extension strategies/advisories for climate adaptation strategies. It would need clear technology options along with credit - market linkages. Appropriate enterprise combinations would need to be worked out for the blocks, clusters and the micro level agro situations for such areas to be promoted by the extension operations. This would need re-orientation of the extension machinery and improved programme delivery. Similarly, the tribal areas, the hill and mountain areas, the rainfed areas, the desert areas and the border areas would perhaps need regionally differentiated extension strategies.

Benchmarks for Extension Performance: Performance standards need to be set for Extension Performance, in a given cluster, block & district. It would make the extension services accountable to the local area and farming communities, enabling extension services to respond to the emerging extension needs. Such performance benchmarks would need to be set for agriculture and allied areas too.

Technology backstopping and R&D Linkages

Enhanced Research Backstopping to Horticultural Extension: Enhanced research backstopping to the field formations is required so as to facilitate strong technological input in the extension processes. The scientists interface with Field Functionaries and with the farmers would need to be augmented. Technology options would need to be generated for the micro level farm situations. Also, validation of farmers own innovations need to be prioritized and mainstreamed. Farmer

Entrepreneurs/ innovators need to be promoted in extending extension services by using them in training and CB activities.

Feedback Collation and Analysis : Feedback collation from the farmers, field functionaries is generally weak in the extension system. Similar is the case of its systematic documentation and analysis. Systematic documentation and analysis would not only improve the relevance of the research, but also, it would make the extension operations flexible and far more relevant / productive suiting to the various categories of farmers.

Technology Mapping and Socio-Economic Dimensions: Technology options for Agro-Climatic Zones and Sub-Zones needs to be systematically worked out and integrated into programme delivery mechanism, as per specificity of each micro agro-eco situation. Socio-economic dimensions and technology options would need to be matched and addressed in extension operations accordingly, would bring in enhanced focus in extension processes as opposed to mere TOT approach.

Future Extension Strategies and Crucial Technologies: Field extension functionaries from agriculture and line departments would need to be adequately oriented in promotion of crucial technologies like Soil health management, IPM, INM, Microbial applications, Climate Change, especially adaptation strategies, farm mechanization, secondary agriculture, IUE & WUE, project based extension at various levels, etc. The approach would benefit the farmers in judicious input use enhancing farm incomes. *R&D Linkages*: *Activating Existing Forums & Follow-up*There are various R& D linkage mechanisms available at various levels as followsNational: Pre-*Kharif*& Pre- *Rabi* Interfaces between DAC&FW and ICAR, Regional: ICAR Regional Committee Meeting, State level : Pre-Seasonal Meetings, Agro-Climate Zone Wise, District Level: SAC of KVKs, GB of ATMA & District level ATMA FAC, Block level : Block Level FACs of ATMAs

Experiences in various States indicate that the performance of these forums need lots of improvement so that they function efficiently. It is also necessary that both research and development sides participate pro-actively in improving R& D agenda, making these forums dynamic & responding to the needs of horticultural farmers as well. ATMA was proposed to be a platform for broad based & intergraded extension operations, the States and the districts would need to think on this proposition seriously.

Training and Capacity Building

Training Co-ordination - Segregated Responsibility: Farmerstraining responsibility down the line in agricultural and allied sectors is shared by the large number of agencies and organizations. For example at the district level the farmers are trained by the agencies like KVKs, ATMAs, SAU Outposts, FTCs, Input Support Agencies, NGOs, etc. Can we think of focussed and segregated training responsibility? Could Director Extension, ATARI & SAMETI take a call and address this challenge? MANAGE & Extension Division of ICAR may take a overview and guide the process. It would streamline the whole training function.

Capacity building of field functionaries (teach to catch a fish rather than feeding him/her daily): It is estimated that over 1.25 lakh field functionaries are operating for the field extension work in agriculture and allied departments in all the Sates. This would include about 7,000 block level officers, about 700 District Agri/Horticulture Officers, about 21,000 SMS (3 per block). Further, it is assumed that there would be about 3.5 lakh Farmer Friends (one for two villages) are engaged in the field extension services. The training and capacity building of such a huge manpower is a gigantic task which could be taken up by the SAUs and ICAR institutes in a systematic way. This issue needs to be focussed adequately. The scientific institutions like SAUs and ICAR Institutes have a great scope for updating technical competence of the SMSs and middle level functionaries. Modalities may have to be worked out jointly by the ATARIs & SAMETIs under the guidance of Extension Division of ICAR and MANAGE. Similarly, the KVKs and FTCs of the State Departments of Agriculture could take on the training and capacity building task of the huge number of Farmer Friends.

Gender Issues: *Gender Mainstream*: Farm women play major roles in farming and their presence is is increasing in all the farm operations (Agriculture, horticulture, animal husbandry, dairy, poultry, fisheries, sericulture, etc). Male migration to towns and cities is one of the main reasons. Further, the extension services are manned by male workers, barring a few States & the development services are not reaching the women farmers at the desired level. Hence there is need to orient these services in favour of favour of women farmers training & capacity building and customized training & capacity building modules need to be operated as per the needs of the farm women at a micro level. Farm women need to be empowered by various means like grouping them into SHGs, Farm Women Groups, Farm Women Organization, etc. Also, there is need to provide representation to the farm women on various forums.

PPPs in Horticultural Extension: *PPPs in Extension Management & Role of Entrepreneurs* PPPs are required down the line to promote participatory extension arrangements between the public and private extension service providers. It is expected that large number of MoU based PPPs must come up at various levels to make the extension services respond to the local situations. However, PPP operations need policy directions (otherwise provisions do not get implemented as it has been seen in ATMA). ATMAs can be a good platform for working out operational flexibilities & resource sharing, keeping in view large number of government, private & NGO extension players in the field. The input support agencies, the companies and corporate, the NGOSs , the Agri Clinics and Agri Business Centres (ACABCs) etc, can also play an important role in promoting and operating PPPs in Extension in Agri/Horti and allied areas.Farm Entrepreneurs could play a major role in agri/ horticultural extension. It has been observed through various studies that he being highly motivated person could take on activities like promotion of aggregated models, providing better forward linkages, driving market led extension strategies, better price realization, etc.

Promote ICTs and Farmer Knowledge Groups

*ICT Applications, promoting Farmer Knowledge Groups(FKGs)*ICT has lots of scope in future extension strategies, especially at the awareness & interest stages of adoption process. However, content development and delivery in respect of print and electronic media is crucial, Kisan Call Centre (KCC) : 1800-180-1551 are becoming very popular day by day, however, the pertinent question is how to increase its access and reach to the large number of farmers. Mobile applications in extension need to be expanded (eg. Agri Apps Bangalore). Internet access needs to be improved by organizing Farmer Knowledge Groups (FKGs) in the villages facilitating/ improving arrangements for knowledge interpretation and knowledge sharing.

Special Focus Areas in Future Extension Strategies: *Future Horti Extension Strategies Must Address*:Future extension strategies must address areas having high yield potentials but performing at lower levels. Extension strategies must follow sequential extension process equilibrium as: Technology Validation (TV), working out technology Options (TOs), Technology Dissemination, Participatory Processes & obtaining feedback for further improvement. There is need to organize large number of FFSs/ FOs & FPCs (may be one per Block) in potential areas. Extension functionaries must identify potential areas for export opportunities (for progressive farmers) and involve processing and export industries in such assessments. Promotion of forward linkages through appropriate extension interventions and enhancing outreach to small and marginal farmers would be essential. Hence, focus on social dynamics would be required in future strategies.

Future Horti Extension Strategies Must Draw Strengths From-The future extension strategies must draw strengths from international extension models and private sector experiences (learning from companies, corporate sectors, multi-nationals, Non - Government Agencies, Entrepreneurs, Farmer Professionals and Para professionals & Outreach Programmes of Research Organizations). This would enable extension contents and delivery move on improved & dynamic mode as per need of the situation.

Farm Journalism as an integral part of Agri/ Horti Extension: In broad terms, farm journalism is the science of conceptualizing, developing and operationalizing information activities through various media supportive to agricultural extension. Farm journalism is an integral part of the agricultural extension system and growth of farm journalism is directly proportional to the performance of extension processes, coverage & impact / adoption. Access to information and improved communication is a crucial requirement for sustainable agricultural development. Modern communication technologies when applied to conditions at grassroots level can help improve communication, increased participation and disseminate information and share knowledge and skills. However, it is observed that the rural population, especially farm women still have difficulty in accessing crucial information. The challenge is not only to improve the accessibility of information and communication technologies but also to make it available to the fellow women farmers.

Media Categories: Information support to Technology Dissemination in agriculture and allied sectors broadly falls in three categories namely print media, the electronic media and the other media. Each has large scope to influence women farmers by depicting success stories, entrepreneurial experiences, etc.

Media alternatives in future extension strategies. Social Media is a powerful communication tool that widens lines of communication, engages a large number of people quickly and has a potential to reach out farmers/farm women and stakeholders. Face book and Twitter are two well known social media sites whose usage in agriculture field would witness radical changes in near future. Emails have come up as fast moving communication channel across the globe. Its use in scientific communications is growing manifold. Young agri- preneurs and the farmers have started using internet information for accessing technologies and credit- market information. This medium has a great scope in high tech agriculture development. Farm portals are also available for dissemination of information, e-commerce and distance learning. Information given includes crop production & protection technologies, inputs, prices, e-commerce, etc. Portals vary widely in their contents, updates, user friendliness and use of visuals.Smart Mobile phones featured with talk, text and special features have emerged as widely available option providing multiple opportunities for communication. They can access internet and can be used for wide range of applications such as SMS transmission, voice to voice specific queries, and voice to machine for obtaining automated response, video screenings, text to pre- packaged response and text to call centres for individualized text or recorded voice response. Communication of Extension workers & of scientists with the farmers/ farm women and reverse has improved greatly by application of mobile phones. Most of the KVKs, ATMAs, SAUs and the ICAR institutes have taken up M-Extension in a big way. Kisan Call Centres (KCC) The Ministry of Agriculture, Government of India took a new initiative by launching the scheme Kisan Call Centres in January,2004, aimed at answering farmers queries on telephone calls in farmers own dialect. These call centres are now working at 14 locations covering all the States/ locations. A country wide common eleven digit Toll free number 1800-180- 1551 has been allotted for Kisan Call Centre. This number is accessible through all mobile and land line telephone networks including private service providers. Replies to the farmers' queries are given in 22 local languages and the calls are attended from 6AM-10 PM on all the seven days of the week at each KCC location. Farm Tele Advisers (FTAs who are post graduates in agriculture and allied areas) called as Level-1 respond to the farmers' queries instantly. The queries which are not answered by the level-1 are transferred to higher level experts Level-II (SMSs of the State Department of Agriculture or scientists of State Agriculture or ICAR institutes) in call conferencing mode, there are 4-7 identified experts in every state for answering KCC Calls. If the calls are not answered even at level-II, then the calls are escalated to level-III, i.e. identified nodal institutions those look after the working of KCC in the concerned State. Access of women farmers to KCC needs to be improved.

Research in Agriculture / Horticulture Extension

Research in Extension is a crucial area but not attended to adequately to look into the efficacy of different Extension approaches being followed in various states. Strong extension research input is required to strengthen the basic knowledge in extension discipline. MANAGE, SAMETIs, ATARIs and Directorates of Extension of the SAUs would need to have a strong extension research window. They may deliberate & define broader Extension research areas annually. The specificities should be left with the local institutions. Synthesis of selected MSc & Ph.D dissertations be considered for academic and application purpose, and the Directorates of Extension of SAUs & ATARIs may initiate this process. Also, there is need to have systemic follow up on the internalization and up scaling of the relevant findings.

Doubling Farm Income - Focused Diffusion of Horticultural Strategies:

Improved backward linkages especially technology interventions:Strong technological interventions would be required in terms of seeds and planting material to get quality production enabling producers to bring down the cost of inputs. The production scenario should be open to both public and private sources. It must also cover technologies and innovations from international institutions.

Market led horticultural extension strategies: There is need for continuous assessment of Market demands and horticultural production, both in short and long term, enabling farmers to obtain better prices for their produce. Access to E-NAM could offer better price scenario in various markets across the country. *Crop Diversification, low volume & high value crops*:Crop diversification especially in horticultural crops, could lead to a better economic proposition to the farmers. For example, producers going for floriculture, intensive vegetable production would get a better price per unit area, if the technologies and the market negotiations are handled properly. Therefore, the horti extension functionaries would need to be oriented on this aspect too.*Horti Farmer Producer Aggregates*:Aggregation of the produce at field or cluster level could give an advantage to the small producers in realizing better prices to their marketable produce. This would also reduce the transport and handling costs and make the net returns remunerative, especially for the perishables like fruits and vegetables. Aggregated sizable produce could also get a better place in operations like storage.

Promoting Involvement of Horti Entrepreneurs & PPPs: Promoting Entrepreneur farmers could enhance the investments in horticultural production operations. Besides investments, they could play an important role in technology and market linkages and in aggregating the produce. The storage and supply lines would also be streamlined by entrepreneurial interventions enabling horticultural producers' better price realizations for their produce. It has been observed that properly oriented entrepreneur would be a better technology disseminator as compared to the grass roots level field extension functionaries. *Promoting Secondary Agri-horticulture*Processing and value addition activities have a tremendous potential for better economic returns provided strategic production and linkages with the processing units are streamlined, ensuring sustained supply. Good number of horticultural crops could be used as raw material for industrial use enabling farmers better income regime for their produce.

Strengthening Horticultural advisories by reorienting both public and private extension service providers (contract buyers and input suppliers: Extension services operated both by the public and private agencies would need to strengthen horticultural advisories. The subject matter specialists of KVKs and the field functionaries of ATMAs who operate at the cutting age would need to be thoroughly oriented on latest production technologies and the market linkages. The Farmer friends would need to be transformed into horti entrepreneurs in potential areas. There is need for carrying out specific HRD programmes for extension functionaries, horti market managers, cold chain operators, nursery managers, etc. Large number of private input support providers and buyers who enter into contract production of horti crops for domestic or export markets provide extension services including technological backup in horticultural clusters and offer better price deals.

Strengthening Outreach Programmes & Training Modules: The outreach programmes of the concerned ICAR institutes and of the SAUs would need to focus on the demonstrating the best possible technological options at the clusters having potentials for a selected crops. Doubling the farm income through horticultural interventions should be carefully worked out and modules developed by the training organizations. The SAMETIs and the ATARIs could play an important role in providing better training modules incorporating better technological options (through research agencies) for different macro and micro situations.

Export opportunities for innovators and investors: Horticultural Sector provides great opportunities for export operations. Exporters and producers interface could be promoted for this purpose for better price realization to the growers. Horticultural R&D agencies could play an important role in mapping such areas.

Growers Associations & Empowered Horti Groups in the production clusters: Promoting Horticultural Growers associations for various commodities could be anther strategy for realizations of better prices for the produce. Such associations have come up in good number of States. They have better access to the technologies and market linkages resulting in better price realization.Both public and private sector extension service providers may promote commodity groups and empower them through proper training and capacity building. Empowered groups provide adequate demands on the R&D mechanism to respond to the emerging needs.

Conclusion

GDP Contribution of Agriculture is sliding down, however, still > 60% population depends on agriculture & allied sectors. Horticulture contributes 34.5% to the agriculture GDP. There are over 135 million farm families, average size of farm holdings being 1.33 ha. Around 60% cropped area would continue to be rainfed, which demands innovative development strategies. Agricultural Extension is one of the crucial inputs to address these issues with focus on improving performance of existing extension models in operation.There exists an agricultural extension system for crops sector with structural and functional gaps affecting its performance from State to State.However, in allied areas like horticulture, animal husbandry, dairy, poultry, fisheries, etc., it is either weak or missing.Horticultural extension has been integral part of agricultural extension, however, needs special focus considering skilled operations in horti sector.

Horti Extension strategies need augmentation in the areas of enhanced researches backstopping, feedback based extension strategies, working out technology options for Agro-Climatic Zones, Sub-Zones & micro situations, focus on integrated programme delivery mechanism, prioritization of focus areas, empowerment of women farmers, etc.Future horticultural extension strategies should focus on technology mapping & activating existing linkage forums. Follow-up by the field formations by themselves may not able to penetrate down the line, especially to the small and the marginal farmers, across the sectors, due mainly to inadequate numbers, their quality and limited outreach. Therefore, it would be better if the chains of extension agents (formal/informal) like farmer groups, farm entrepreneurs, and grower's associations are systematically promoted and used. Flexibilities to the field formations are required enabling them to respond to the emerging local extension challenges.

Horti Extension Strategies must focus on producer aggregates at various levels & provide strong forward linkages. Farmer to Farmer Extension has been one of the most effective mechanisms, the question is how to promote, encourage & fund it.Farm women's presence is seen increasing in all the farm operations because of male migration to towns and cities, hence extension services need to be re-oriented to their technology dissemination needs. ICT has lots of scope for future extension strategies, however, content development and delivery for print and electronic media is crucial. Internet access needs to be improved by organizing Farmer/Farm Women Knowledge Groups (F/FWKGs) in the villages facilitating improved arrangements for knowledge interpretation and sharing. Training co-ordination (segregated responsibility), convergence and programme delivery, extension priority setting, extension for farmer distress areas & PPPs in extension management need to be streamlined as pertained to the local extension needs. Future Horticultural dissemination strategies must address yield potentials/gaps and organize large number of FFSs / FOs/GAs & FPCs in potential areas. Identification of potential areas for export opportunities (for entrepreneur farmers), involve processing and export industries in such assessments, draw strengths from international extension experiences & set quality standards for extension services. This may form essential parameters of extension performance. Also, there is an urgent need for intensive research in horticultural extension to look into efficacy of different approaches.

Farm Journalism is an effective instrument for augmentation of information support to horti/agricultural extension. This could be achieved through strategic and location specific media combination focussed on print, electronic and social media, keeping the targeted audience in view. Important considerations like content development, presentation and delivery of the same are pre-requisites for effective communication strategy in horti sector. The agricultural / horticultural universities and the ICAR institutes would need to take a lead role in promoting training and capacity development of field functionaries. This has to be done in collaboration with the user departments at various levels and as per felt needs of the clientele. Specific modules are required to be designed for this purpose through specialized institutes. Perhaps Zonal Agricultural Technology Application & Research Institutes of the ICAR, the State Agricultural Management & Extension Training Institutes(SAMETIs) of the State Department of Agriculture are required to develop systematic training modules on the subject under the guidance of Extension Division of Council and MANAGE. A few such modules are necessary to be offered to KVK scientists and ATMA functionaries. Also, there is urgent need to collate, analyze and internalize farm information augmentation experiences across the globe.

We may have the technologies, the investments, but if the dissemination arrangements are not properly defined/streamlined, then development efforts would be far more inadequate. Agri/Horti Extension has to deal with the applied social sciences when dealing with the different socio-economic groups and categories of farmers. Hence, information augmentation, socio economic considerations and dissemination are important for effective horti extension performance. Horticultural Sector offers better price realization opportunities provided the production and the market linkages are streamlined. Specific strategies like processing and value addition, sustained supplies to processing units, crop diversification, empowered horticultural groups, re-oriented extension services, producer aggregates, growers associations,etc would certainly enable the producers to double their farm incomes.

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Initiatives and Options in Transition for Doubling Farmers' Income

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Agriculture, with its related sectors, is indisputably the largest livelihood provider in India, more so in the massive rural areas. It is well known that more than 58% of the rural households is dependent on agriculture, thus primary focus of the government has been on rural development to improve the livelihood of rural people. Agriculture, along with fisheries and forestry, is one of the largest contributors to the Gross Domestic Product. As per the 2nd advanced estimates by the Central Statistics Office, the share of agriculture and allied sectors which include agriculture, animal husbandry, fishery and forestry, is expected to be 17.3 per cent of the Gross Value Added (GVA) during 2016-17 (2011-12 base prices). In the event of pursuing sustainable agriculture, food security, rural employment, and environmentally sustainable technologies are essential for holistic development. Indian agriculture and allied activities have witnessed a green revolution, a white revolution, a yellow revolution and a blue revolution. But in the years to come challenges to agriculture will continue to increase because large population is to be fed from declining land and water, in the scenario of climate change. Large portion of the farming is still dependent on monsoon, given there is mere 45% irrigation penetration. It is worth mentioning that two consecutive years (2014-15 and 2015-16) of scanty rains have negatively affected farm income. It has been witnessed recently during *kharif* 2016 that a good monsoon can itself drive agriculture growth to as much as 8%. It is also evident that good rains can only help in the short run, but long term solutions are needed through water saving infrastructures and technologies. Last year in the Union Budget 2016, the Finance Minister announced that the government would strive to double rural income by 2022. Excerpts of the speech are depicted here as such that doubling rural income in nominal terms is possible by increasing agri output & minimum support prices (while keeping inflation below 5%), doubling rural income in real terms would be a daunting task considering increasing agri output by 12% every year with no additional land likely to be utilized for agricultural activity. There is every possibility not only to double the income of farmers through enhancement in productivity, changes in cropping pattern, inspire additional income through many supplementary activities but also provide stability in farmers income. There is need to think beyond food security and give our farmers a sense of income security.

Agriculture Scenario in India & Relevance to Doubling Income

Let me mention about the state of our agriculture which supports livelihood to over 600 million people and retains the dominant role in Indian economy, though it contributes only 14% to Gross Domestic Product (GDP). Over 50% of population depends directly or indirectly on agriculture for their livelihood. It is 70% of primary source of income in rural areas. During the last more than six decades, Indian agriculture witnessed a remarkable increase in production of food grains from a modest 51 million tonnes in 1950-51 to 272 million tonnes in 2016-17 and touched an all time high production. Some of the recent achievements have been possible due to spirit of our farmers, their hard work even in adverse conditions and in countable initiatives of the

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Government of India, like, National Food Security Mission, Rashtrya Krishi Vikash Yojna, National Horticulture Mission as well as several research initiatives. We have been highly comfortable on our food front, when many countries have experienced shortages of food during global crisis of 2008-09.

There is increasing demand for diversified production of food grain, pulses, fruits, vegetables, milk & live stock. By 2030 in India, cereal demand is expected to grow by 11 percent but demand for vegetables will grow by 37 percent, milk and dairy by 52 percent and poultry by over 100 percent. The present population of 132 crores is likely to increase to 145 crores by 2030 in the country. By 2030, we need to produce 300 million tonnes of food grains against present level of about 272 million tones and 320 million tonnes of fruits and vegetables against 287 million tonnes will be required. The increase in production can only come from increase in productivity. Our productivity and income levels can be substantially increased by better use of technology and adoption of newer method. The world over, the shifts is from agricultural to industrial economies and towards information and knowledge driven ones that creates a new service society with new objective. We must take these trends into consideration and recognize the fact that less and less people will have to produce more and more in the coming decades to feed our millions with high profitability considering income security above the food security.

According to NSSO, the study was made in 2012-13 which showed the nominal (not adjusted for inflation) income of farmers usually doubles every six years. It pegged the income at Rs 6,426 a month in 2012-13 as against Rs 2,115 a month in 2002-03, annual increase of 11.7 per cent.

For real incomes of farmers' to double by 2021-22, agriculture and allied activities need to grow at a much faster rate than the current average. To double the income of farmers by 2022, in nominal (numerical) terms, which do not take inflation into account, would require a 15% compounded income growth rate, which is a marginal increase over the achieved increase from 2003 to 2013. There will be need to organize differently the agriculture processes & policy interventions to double the income in real manner. In order to realize this concept, active collaboration between all stakeholders from public and private sector involved in food system would need new approaches and innovations to be adopted. Such interventions would need integrated value chains that connect farm to fork, competitive markets that provide better prices to farmers and an enabling environment that supports innovation and action. Besides, it has unveiled strategies ranging from irrigation to crop insurance. But if the food value chain is to undergo true transformation, it needs to move from a production-driven system to one driven by demand, one that increasingly link consumers with producers.

Deliberations on Strategy to Achieve Double Income

The Hon'ble Prime Minister has announced on 28 February, 2016 at Bareilly that as we celebrate completion of 75 years of independence in 2022, the income of our farmers should be doubled. The Union Budget 2016-17 also lays stress on this. The Hon'ble PM has advocated seven point strategy to achieve this. These are i) Special focus on irrigation with sufficient budget, with the aim of "Per Drop More Crop"; ii) Provision of quality seeds and nutrients based on soil health of each field.; iii) Large investments in Warehousing and Cold Chains to prevent post-harvest crop losses; iv) Promotion of value addition through Food Processing; v) Creation of a National Farm Market, removing distortions and e-platform across 585 Stations; vi) Introduction of a New Crop Insurance Scheme to mitigate risks at affordable cost and vii) Promotion of ancillary activities like Poultry, Beekeeping and Fisheries. Further, Finance Minister Shri Arun Jaitley in his budget speech dated February 29, 2016 stated that *"We are grateful to our farmers for being the backbone of the country's food security. We need to think beyond food security and give back to our farmers a sense of income security. Government will, therefore, reorient its interventions in the farm and non-farm sectors to double the income of the farmers by 2022."*

To achieve this target of doubling of farmers income by 2021-22, this Department has constituted a Committee under the Chairmanship of Additional Secretary (Policy) to examine issues relating to doubling of farmers' income by year 2021-22. The broad mandate of the Committee is i) To study the current income level of farmers/agricultural labourers; ii) To measure the historical growth rate of the current income level; iii) To determine the needed growth rate to double the income of farmers/ agricultural labourers by the year 2021-22, iv) To consider and recommend various strategies to be adopted to accomplish (iii) above, v) To recommend an institutional mechanism to review and monitor implementation to realise the goal and vi) To examine any other related issue.

Finally, as input management with respect to quality and cost, is critical to regulate the cost of cultivation, a meeting be convened with concerned Divisional Heads under chairmanship of Secretary (AC&FW). It was decided that the targeted timeline for income doubling by March, 2022, the total number of crop seasons available are 12 beginning Kharif 2016. Hence, the strategy has to finalized at the earliest and the interventions will have to begin from the current crop season itself. The Committee shall work as a 'Rolling Committee' and promote/ persuade appropriate interventions on a regular basis. It was explained, that initiatives of the department including 'Input Management', 'Promotion of Bee-keeping', Promoting Pulse Production' etc. are steps in that direction. During this meeting, it was decided that NCAER would be the Knowledge Partner. The committee, the Knowledge Partner and the Sectoral heads shall work on bringing out practical recommendations and may rely upon various Reports and Articles already available. Since doubling of farmers' income will warrant consistently high growth rate on production front year after year, it will help intervention on post-production and particularly with respect to storage & transportation (including cold chain logistics) and food processing. 'Savings Realised is Growth Realised' should be the approach. Considering the estimated cost of agri-commodities worth Rs. 92,000 crore for the year 2014-15, which is almost 10 percent of Agri-GDP at Rs. 11,355,073 crore [2013-14 (RE)], it signifies that improvements on this aspect will automatically raise the income level at farmers' level and at the macro-level i.e. Agri-GDP of the nation.

It was decided that seven to eight sub-committees need to be formed pertaining to different sectors in the Ministry, which would also include skill development. These include Agriculture, Horticulture, Livestock & Dairy, Fisheries, Supply Chain management, Food Processing and Skill Development. These committees would be given a macro picture of the growth scenario and they would be indicated the required annual growth rate to achieve the target of doubling of farmers' income by March, 2022. The Committees would be guided with regard to input efficiency – a key factor; means to reduce cost of production/increase productivity; post-production practices, including supply chain management and risk negotiations. These Committees would, in turn, cull out past practices to give a strategy in their respective areas for achieving the target by also factoring 'sustainability'. In order to orient these sub-committees, it would be necessary to prepare a base paper for their use to prepare the strategy/s. Accordingly, ICAR-NIAP would prepare a paper immediately combining the two presentations made so far i.e. one relating to the pathway for finalisation of approach for measuring and doubling the farm income and the methodology of determining the farm income and present the same to the Ministry of Agriculture and Farmers Welfare to take the matter further. The Department had on the eve of the NABARD Foundation Day on 12th July, 2016 had participating in the inaugural session of the national seminar which focused on 'what it takes to double the income of farmers over next six years and what are the strategies that are needed'? It further decided to organize regional conferences on doubling the farmers income at different venues of six State capital of Assam. Odisha, UP, Rajasthan, Maharashtra and Karnataka with the objective to provide this Department required inputs for forming national strategy for doubling of farmers' income. The committee has yet to submit the report, however DAC&FW is now taking care for focus on income security through ongoing Mission programs (NFSM, NMOOP, BGREI, CDP, NHM, HMNEH, RKVY) and flagship programs (PMKSY, PFBY, PKVY).

OPTIONS IN TRANSITION FOR DOUBLING FARMERS' INCOME

The Government of India has taken appropriate measures to increase farm income, stabilize production and, consequently, improve small farm productivity. The government's focus on improving farm productivity led to the initiation of a variety of new schemes related to area of soil health care, micro irrigation, water harvesting, high quality seeds, credit & insurance availability, creation of a vibrant e-market and encouraging livestock & bee keeping with the support of the food processing industry.

1. Achieving productivity led growth in crop production

India's farm yields are much lower as compared to other developing countries. Per hectare rice production in India is 3.6 tons compared to 6.7 tons in China, 5.1 tones in Indonesia and 5.6 tones in Vietnam. Similarly, per capita wheat production in India is 3.1 tons compared to 5.0 tons per hectare in China. Modern tools of science such as biotechnology can play critical role in increasing crop yields, nutritional quality, tolerance to biotic & abiotic stresses. One of the disquieting features of the Indian horticulture sector is the low productivity of fruits and vegetables. Among fruits, with the exception of banana and papaya, the average productivity is much lower (12 t/ha) in India compared to many leading fruit producing countries [Indonesia (22.4), U.S.A (22.2), Brazil (16.1), Philippines (14.0), Italy (13.2)]. In case of vegetables, the productivity in India is around 17t/ha for the past several years which is much below the productivity of several leading vegetables producing countries [Spain (37.2) U.S.A (31.4),Iran (26.2), Egypt (25.7),Italy (25.1)]. Fruits and vegetables together registered a growth of 6.34 per cent in production, 4.7 per cent in area, but a meager 1.57 per cent in productivity in India during the past decade. The prime reasons for the low productivity are non availability of quality planting material, dwindling natural resources, resource poor farmers, low adoption of modern technologies etc., Low productivity levels decrease the profitability of farmers, especially the small and marginal growers and also indicate production inefficiencies that need to be corrected. The challenge is to enhance productivity by increasing the factor productivity of all the horticultural production inputs and at the same time sustaining it by adoption of good agricultural practices and precision farming principles.

The policy support accordingly be provided for the development of seed and biotech industry in the country. As per studies BT cotton, root stock of grapes alone has contributed more than Rs. 80,000 crores and Rs. 10000 crores of additional output value to farmers. Several such high impact technologies may help for enhancing farmers profitability. Rainfed farming system with arrangement for water saving technologies & providing life saving irrigation for the crops can enhance output and income of farmers. Yield gap for major crops in the country as revealed by various studies is considerably high. Factors influencing yield gap are biophysical & social economic. Bio physical factors include nutrient deficiencies and imbalances (NPK, zinc, etc.), water stress, flooding, suboptimal planting (timing or density) soil problems, weed pressures, insects, diseases, seed quality, etc. Socio Economic factors include insufficient credit, lack of compliances, lack of knowledge on best practices, profit maximization approach, etc., need to be addressed.

2. Enhancing seed availability for adoption of high yielding varieties and hybrids

There have been technological changes in seed production, techniques for production of hybrid seeds, using of cytoplasmic male sterile lines (CMS), technologies for vegetative methods of propagation, now in *vitro* propagation technologies, a success story in banana, potato and citrus. Knowledge has also improved about the diseases being transmitted through the vegetative propagation chain, and now diagnostic technologies are available for early detection. Enabling policies have also facilitated the availability of the best materials to the farmers. However, seed chains addressing the production of nucleus, foundation and certified seeds area weak and supported under National Horticulture Mission. Management of quality and health of plants needs upgradation, in order to ensure quality seeds and healthy planting material. Therefore, it is essential that the dynamics of technologies and policies are analysed in perspective to address the challenges of the future, because appropriate seeds and planting material hold the key to success in horticulture. Seed Replacement Rate (SRR) is directly proportional to productivity of all crops, therefore, higher the SSR, higher will be the productivity and will certainly help in doubling the food grain production. The hybrid technology has capacity to revolutionize the production of vegetable crops and demand for hybrid seeds is continuously increasing. Hybrids of tomato, chilli, cucumber and muskmelon are being produced at several locations in the country. ICAR has so far recommended the cultivation of more than 45 hybrids. Besides, many hybrids of vegetable crops, developed and marketed by the private sector are also available to the farmers. At present, the area under vegetable hybrids accounts for 10% of the total area. Area under high yielding F_1 hybrids in important vegetable crops have been developed in tomato, cabbage and brinjal and the area under hybrid capsicum and chilli is on the increase. High production, earliness, superior quality, uniform produce and resistance to biotic and abiotic stresse are the main advantages of F_1 hybrids. Adoption of hybrid varieties can increase 2-3 times more yield.

Rootstocks for production and profitability: Appropriately selected rootstocks have potential to modify the architecture of plants for efficient utilization of resources. It can ameliorate the soil, enhance nutrient and water use. Therefore, rootstocks have become integrated in the production system of grapes, citrus, apple and many fruit crops for successful production. Citrus rootstock, *Rangpur lime* can adapt to water stress, calcareous soils and resist *Phytophthora*. The use of rootstock in grape cultivation has gained popularity, and almost all newer vineyards are being planted on stress tolerant rootstocks only. The popular rootstocks for grape are Dog ridge B-2/56 and 110R, which can sustain abiotic stresses like drought and soil salinity and provides vigour of vine needed for production. In sapota, *Khirni (Maninkar hexandra)* has proved drought tolerant and productive in marginal soil. Root stock technology has capacity to double the production and even make it possible to grow fruit crops under stress conditions with drought hardy root stocks.

3. Integrated Farming System

The emergence of Integrated Farming Systems (IFS) has enabled us to develop a framework for an alternative development model to improve the feasibility of small sized farming operations in relation to larger ones. It is a commonly and broadly used word to explain a more integrated approach to farming as compared to monoculture approaches. The prosperity of any country depends upon the prosperity of farmers. This in turn depends upon the adoption of improved technology and judicious allocation of resources. Integrated farming systems are often less risky, if managed efficiently, they benefit from synergisms among enterprises, diversity in produce, and environmental soundness. It is only by combining all these farming activities together in a symbiotic process that the small tropical farm can become a viable and economic proposition. On this basis, IFS models have been suggested by several workers for the development of small and marginal farms across the country. Such identified judicious blend of agricultural enterprises like agriculture, dairy, poultry, piggery, fishery, sericulture, forestry etc. suited to a given agro-climatic conditions and farmers social dynamics needs to be adopted.

The IFS approach is based on effective management of water, energy and food systems by individual farm families on 2-4 acres of land, and involves a complete re-cycling program. Using the sun as the only external energy source - hydro-power is reserved for centralized systems - the production of food, animal feed and fertilizer is accomplished with minimal cost and without significant pollution. All the activities in the IFS are cost-effective and contribute to waste re-cycling or resources recovery processes, while producing a diversified range of products. Farmers in semi-arid areas with 2-3 cows or 8-10 goats and cultivating dual purpose food grain crops on 0.4 ha land, have been earning Rs. 60,000 – 75,000 per annum. With efficient watershed development, land use planning and selecting of suitable crops, the income of the farmers can go up by 80-100% to generate an annual income of Rs. 40,000 to Rs. 60,000. A farming system and cropping system approach for sustainable use of farm resources and reduced risks has been successfully demonstrated in perennial horticulture. Various farming system models have been developed. Shade loving medicinal and aromatic crops like *patchouti*, rose geranium, long pepper, *sarpgandha, kacholam*, etc., are successfully grown under coconut and areca nut. The elephant foot yam is widely grown as intercrops in litchi, coconut, banana orchards. Spices like black pepper, ginger, turmeric, vanilla, nutmeg, clove and some medicinal plants are ideal intercrops for coconut.

Therefore, Integrated Farming system envisages the integration of agroforestry, horticulture, dairy, sheep and goat rearing, fishery, poultry, pigeon, biogas, mushroom, sericulture and by-product utilization of crops with the main goal of increasing the income and standard of living of small and marginal farmers. The challenge is to upgrade the technological and social disciplines on a continuous basis and integrate these disciplines to suit the region and farm families in a manner that may ensure increased production with stability, ecological sustainability and equitabilities.

Water use technology for high efficiency

Good water management using well designed systems is critical for sustaining production and quality of produce, specially in the case of horticultural crops. if a water deficit its experienced at the active growth phase or fruit development stages it causes severe loss to production and quality. Therefore, it is imperative to manage the water by posing questions of when, where and how to use this resource to draw maximum efficiency and productivity. Therefore, a scheduling based on plant water balance in consonance with soil and climate is appropriate. Water has to be applied to the root zone to save the losses. Among various methods tried drip irrigation has proved successful in exhibiting high water productivity by saving irrigation water from 25 to 60% in various orchard crops and vegetables with a 10 to 60% increase in yield as compared to the conventional method of irrigation. It is one of the latest methods of irrigation which is becoming popular in areas with water scarcity and salt problems. Fertigation has become the state of art technique in orchard crops and vegetables because nutrients can be applied to plants in the correct dosages and at the time appropriate for the specific stage of plant growth. Fertigation requirement in fruits (mango, banana, grapes, papaya, and pomegranate, citrus and strawberry), vegetables (tomato, chillies, brinjal, okra, potato, muskmelon, cucumber) and ornamental crops (rose, carnation, gerbera) and plantation crops (coconut, arecanut and coffee) have been standardized to improve the nutrient and water use efficiency from 120 to 290%. With the launch of the Pradhan Mantri Krishi Sinchai Yojana, which aims to provide water to every farm (Har Khet Ko Pani) the government has made a commitment to spend Rs 50,000 crore on it. The effort to create awareness about micro-irrigation has been greater than ever. In Budget 2016, Rs 5717 crore was allocated under Pradhan Mantri Krishi Sinchai Yojana, of which Rs 2340 crore was allocated to micro irrigation. It is estimated that 59 billion cubic meter per annum of water can be saved though micro irrigation. Till today total 9 million ha area has been covered under micro-irrigation system in India. This eventually improves production levels, reduces the cost of farming and, in turn, enhances farmer's income.

Electronic National Agriculture Market (e-NAM) for enhanced income to farmers

National Agriculture Market (NAM) is a pan-India electronic trading portal which networks the existing APMC mandis to create a unified national market for agricultural commodities. The NAM Portal provides a single window service for all APMC related information and services. This includes commodity arrivals & prices, buy & sell trade offers, provision to respond to trade offers, among other services. While material flow (agriculture produce) continue to happen through mandis, an online market reduces transaction costs and information asymmetry. Agriculture marketing is administered by the States as per their agri-marketing regulations, under which, the State is divided into several market areas, each of which is administered by a separate Agricultural Produce Marketing Committee (APMC) which imposes its own marketing regulation (including fees). This fragmentation of markets, even within the State, hinders free flow of agri commodities from one market area to another and multiple handling of agri-produce and multiple levels of mandi charges ends up escalating the prices for the consumers without commensurate benefit to the farmer.

NAM addresses these challenges by creating a unified market through online trading platform, both, at State and National level and promotes uniformity, streamlining of procedures across the integrated markets, removes information asymmetry between buyers and sellers and promotes real time price discovery, based on actual demand and supply, promotes transparency in auction process, and access to a nationwide market for the farmer, with prices commensurate with quality of his produce and online payment and availability of better quality produce and at more reasonable prices to the consumer. This initiative has been envisaged to provide win-win situation for both farmers and consumers. It will bring transparency in selling and buying crops through digital portal. It will strengthen price risk management of the farmers by averting the need to bring produce in the market physically and stored in the warehouse. The national market would also seamlessly connect the cash, forward & future markets so that farmers have the option to sell their produce in a forward market at a pre-determined price. Currently, farmers have to sell their produce whenever they visit the local mandi due to logistical issue and price negotiations leading to suppressed returns for farmers. We believe selling their produce through e-NAM would be the single biggest factor in enhancing farmer's income level in the near term.

Globally position Indian food and agri produce

India is best known as an exporter of organic tea and also has a niche market for spices, fruits and vegetables. The protocol for organic production in many horticultural crops has been worked out which includes a use of resistant varieties, management of soil vermin-compost and biofertilizer, and management of disease and pests using biological control as well as bio-pesticides. Establishing Special Agriculture Zones (SAZ) by selecting export oriented and industrial use crops. Promoting Crop Stewardship Programs, GAP and Certification, formation of Global Commodity Boards, on the pattern of Australian Walnuts, California almond, Washington Apples etc., can help double in 5 years the current level of 1.70 lac crores of agri exports, which will benefit farmers significantly. We need to globally position Indian food and agri produce such as North Eastern region as Organic Zone, Spices of Kerala, Cardamom of Sikkim, Mango of Malihabad, Orange of Nagpur, Kashmiri Apples, Bihari Litchies and Ratnagiri Mangoes, Tea of Darjeeling, Soybean of Indore and Nilgiris…and so on and promoting Geographic Appellation. Like tea belt of Assam, cotton belt of South India, the nation has to streamline rice belt, wheat belt, corn belt, oil seed belt, Pulses belt, sugarcane belt, tomato belt, mango belt, apple belt, ginger belt, turmeric belt, orange-lime-lemon belt, orchid belt, cut flower belt, jack fruit belt, peach and plum belt. Likewise livestock, fishery, apiary and sericulture belts be created across the country with the objective to improve production and export.

Reducing post harvest losses (Food saved is food produced)

India occupies the prime position in the production of fruits and vegetables which constitutes about 90.0% of the total horticulture production in the country. There is a considerable gap between the gross production and net availability of fruits and vegetables due to heavy post harvest losses. Furthermore, only a small fraction of fruits and vegetables is utilized for processing and export compared too many countries in the world whose position is much below India's production level. Therefore, in order to achieve our target of feeding the population as well as meeting the requirement of the processing including and export trade, only increasing the production and productivity will not only be enough. A lot more emphasis needs to be given to post harvest management of fruits and vegetables. In order to make horticulture a viable enterprise, value addition is essential. Harvest indices, grading, packaging, storage techniques have been developed and standardized for major horticultural crops. Value addition through dehydration of fruits and vegetables including freeze drying, dried and processed fruits, vegetables and spices and fermented products have also been developed. Potato chips, spices flakes and fingers, French fries are becoming popular as fast food business. Development of new products like juices, chips, essential oils, fruit wines are gaining popularity. Packing materials like Corrugated Fibreboard boxes (CFBs), perforated punnettes, cling film wraps, sachets, etc. have been standardized for packaging of different fresh horticultural produce. As food consumption patterns are changing towards more convenient foods, the demand for products like pre-packed salads, packed mushrooms and baby corn frozen vegetables, etc. has increased. In order to reduce the dependence on refrigerated storage, the low cost eco-friendly cool chamber for on farm storage of fruits and vegetables has been a greater emphasis on safety (pesticide free), nutrition and quality is being given a priority in research programs. Curbing these losses would benefit farmers and, in turn, improve farmer's income.

Covering risk through crop insurance will bring stability in farm income

Agriculture in India is highly susceptible to risks like droughts and floods, deficient rain, untimely showers, hailstorms and other vagaries of the weather have resulted in crop loss, unstable agricultural output and unpredictable rural income. It is necessary to protect the farmers from natural calamities and ensure their credit eligibility for the next season. For this purpose, the Government of India introduced a new crop insurance policy Pradhan Mantri Fasal Bima Yojana (PMFBY) in February 2016. There were three clear outliers in the current scheme. The current scheme insured areas that were deprived of sowing/ planting due to adverse weather & deficit rainfall. The scheme includes comprehensive risk insurance from sowing to harvesting mainly to cover yield losses due to non-preventable risks like drought, dry spells, flood, inundation and pests. The government is aggressively promoting a new crop insurance (PMFBY) given increased challenges by farmers due to frequent climatic disturbances. It intends to increase crop insurance penetration from the current 25% to 50% in 2018 by increasing central governments allocation from Rs 3100 crore in 2015 to Rs 8800 crore in 2018. The government would be adopting an innovative technology, especially smart phones for capturing and uploading data directly from the farmer's field. This would help in completing the settlement process in time. The Pradhan Mantri Fasal Bima Yojana (PMFBY) launched in the country from Kharif 2016 has made impressive progress in the first season itself. As on date the scheme has provided coverage to 366.64 lakh farmers (26.50%) and at this rate it is likely to exceeding the target of 30% coverage for both *kharif* and *rabi* seasons in 2016-17. Furthermore there has been a quantum jump of more than 6 times in the coverage of non-loanee farmers from 14.88 lakh in *kharif* 2015 to 102.6 lakh in *kharif* 2016, which shows that the scheme has been well received by the non-loanee segment. Another significant achievement in this season has been 104% enhancement in sum insured. This was made possible as PMFBY mandates that the sum insured must be equal to the Scale of Finance and therefore, reflects better risk coverage of farmers. Risk coverage through crop insurance shall build confidence of farmer to take risk and shall further help in stabilizing farmer's income.

Earning ancillary and supplementary income

Agriculture consists of all of the farmer's activities such as crops, poultry, livestock and the allied industries of small and medium enterprises that depend directly or indirectly on the activity of Agriculture. Agriculture/horticulture and its various sub-segments *viz.,* fruits, vegetables; aromatic and herbal plants, flowers, spices, plantation crops, ornamental plants and landscaping business provide lot of opportunities for self-employment. Horticulture which includes floriculture represents business and activities involving production of ornamental plants, cut flowers, turf, foliage and delivers a range of services for such projects. The business has transformed to landscape design, contracting and maintenance services, whole sale and retail sales, development of parks and leisure places, gardens, greenhouses including various greenhouse inputs besides providing technical advices. Likewise, bee keeping, mushroom farming, protected cultivation, plant nursery and seed production, food processing, dairy farming, poultry farming, fisheries, mini dal mills and many other allied activities can be adopted for supplementing income to the farmers. Such interventions has provided not only opportunities for integrated farming but also for improving livelihood and providing very good business opportunities in other allied sectors like specialized transport services and production of supply of allied products, nursery bags, pots, potting media, tools, plant protection and other equipments etc. There are several other areas in agriculture where ancillary income through value added agri activity, could be earned to reduce farming cost. Such areas are rice straw utilization, diversion of bio-waste towards ethanol manufacturing. This would provide additional income in the hands of farmers. Many benefits may accrue from this measure. Farmer's fields can also be utilized to generate solar power by installing solar panels at farm. Further, the excess power generated in fields can be sold to grid to earn additional income. These moves would eventually give additional income in the hands of farmers and would help double rural income levels in the next six years.

Conclusion

Farmers' income can be improved when productivity goes up, cost of production comes down, if agricultural commodities produced get a remunerative price through a transparent price discovery mechanism. It can also happen due to improved income from allied activities to agriculture and non-farm sector or even wage employment during the agricultural off season. The strategy must integrate them all. Doubling of farmers' income must be attempted by creating a framework where all related agencies come together and work in harmony, with a maestro conducting that orchestra. In its initial years of reforms started by China between 1978 and 1986, witnessed growth of 14% per annum in farm income. This led to a reduction in poverty by half by generating demand for industrial products in rural areas. Doubling rural income in nominal terms is possible by increasing agriculture output & minimum support prices (while keeping inflation below 5%), doubling rural income in real terms would be a daunting task considering increasing agriculture output by 12% every year with no additional land likely to be utilized for agricultural activity. However, a long term solution remains faster execution of policies that could develop infrastructure to support irrigation system and reduce the dependency on rains. There is every possibility not only to double the income of farmers through enhancement in productivity, changes in cropping pattern, inspire additional income through many supplementary activities but also provide stability in farmers' income. There is need to think beyond food security and give our farmers a sense of income security.

Advertisements

Junagadh Agricultural University (JAU)

Vice Chancellor: Dr. A.R. Pathak
Telephone (Office): (0285) 2671784, **Fax:** (0285) 2672004
Email: vc@jau.in **Website:** www.jau.in

Vision: Junagadh Agricultural University intends to be one of the nation's leading universities in terms of its academic quality, advancement in technological research and enhancement of farmers' knowledge for sustainable agriculture as well as ensuring food & nutritional security to the people.

Mission: Play pivotal role in teaching, research and extension education related to agriculture and allied sciences.

Jurisdiction / Area of Operation: JAU is one among the four Agricultural Universities in the Gujarat and came in to existence from 1st May, 2004. University's jurisdiction is spread over the districts of Junagadh, Jamnagar, Rajkot, Porbandar, Surendranagar, Bhavnagar, Amreli, Devbhoomi Dwarka, Gir Somnath and Morbi of the Gujarat state. The university has eight colleges offers higher education (UG & PG up to Ph.D.) in the faculties of Agriculture, Agricultural Engineering & Technology, Fisheries Science, Veterinary Science & Animal Husbandry, Horticulture and MBA in Agri-Business Management. University also offers Polytechnic/Diploma/Certificate Courses in the field of Agriculture, Horticulture, Agro Processing, Agricultural Engineering, Animal Husbandry, Home Science, Bakery and Mali.

Programmes Offered

SNo.	Name of the Constituent College/Faculty	Bachelor's Programme	Master's Programme	Ph. D. Programme
1.	College of Agriculture (COA),Junagadh	Bachelor of Science (Hons) inAgriculture	M.Sc. in Agriculture in Agricultural Extension, Agricultural Economics, agricultural Statistics, Agronomy, Soil Science, Agricultural Meteorology, Agricultural Entomology, Plant Pathology, Genetics & Plant Breeding, Seed Science & Technology, Plant Physiology, Biochemistry, Plant Molecular Biology & Biotechnology, M.Sc. (Horti.) in Fruit Science, Floriculture and Landscape Architecture	Ph.D. in Agriculture in Agricultural Extension, AgriculturalEconomics, Agricultural Statistics, Agronomy, Soil Science,Agricultural Meteorology, Agricultural Entomology, Plant Pathology,Genetics & Plant Breeding, Plant Physiology, Biochemistry, PlantMolecular Biology & Biotechnology, Ph.D. (Horti.) in Fruit Science,Floriculture and Landscape Architecture
2.	College of Veterinary Science & Animal Husbandry (COVSAH), Junagadh	BVSc & AH	MVSC in Animal Genetics & Breeding, Livestock Production and Management, Animal Nutrition,Veterinary Surgery and Radiology, VeterinaryMicrobiology, Veterinary Pharmacology and Toxicology, Veterinary and Animal Husbandry Extension	Ph.D. in Veterinary Science in Animal Genetics and Breeding,Livestock Production and Management, Animal Nutrition
3.	College of Agricultural Engineering & Technology (CAET),Junagadh	B. Tech. (Agril.Engg)	M.Tech. (Agril. Engg) in Soil & Water Engg,Farm Machinery & Power Engineering, Processing & Food Engg, Renewable Energy Engg	Ph.D. (Agril. Engg) in Soil & Water Engineering, Farm Machinery & Power Engineering, Processing & Food Engineering
4.	Post Graduate Institute of Agri Business Management (PGIABM), Junagadh	-	MBA in Agri Business Management	-
5.	College of Fisheries	B.F.Sc.	M.F.Sc. in Fisheries	Ph.D. in Fisheries Resource

	Science(COF), Veraval		Resource Management, Fish Processing Technology, Aquaculture	Management
6.	College of Agriculture, Amreli	B.Sc. (Hons) inAgriculture	-	-
7.	College of Horticulture, Junagadh	B.Sc. (Hons) inAgriculture	-	-
8.	College of Agriculture, Khapat	B.Sc. (Hons) in Agriculture	-	-

Major Areas of Research

Junagadh Agricultural University has 31 research stations including multidisciplinary main research stations, sub centres on various crops and testing centres spread over in whole North Saurashtra & South Saurashtra Agro-climatic Zones and part of North-west and Bhal & Coastal Area Agro-climatic Zones of Gujarat. The research carried out on various issues related to different crops and disciplines including Wheat, Millet, Pulses, Oilseeds, Cotton, Sugarcane, Fruit Crops, Vegetables, Dry Farming, Grassland, Agricultural Engineering, Cattle Breeding and Fisheries. To strengthen the location specific research 20 AICRPs are functioning in the University. Since inception of the university, as an outcome of the research by release of about 50 varieties Out of these nearly 15 varieties got recognition at national level. University has developed 427 technologies / package of practices for the benefits of the farmers.

Highlights of Extension Education Activities

The University is having seven Krishi Vigyan Kendras (KVKs), Sardar Smruti Kendra (SSK), evenCentre of Comunication (CoC), Agricultural Technology Information Centre (ATIC) etc. for extension activities impart training to extension functionaries of the line departments, to transfer the agricultural technologies to the farmers and end users. Agro based ITI are also running in the university. Community FM Radio Station releasing extension progarmme on “Janvani 91.2” started by the university. FLDs are being conducted on various crops and technologies at Farmers’ fields through KVKs and Research Stations. A mega event Krushi Mahotsav is organized every year since 2005 for dissemination of latest technology at farmer’s door step.

Strength of the University

- Well qualified faculty for latest quality education and research
- Well-developed infrastructure including laboratories, libraries, internet connectivity, smart class rooms, boys & girls hostels, indoor & outdoor sports, auditorium, etc.
- Good governance + original initiatives
- Good placement through campus interview
- Healthy environment and medical facilities
- NSS and extra-curricular activities like capacity building lecture, summer training, cultural, sports, tracking, internship, RAWE programme,
- The technologies of crop production through research and development activities of the University.
- The substantial support from agricultural department in the State with technical human power and the much needed infrastructure, to keep agricultural development going.
- The departments have plan and other agency schemes with abundant funds for research and development.
- Proximity to the largest fish landing centre in the western coast of the country.

Important Achievements

- 51 new varieties were developed for major crops of the Saurashtra out of which 18 varieties were released at National level.
- Cow urine elemental composition and metabolites detection. Above, 380 metabolites detected in cow urine samples, some of them has great medicinal values.
- For the first time in the scientific realum the Gold content is detected in more than 300 samples of Gir Cow urine.
- Whole genome sequences of antagonist microbes (*Bacillus. Rhizobacter, Pseudomonas*) and plant pathogenic fungi (*Sclerotia, Macrophomina, Puccinia*) and their functional annotation
- DNA Barcoding of developed crop varieties and fish for identification and conservation purpose.
- A foldable container for storage and transportation of agricultural produce.
- Noticeable increase in the seed production and distribution of various crop seeds, viz., Groundnut, Wheat, Chickpea, Pearl Millet, Castor, Sesame and other crops of Saurashtra region. Plantlet, grafts, saplings of the horticultural crops and other ornamental plants are also being sold out at reasonable price.
- Diff. bio-agent and bio-fertilizers viz. *Trichoderma, Rhizobium, Azotobacter*, PSB, *Beaveria* etc. are supplied to the farmers at reasonable prices.
- The NABL accredited Food Testing Laboratory is functioning under the Department of Biotechnology.
- Demand for DxT Coconut hybrid seedling is increasing. Elite farm developed in 20 ha area at Mahuva center to meet the requirement of farmers.
- Control measures of Pink bollworm in cotton crop were developed and suggested for farmers.
- Sea weed is used for preparing the liquid fertilizer at Fisheries Research Station, Okha and it will be useful for Zinc and Iron deficient soil.
- Larvae of pearl oyster were released in the sea at Fisheries Research Station, Sikka for further harvesting of matured pearl oyster by fish farmers.
- Popular Kesar mango of Saurashtra has received the GI certificate.

NAVSARI AGRICULTURAL UNIVERSITY
NAVSARI -396450, GUJARAT, INDIA

Dr. C. J. Dangaria
Vice Chancellor

MISSION

Attain excellence in education, relevance in research and outreach in extension education.

VISION

Transform Navsari Agricultural University in to a Knowledge Power Centre by the year 2020

ACCREDITATION

ICAR accredited Colleges:

1. N.M. College of Agriculture
2. ASPEE College of Horticulture

ICFRE accredited College:

1. College of Forestry

VCI recognized College:

1. Vanbandhu College of Veterinary Science & A. H.

Our Products:

Seeds: More than 5000 q/ annum

Tissue Culture Plantlets: More than 3.0 lakh/ annum (sugarcane/banana)

Liquid Bio-fertilizers: About 1.0 lakh/annum

Novel Sap: About 25000 litres/annum

Grafts/Seedlings/saplings: More than 9.0 lakh/annum

Navsari Agricultural University is a hub of Agriculture and allied subject Teaching, Research, Development and Extension in South Gujarat. University was established in May 01, 2004; however, its research stations started paving the road of organized agriculture well before the independence. Since then it was progressing leaps and bounds in all the domains and after the attaining the status of independent university, it became one of the best centre in its field. Presently, the university is imparting college education in the six different disciplines viz., Agriculture (N.M. College of Agriculture at Navsari since 1965, College of Agriculture at Bharuch and Waghai since 2012) Horticulture and Forestry (ASPEE College of Horticulture & Forestry at Navsari since 1988), Veterinary Science (Vanbandhu College of Veterinary Science and Animal Husbandry at Navsari since 2008) Agricultural Biotechnology (ASPEE SHAKILAM Agricultural Biotechnology Institute at Surat since 2012) Agricultural Engineering (College of Agricultural Engineering & Technology at Dediyapada since 2013) and in Fisheries (College of Fisheries Science at Navsari since 2015). Apart from these, Aspee Institute of Agri-Business Management at Navsari is offering M.B.A. (Agri-business Management) and M.Sc. (ICT in Agriculture) since 2007.

University offers courses for developing medium skilled manpower in the field of agriculture to work at grass root level through seven Polytechnics located at different stations. NAU offers Polytechnic in Agriculture (Bharuch, Vyara and Waghai), Polytechnic in Horticulture (Navsari and Paria), Polytechnic in Animal Husbandry (Navsari) and Polytechnic in Agricultural Engineering at Dediyapada. Besides, University also offers Certificate courses in Turf-grass management, Wild-life photography, Landscaping and Gardening, Agro ITI and Bakery etc.

Degree Programmes of NAU

Bachelors	Masters'	Doctoral
B.Sc. (Hons.) Agriculture, B.Sc.(Hons.) Horticulture, B.Sc. (Hons.) Forestry, B.V.Sc.&A.H., B.Sc.(Agril. Biotechnology), B.Tech.(Agril. Engineering) B.F.Sc.	M.Sc. (Agri.) M.Sc. (Horti.) M.Sc. (Forestry) M.V.Sc. M.B.A. (Agri-business Management) M.Sc. (ICT in Agriculture) M.Tech. (Agril. Engineering)	Ph.D. (Agriculture) Ph.D. (Horticulture) Ph.D. (Forestry) Ph.D. (Veterinary)

* For admission & other details please visit University Website : www.nau.in

E-Mail: registrar@nau.in Ph: 02637-282823

Technologies Developed :

- Precision Farming
- Protected Cultivation
- Organic Farming
- Waste Management
- High Density Farming
- Rejuvenation of Mango Orchards
- Bio-fertilizer & bio-pesticides
- Integrated Nutrient Management
- Fruit Fly Traps
- MIS and Mulching
- Closed Sub-surface Drainage
- Integrated Pest Management
- Vertical Cultivation
- Value Addition of Banana Pseudo-stem/ various fruits
- Brackish Water Aquaculture

Varieties Released: 45

Cotton (9) including 3 *Bt* hybrids, Sugarcane (6), Rice (8),Pulses (6), Nagli (4), Vari (2), Sorghum (3), Turmeric (2), Vegetable(3), Castor(1), Niger(1)

Extension Activities:

Extension wing of NAU disseminates useful technologies to farmers by organizing more than 5000 extension programmes including FLDS, on-campus/ off- campus trainings, farmers' Day, *Kisan Gosthi*, Agriculture exhibition, seminars and educational tour, mass communication programmes like *Krushi Mahotsav*,release of press notes, SMS, Video shows and radio/TV talks etc. every year. These programmes benefit more than 1.60 lakh farmers every year.


NAVSARI AGRICULTURAL UNIVERSITY
NAUROJI
NOVEL
PATENTED
નૌરોજી
નોવેલ
Banana Pseudostem Based
Organic Liquid Fertilizer
કેળનાં થડમાંથી બનાવેલ
સેન્દ્રિય પ્રવાહી ખાતર
ADVANTAGES
• It is pure organic product.
• It contains NPK as well as micro nutrients.
• It contains naturally occurring growth promoters.
• It is a growth promoter, it is very helpful in nursery plants.
• It enhance total plant growth, number of flower, maximum conversion of flowers into fruits and pods
• Enhance vigorous root development and growth
ફાયદાઓ
• સંપૂર્ણ સેન્દ્રિય પ્રવાહી ખાતર છે.
• નાઈટ્રોજન, ફોસ્ફરસ, પોટાશ ઉપરાંત શુક્ષ્મ તત્વો પણ ધરાવે છે.
• કુદરતી રીતે પેદા થતાં વૃધ્ધિવર્ધક ધરાવે છે.
• જુદા જુદા પાકમાં ફુલ, ફળ અવસ્થાએ છંટકાવ કરવાથી ઉત્પાદન વધે છે.
• વૃધ્ધિવર્ધક હોય નર્સરી તબક્કા માં છોડનો વૃધ્ધિ અને વિકાસ ઝડપી થાય છે.
ઉત્પાદક અને વિક્રેતા
બનાના સ્યુડોસ્ટેમ પ્રોસેસીંગ યુનિટ
જળ અને જમીન વ્યવસ્થાપન સંશોધન એકમ
નવસારી કૃષિ યુનિર્વસીટી, નવસારી. ફોન : ૦૨૬૩૭-૨૯૨૧૦૩


NAUROJI SEEDS
NAVSARI AGRICULTURAL UNIVERSITY
NAUROJI SEEDS
યુનિવર્સિટી દ્વારા બહાર પાડવામાં આવેલ જુદા જુદા પાકોની નવી જાતોની ઉપલબ્ધતા
Availability of new varieties seeds of different crops produced by the University
૧. ડાંગર :- એન.એ.યુ.આર.-૧, જી.એન.આર.-૨, જી.એન.આર.-૩, જી.એન.આર.-૪, પુર્ણા
૨. જુવાર :- જી.જે.-૩૮, જી.જે.-૪૨, સી.એસ.વી-૨૧ એફ (ઘાસચારા માટે)
૩. નાગલી :- જી.એન.-૪, જી.એન.-૫, જી.એન.એન.-૬
૪. વરી :- જી.વી. -૧, જી.વી. -૨,
૫. ખરસાણી :- જી.એન. -૨
૬. તુવેર :- વૈશાલી, જી.ટી. -૧૦૨, બી.ડી.એન. -૭૧૧
૭. મગ :-સી.ઓ.-૪, જી.બી.એમ. -૧
૮. પાપડી/વાલ :- જી.એન.આઈ.બી.-૨૧, ગુ.વાલ-૧, ગુ.વાલ-૨,
૯. કપાસ :- જી.કોટ. હાઈબ્રીડ-૬, જી.કોટ. હાઈબ્રીડ-૮, જી.કોટ. હાઈબ્રીડ-૧૦, જી.કોટ. હાઈબ્રીડ-૧૨(બી.જી.-II), જી.કોટ.-૨૦, જી.એન.કોટ.-૨૫
૧૦. હળદર :- જી.એન.ટી. -૧
૧૧. શેરડી :- જી.એસ.-૪, જી.એસ.-૫, જી.એસ.-૬, જી.એસ.-૭, જી.એસ.-૮
1. Paddy:- NAUR-1, GNR-2, GNR-3, GNR-4, Purna
2. Sorghum:- GJ-38, GJ-42, CSV-21-F
3. Finger millet:- GN-4, GN-5, GNN-6
4. Little millet:- GV-1, GV -2
5. Niger:- GN-2
6. Pigeonpea:- Vaishali, GT-102, BDN-711
7. Mungbean:- CO-4, GBM-1
8. Indainbean:- GNIB-21, G.Wal-1, G.Wal-2
9. Cotton:- G.Cot.Hy.-6, G.Cot.Hy.-8, G.Cot.Hy.-10, G.Cot.Hy.-12(BG-II), G.Cot- 20, G.N.Cot-25
10. Turmeric:- GNT-1
11. Sugarcane:- GS-4, GS-5, GS-6, GS-7, GS-8
ખાસિયતો
જનીનીક શુદ્ધ અને ઉચ્ચ ગુણવત્તાયુકત બિયારણ
વૈજ્ઞાનિક અભિગમથી તૈયાર કરેલ પ્રમાણીત બિયારણ
Features
Genetically pure and quality seeds
Produced scientifically certified seeds
OUR MISSION
" Our Mission is accelerating Agricultural productivity and production for improving the viability of agriculture "
ઉત્પાદક અને વિક્રેતા
નવસારી કૃષિ યુનિવર્સિટી
નવસારી - ૩૯૬ ૪૫૦
ફોન નં :- (ઓ). ૦૨૬૩૭-૨૮૨૦૨૮
PRODUCED AND MARKETED BY
Navsari Agricultural University
Navsari - 396 450
Phone (O) 02637-282028


NAVSARI AGRICULTURAL UNIVERSITY
NAUROJI BIOFERTILIZERS
ઉચ્ચ ગુણવત્તા ધરાવતા સંશોધિત નૌરોજી જૈવિક ખાતરો
Azotobacter
Rhizobium
Acetobacter
Azospirillum
PSB
KMB
નૌરોજી પ્રવાહી એઝોટોબેક્ટર
નૌરોજી પ્રવાહી રાઈઝોબીયમ કઠોળ પાક માટે
નૌરોજી પ્રવાહી એસીટોબેક્ટર શેરડી પાક માટે
નૌરોજી પ્રવાહી એઝોસ્પાયરીલમ
નૌરોજી પ્રવાહી પી.એસ.બી. દરેક પાક માટે
નૌરોજી પ્રવાહી પોટાશ મોબીલાઈઝર દરેક પાક માટે
Benefits of Biofertilizers
✓ 50% reduction in chemical fertilizers
✓ 20% increase in production
✓ 20-40 kg/ha increase phosphorous solubilization
✓ Improve soil texture and Increase soil fertility
✓ Eco-friendly
✓ Increase seed germination
✓ Improve plant growth by vitamins and growth hormones
જૈવિક ખાતરો થી થતા ફાયદા
✓ ૫૦% રાસાયણીક ખાતરો ની બચત
✓ ઉત્પાદન માં ૨૦% વધારો
✓ પ્રતિ હેકટર ૨૦-૪૦ કિ.ગ્રા રાસાયણીક ફોસ્ફરસ ખાતરની લભ્યતા વધારે
✓ જમીનનું બંધારણ સુધારે અને તેની ફળદ્રુપતામાં વધારો
✓ કિફાયતી તેમજ પર્યાવરણ માટે સુરક્ષિત
✓ છોડના ઉગાવાના દરને વધારે
✓ વિટામીન તેમજ વૃધ્ધિ વર્ધકો બનાવી છોડને પોષણ પુરુ પાડે
Manufactured and Marketed by
Biofertilizers Production Unit
Department of Plant Pathology, N.M. College of Agricutlrue
Navsari Agricultural University, Navsari-396450
Contact No.: +91 9537294343
ઉત્પાદન કર્તા તેમજ વિક્રેતા
બાયોફર્ટીલાઈઝર્સ પ્રોડક્શન યુનિટ
વનસ્પતિ રોગશાસ્ત્ર વિભાગ, ન.મ.કૃષિ મહાવિદ્યાલય
નવસારી કૃષિ યુનિવર્સિટી, નવસારી-૩૯૬ ૪૫૦
સંપર્ક: +૯૧ ૯૫૩૭૨૯૪૩૪૩


Bactrocera dorsalis
NAVSARI AGRICULTURAL UNIVERSITY
Bactrocera cucurbitae
NAUROJI
STONEHOUSE
FRUITFLY TRAP
નૌરોજી
સ્ટોન હાઉસ
ફળમાખી ટ્રેપ
❖ To control the Fruit flies in mango, sapota and other fruits and in climber vegetables
❖ It prevents yield loss up to 85% and eco-friendly in nature
❖ Fruit Crops- Methryl Eugenol Block Vegetables- Cuelure Block
❖ 10 Traps/ha
❖ Hang above 5 to 6 feet from the ground
NAUROJI-STONEHOUSE FRUIT FLY TRAP
❖ કેરી,ચીકુ અન્ય ફળોમાં તથા વેલાવાળા શાકભાજીમાંફળ-માખીના નિયંત્રણ માટે
❖ ઉત્પાદનમાં ૮૫% સુધીના નુકશાન અટકાવે છે
❖ ફળ પાકો માટે- મિથાઈલ યુજીનોલ બ્લોક અને વેલવાળા શાકભાજી માટે - ક્યુલુર બ્લોક
❖ ૧૦ ટ્રેપ પ્રતિ હેક્ટર
❖ જમીનથી ૫ થી ૬ ફૂટ ઊંચે લટકાવો
ઉત્પાદક અને વિક્રેતા:
ફૂડ ક્વોલિટી ટેસ્ટિંગ લેબોરેટરી
ન. મ. કૃષિ મહાવિદ્યાલય
નવસારી કૃષિ યુનિવર્સિટી
નવસારી- ૩૯૬ ૪૫૦
સંપર્ક. ફોન. નં. ૦૨૬૩૭ ૨૮૨૯૭૮

Dr. N. C. Patel
Vice Chancellor

ANAND AGRICULTURAL UNIVERSITY
ANAND – 388110, GUJARAT, INDIA

Email: registrar@aau.in **Phone No.** (02692) 261310
Website: www.aau.in **Fax:** +91-02692-261310

Anand Agricultural University is among the four Agricultural Universities in Gujarat state carved out of Gujarat Agricultural University under GAU Act – 2004 and came into existence from 1st May, 2004. Jurisdiction of AAU is spread over nine districts of middle Gujarat. The vision of the University is agriculturally prosperous Gujarat and India with a mission to serve for farming community.

EDUCATION

The university offers various under-graduate and post-graduate courses as well as polytechnic courses, at 10 different colleges and 6 polytechnics in different disciplines.

Courses offered

Under Graduate
- B.Sc. (Hons) Agri. – 8 semesters
- B.Sc. (Hons) Horti. – 8 semesters
- B.Tech. (DT) – 8 semesters
- B.Tech. (Agri.Engg.) – 8 semesters
- B.Tech. (FT) – 8 semesters
- B.Tech. (AIT) – 8 semesters
- B.V.Sc. & A.H. – 10 semesters

Post Graduate
- M.Sc. (Agri.) – 4 semesters
- M.Sc. (Horti.) – 4 semesters
- M.V.Sc. – 4 semesters
- M. Tech. (DT) – 4 semesters
- M. Tech. (Agri. Engg.) – 4 semesters
- M. Tech. (FT) – 4 semesters
- M.B.A. (Agri. Business Management) – 4 semesters
- M.Sc. (Agri. Mkt./Agril. Jour.) – 4 semesters (Distance learning)
- Ph.D. – 6 semesters

Polytechnic
- Diploma in Agriculture
- Diploma in Agri. Engg.
- Diploma in Food Sci. & Home Economics
- Diploma in Horticulture

RESEARCH

Anand Agricultural University has 48 research stations spread over nine districts of middle Gujarat. The research activities have been carried out in various fields such as Crop Improvement, Crop Production, Plant Protection, Basic Science, Social Science, Agril. Engineering, Agril. Information Technology, Dairy Science, Animal Production, Animal Health etc. As an outcome of research, total 57 varieties of different important crops of the region and 590 recommendations (technologies) have been developed for farming community of the state since inception of AAU. The university produces quality seeds of important crops of the state and sale to the farmers under the brand name '**Anubhav seeds**'.

The University has state of the art facility for biotechnological research in Agriculture as well as in animal husbandry, NABL – 17025: 2005 accredited laboratories in the field of pesticide residue laboratory and food quality testing laboratory. The university has developed commercially viable technologies for Biofertilizers and *Trichoderma* based biofungicide.

EXTENSION

Technologies developed by the university has to reach the farmers in time. Anand Agricultural University provides extension advisory services to the extension officials and farmers of the state. Technologies developed by the Agril. Scientists are transferred to the end users through KVKs, T&V scheme, SSK, ATIC, Farm Advisory scheme etc.

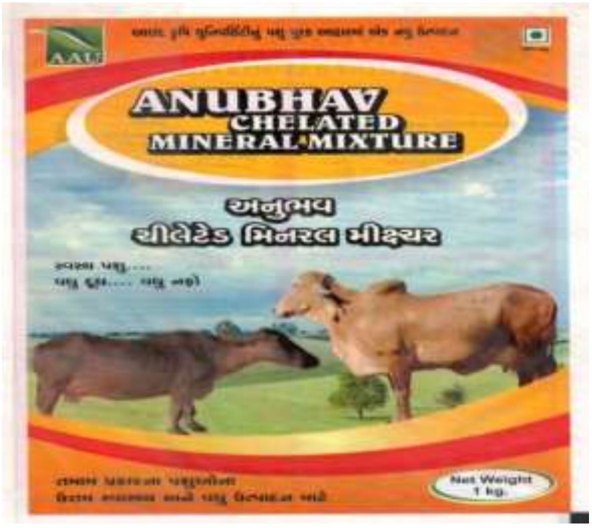
Products of Anand Agricultural University, Anand

ANUBHAV SEEDS ®
ANAND AGRICULTURAL UNIVERSITY, ANAND

Anubhav Seeds

Anubhav *Trichoderma*

Anubhav Biofertilizers



Anubhav Chelated Mineral Mixture

Date palm

Pointed gourd

Pomegranate

Tissue Culture raised plants

Contact

Director of Research, AAU, Anand
Ph.: (02692) 263600, E-mail: dr@aau.in

Kamdhenu University

Established by Government of Gujarat by Gujarat Act No. 9 of 2009.

Wing B1, 4th Floor, Karmyogi Bhavan, Block 1, Sector-10-A, Gandhinagar - 382010.

The Kamdhenu University is established and incorporated by the Government of Gujarat vide Kamdhenu University Act, 2009 (Gujarat Act No. 9 of 2009) as a teaching and affiliating university for the development of veterinary and animal sciences and for furthering the advancement of learning, conducting of research and dissemination of findings of research and other technical information in veterinary and animal sciences including dairy, fisheries and allied sciences in the state of Gujarat. Hon'ble Governor of Gujarat on July 7, 2009 assented the Act and a new era of research and education in veterinary and allied sciences including dairy and fisheries began in Gujarat. At present the Head Quarter of the University is at Gandhinagar. The territorial jurisdiction and privilege of the University is the entire state of Gujarat in respect of all constituent colleges, research and experimental stations as well as affiliated institutes. Prof. M. C. Varshneya, a renowned Agro-Meteorologist and Former Vice-Chancellor of Anand Agricultural University, Anand is the first Vice-Chancellor appointed by the Government of Gujarat. He assumed the office of Vice-Chancellor with effect from 19th August, 2014. The University offers following educational programmes in 13 institutes and colleges across the State of Gujarat.

POST GRADUATE PROGRAMME

Post Graduate Institute of Veterinary Education and Research, Gandhinagar.

Intake Capacity : 14 Students.

Programmes offered : M.V.Sc in Animal Genetics & Breeding, Livestock Production and Management, Animal Reproduction, Gynaecology and Obstetrics, Animal Nutrition.

Post Graduate Institute of Dairy Education and Research, Amreli. Intake Capacity : 09 Students.

Programme offered : M.Tech (Dairy) in Dairy Microbiology, Dairy Chemistry, Dairy Technology.

Post Graduate Institute of Fisheries Education and Research, Gandhinagar. Intake Capacity: 08 Students.

Programme offered : M.F.Sc in Aquaculture.

Ph.D PROGRAMME (AT PRESENT INSERVICE ONLY) :

Ph.D. (in Veterinary) - Animal Genetics & Breeding , Animal Reproduction, Gynaecology & Obstetrics.

Ph.D. (in Dairy) Microbiology & Dairy Chemistry.

BACHELOR DEGREE PROGRAMMES (4 YEAR) - B.Tech (Dairy Technology)

(INTAKE CAPACITY IN EACH COLLEGE : 40 STUDENTS)

CONSTITUENT COLLEGE

College of Dairy Science, Opp. Balbhavan, Library Road, Amreli-365601.

AFFILIATED COLLEGE

Mansinhbhai Institute of Dairy & Food Technology, Dudhsagar Dairy Campus, PO Box No-1, Highway, Mehsana - 384002.

DIPLOMA PROGRAMME - DIPLOMA IN ANIMAL HUSBANDRY (3-YEAR)

(INTAKE CAPACITY IN EACH POLYTECHNIC : 50 STUDENTS)

CONSTITUENT POLYTECHNIC

Polytechnic in Animal Husbandry, AT: Rajpur, (Nava) Campus, Himmatnagar - 383010.

AFFILIATED POLYTECHNIC

Polytechnic in Animal Husbandry, Shree Gram Seva Kendra, Khadsali, Ta. Savarkundala, Dist. Amreli - 364530.

Keshavam Polytechnic in Animal Husbandry, At & PO : Chhapi, Ta. Idar, Dist. Sabarkantha - 383230.

Navsarjan Polytechnic in Animal Husbandry, At. Ranchhodpura, PO. Devpura, Ta. Vijapur, Dist. Mehsana - 382870.

Riddhi Polytechnic in Animal Husbandry, Shree Riddhi Education Campus, Chandranagar Society, Motipura, Ta: Himmatnagar, Dist. Sabarkantha - 383001.

Vrundavan Polytechnic in Animal Husbandry, Tower Chowk, At., Po - Jasdan, Dist. Rajkot - 360050.

GVM Polytechnic in Animal Husbandry, At. Aniyad, Taluka Shahera, Dist. Panchmahal.

Nobel Polytechnic in Animal Husbandry, Nobel Campus, Bamangam Road, Dist. Junagadh.

UPL
યુપીએલ ના સૌથી વધુ અસરકારક ઉત્પાદનો
ઉલાલા, સાફ, લાન્સરગોલ્ડ અને ફોસકિલ
પ્રસિદ્ધ છે યુપીએલનું ઉલાલા સૌથી અસરદાર
તો પછી પ્રારંભિક છંટકાવથી શાને કરો ઈનકાર
સૌથી લાંબી અસર
લીલા ચૂસિયા
સફેદ માખી
મોલોમશી
અસર શરૂ માત્ર 30 મિનિટમાં
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INSECTICIDE
ઉલાલા
યુપીએલનું સાફ
ઉપયોગની સ્ટાઈલ જુદી હોઈ શકે છે,
સ્વસ્થ પાક સુનિશ્ચિત...
બહુઉપયોગી ફૂગનાશક
બીજ ઉપચાર
3 ગ્રામ/કિલો બીજના દરથી
અંકુરને ડૂબાડવા
૯ લિટર પાણીમાં 3 ગ્રામ
માટીને પલાળવી (સોઈલ ડ્રેંચિંગ)
3 ગ્રામ/લિટર પાણીના દરથી
પાન પર છંટકાવ
330 ગ્રામ/એકરના દરથી
SAAF
UPL
SAAF
FUNGICIDE
1 kg
साफ
યુપીએલનું લાન્સરગોલ્ડ
બીજા વારથી, કરો વાર દમદાર
એક એકર માં 500 ગ્રામ કરે વધુ કામ
દમદાર અસર આવે ૨ ચમચીમાં*
UPL
LANCERGOLD
INSECTICIDE
1 kg
લાન્સરગોલ્ડ
લીલા તડતડિયા
એફિડ/મોલો
થ્રીપ્સ
*લાન્સરગોલ્ડને પ્રતિ એકર ૫૦૦ ગ્રામ અથવા પ્રતિ નેપસેક પંપ ૫૦ ગ્રામ અથવા
પ્રતિ લિટર પાણી માં ૩ ગ્રામના હિસાબે ઉપયોગ કરો.
દેશનું સૌથી વધુ વેંચાતુ મોનો
યુપીએલનું ફોસકિલ
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યુપીએલ હાઉસ, ૬૧૦ બી/૨, બાંદ્રા વિલેજ,
ઑફ વેસ્ટર્ન એક્સપ્રેસ હાઈવે,
બાંદ્રા–પુર્વ, મુંબઈ ૪૦૦૦૫૧, ભારત.
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The land available for agriculture is decreasing rapidly. Now, more than ever, we need to increase our productivity and deliver more from less.

We at PI, are constantly in search of new answers. For more than 60 years, our line of products for rice crop such as Foratox®, Biovita®, Nominee®Gold, Osheen®, Vibrant® Kitazin®, Fluton®,Sanipeb, Bunker® etc. have been aiding farmers in improving their crop quality, increasing productivity and protecting their crops from insects, weeds and fungi. Today, we are helping to feed millions of hungry mouths while improving the farm income. Our comprehensive solution to enable the adoption of Direct Seeded Rice (DSR) has helped increase the farm income, conserving the precious natural resource, water. It is this technology that is helping us in building a better tomorrow.

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www.piindustries.com | mktg@piind.com

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સુમિત
બાગ & નર્સરી
બાગાયત ખાતા દ્વારા પ્રમાણીત.
• આંબા કલમોની ૬૮ વેરાયટી
• ચીકુ કલમ
• લીંબુ કલમ
• થાઈ નીમ
• ચંદન તથા અગર વુડ
• પેશન ફ્રુટ
જેવા અવનવા રોપા કલમોના વિક્રેતા
• વિષેશતાઓ :
• કેસર આંબા કલમ નુતન તથા ભેટ ગ્રાહકોની પસંદગીની સાઈજ માં ઉપલ્લધ
• નેશનલ હોર્ટીકલ્ચર બોર્ડ પ્રમાણીત નર્સરી
• ISO 9001-2008 પ્રમાણીત
• સોઈલ લેસ પ્લાન્ટ ઉપલબ્ધ
• પ્રમાણીત માતૃ છોડ માંથી વૈજ્ઞાનિક ઢબે તૈયાર કરેલ સમરૂપ કલમો.
નર્સરી : મુ. રતાંગ (ગીર), તા. વિસાવદર, જિ. જૂનાગઢ. ફોન/ફેક્સ : (૦૨૮૭૩) ૨૪૩૩૩૦
મો. ૯૯૨૫૦ ૭૯૦૮૭ મો. ૯૪૨૬૪ ૪૩૩૬૭
Email : sanjayc.vekaria@yahoo.com | sumitbaug1999@gamil.com
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શું આપ ઇશ્વરની આપેલી પ્રકૃતિ-પર્યાવરણને ચાહો છો...
શું આપ પૃથ્વીને ગ્લોબલ વોર્મીંગથી બચાવવાની ઇચ્છા ધરાવો છો...
શું આપને વિવિધ પ્રકારનાં વૃક્ષો-વનસ્પતિઓના રોપા-કલમો જોઇએ છે...
શું આપ લુપ્ત થઇ રહેલી દેશી પ્રજાતિનાં ઔષધિય છોડ વિશે જાણવા માંગો છો...
શું આપને એક સાથે એક જગ્યાએ ૨૦૦થી વધારે જાતનાં આંબાના વૃક્ષો જોવા છે...
?
જો ઉપરનાં પ્રશ્નો માટે આપનો જવાબ "હાં" હોય તો... એક વખત અવશ્ય મુલાકાત લો
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જયાં આપને મળશે...
હાફુસ, કેસર, રાજાપુરી, તોતાપુરી, જમાદાર, દૂધપેંડો, લંગડો સહિત આંબાની ૨૦૦ જેટલી વિવિધ જાતો કલમો
ગુલાબ, મોગરો, જાસુદ, રાતરાણી, ચંપો, ચમેલી, જુઇ, કમળ સહિત અવનવી જાતના ફૂલઝાડની કલમો
નાળીયેરી, બોરડી, જાંબુ, લીંબુ, સફરજન, દાડમ, ચીકુ, જામફળ, પપૈયા, કેળા વગેરે ફળઝાડની શુદ્ધ કલમો
આમળા, હરડે, બહેડા, કૌંચા, ગોખરૂ, કુંવારપાઠું, કેતકી, અરીઠા, અશોક તથા અનેકવિધ આયુર્વેદિક વનસ્પતિ
ઉપરાંત સાગ, ખાખરો લુપ્ત થતા દેશી જંગલી ઝાડ તેમજ તમામ પ્રકારના રોપા - કલમ બનાવનાર તથા વેંચનાર
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તાલાલા પંથકના સૌ કિસાનભાઈઓને રાષ્ટ્રીય પર્વની શુભકામનાઓ
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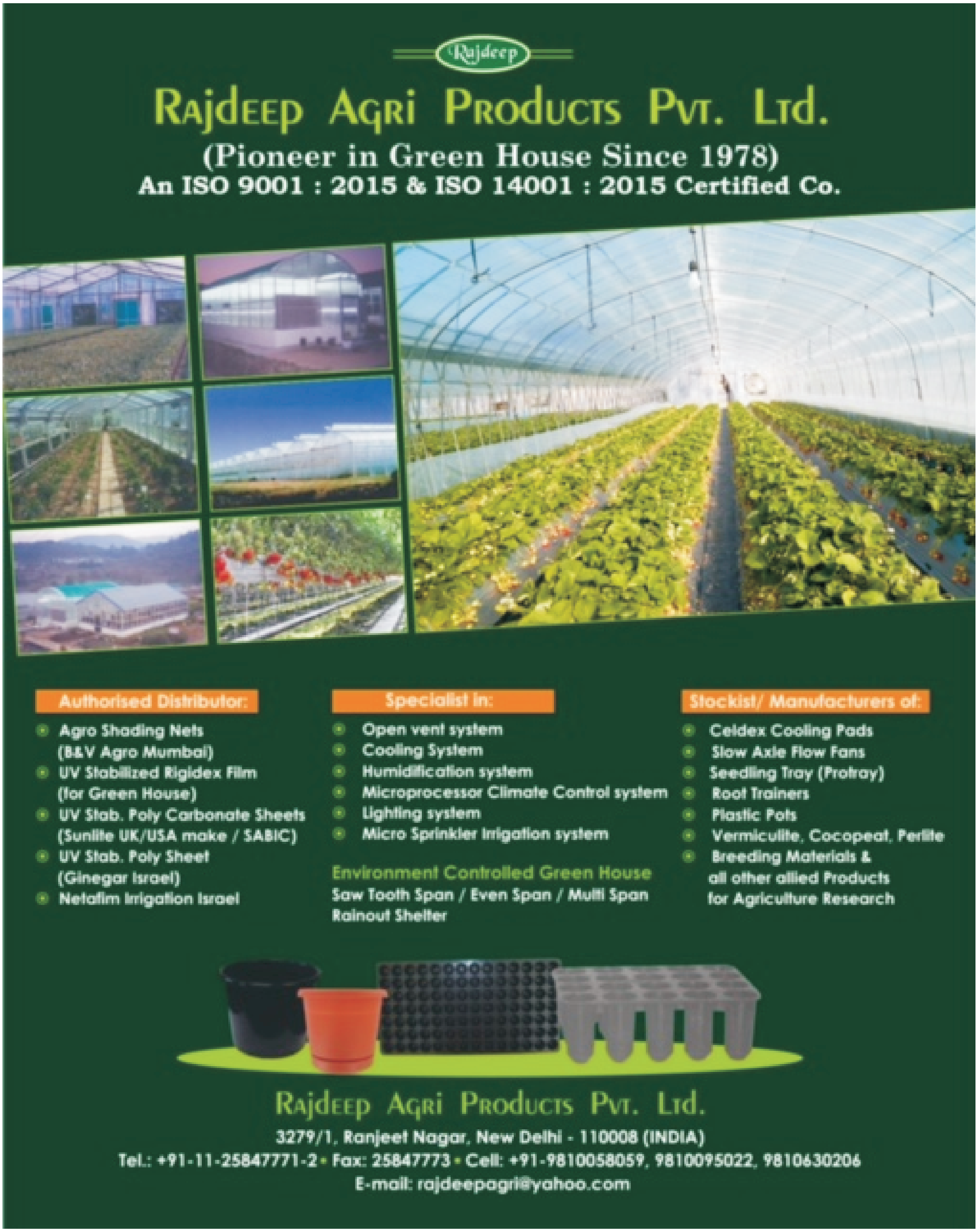
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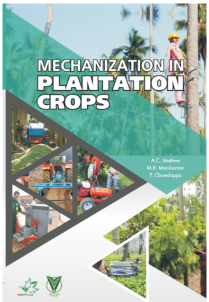

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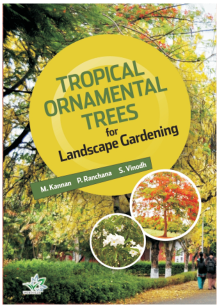

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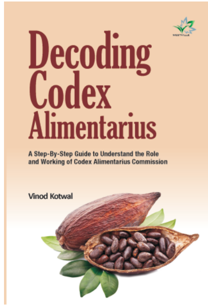

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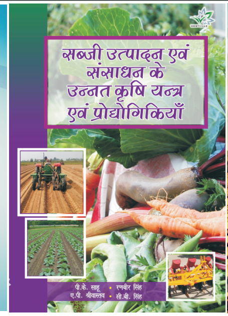

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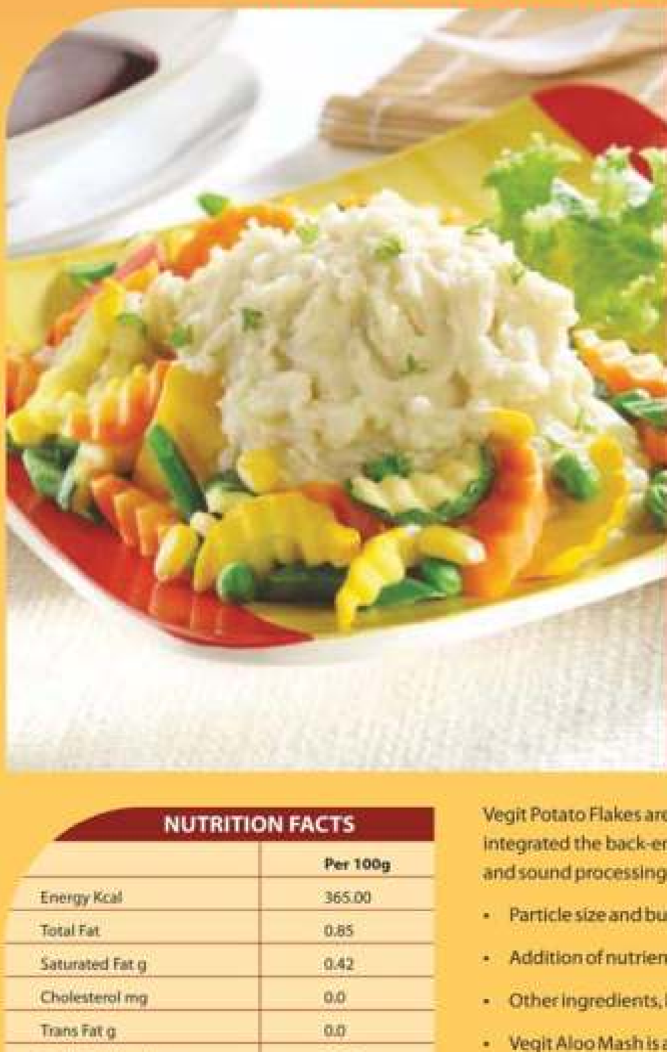

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	Per 100g
Energy Kcal	365.00
Total Fat	0.85
Saturated Fat g	0.42
Cholesterol mg	0.0
Trans Fat g	0.0
Total Carbohydrate g	79.0
Protein g	10.4
Dietary Fibre g	12.9
Sugar g	0.0
Sodium mg	62.0
Vitamin A mg	160.0
Vitamin C mg	30.8
Iron mg	2.5

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