SHODH CHINTAN

Volume 6

Navsari Agricultural University
Navsari- 396 450, Gujarat

कृषिमूला ऋध्दिः

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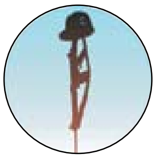

6th Swadesh Prem Jagriti Sangosthi- 2014

Global Conference on Technological Challenges and Human Resources for Climate Smart Horticulture - Issues and Strategies

Lt. Amit Singh Memorial Foundation

28-31 May, 2014
NAU, Navsari, Gujarat

SHODH CHINTAN - 2014

Organised by

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In collaboration with

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Confederation of Horticulture Associations of India (CHAI), New Delhi

Synergy Partners

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MESSAGE

I am happy to know that ASM Foundation, New Delhi and Navsari Agriculture University, Navsari, Gujarat is jointly organizing the 6th Swadesh Prem Jagriti Sangosthi (SPJS) and a Global Conference on Technological Challenges and Human Resources for Climate Smart Horticulture- Issues and Strategies, on 28-31 May, 2014.

Integrated efforts of science and technology, in consonance with socio-economics, an approach to address the emerging issues related to food and nutrition, complimented with information technology, referred to as a Smart Horticulture, is attracting attention word-wide, for producing more to feed growing population with declining land and water in the scenario of climate change. This essentially needs understanding of the current status of knowledge on technological challenges and commensurating requirement of human resources to service climate smart horticulture. Therefore, organising of this Global Conference is timely, to take a stock of situation and plan strategies to address emerging challenges.

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

I wish the Global Conference and Sangosthi, a great success.

(S. Ayyappan)

Dated the 5th May, 2014
New Delhi

From the Desk's of Chairman….

You will agree with me that, in the ancient and modern vision of patriotism, individual responsibility to fellow citizens is an inherent component of patriotism. One of the philosophers has defined patriotism as devotion to humanity and beneficence. Therefore, in this endeavour, Lt. AmitSingh 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 agriculture/horticulture for farmers. The ASM Foundation is working for fulfilling the objectives and mandate of Foundation, and is happy that foundation is altogether implementing the proposed programmes, and is bringing out overall development of themarginalised people, in all aspects, and taking them towards self- sufficiency.

Inspired by the past efforts, the ASM Foundation organized the 5th SwadeshPremJagritiSangosthi 2013 (SPJS- 2013) at the **Jain Irrigation Systems Limited, Jains Hill, Jalgaon** 28-31st May, 2013. It comprised of **International** conference on water quality and management for food, climate resilient hort agriculture, Mango Diversity Show, farmers' quiz,essay competition, mango eating competition,award function and visit to techno parks at campus of JISL, Jalgaon, in furtherance of the goal of the Foundation. The Sangosthi platform was shared by diverse group of stakeholders, such as farmers, workers, scientists, entrepreneurs, industrialists, policy planners, which facilitated an effective interaction.

The participation of diverse group of people from India and abroad was the uniqueness of the Sangosthi which benefitted large number of people including youth and farmers. The ASM Foundation is extremely grateful to HonourableShriBhola Prasad Singh, Member of Parliament, Padma Bhushan Dr. R. S.Paroda, Chairman,Farmers' Commission Haryana, Padma ShriDr. B. H. Jain, Chairman, JISL, Jalgaon Dr.Gurubachan Singh, Chairman, ASRB, New Delhi, Dr. A. R.Pathak,Vice-Chancellor, Navsari Agricultural University, and to all Directors,Coordinators, scientists, representatives of Industries, entrepreneurs, scientist and farmers to grace the occasion. The activities during the year also included, distribution of seeds, bags to school children, demonstration of new technologies to farmers and confidence building in youth.

In the honour of Lt. Amit Singh, “ShahidDiwas” was observed on 3rd September 2013 under chairmanship of Dr S K Mittal, Vice- Chancellor, Rajendra Agricultural University, Pusa, Samastipur, a one day KisanGosthi was arranged and seed of hybrid maize and mustard and also vegetable seeds were distributed. Apart from the above, the ASM Foundation office at Mahamada also executed several activities for the benefit of children by providing them education and vocational support besides celebrating the Independence Day and Republic day. This office is involved in several activities to improve livelihood and socio-economic condition of the rural people. Notable among them are: technology dissemination of improved agricultural technology and distribution of seeds of stress tolerant varieties of paddy Swarna-sub-1. The Foundation also organized KisanGosthi at many locations which was attended by many farmers. Managing trustee MrsBimala Singh visited fields of farmers along with Dr H P Singh to motivate them for improved practice and diversification.

ASM foundation has also instituted many awards for various categories viz., AmitKrishi Rishi Award, Amit Padma Jagriti Award, AmitPrabudhManishi Award, AmitSwah Award, to confer on the achieves, who have outstandingly contributed in Indian Agriculture and have dedicated their service to Nation. UdyanRatan Award, Lt. Amit Singh Memorial Award for best Coordinating Centre of AICRP Vegetables and Palms, AmitAgrani Award, National Talent Search for Technical Understanding and National Elocution/Essay Competition for school students has now become a regular phenomenon.

I take this opportunity to express my sincere gratitude to all the staff, volunteers and well-wishers of the foundation, who are working hard incessantly for achieving the objectives of the Foundation. I also congratulate all farmers/ students/ delegates/ guests who have contributed significantly during the last SPJS- 2013, and owe the entire credit for our successful journey into 2013-2014 and helped in preparation for the activities of especially, Global Conferencebeing organised at Navsari. I have a great pleasure in presenting to you this “Shodh Chintan-2014”especially published to commemorate the occasion. The Sodhchintan has articles under education, ethics and values and technologies related to Smart Horticulture.I am sure you will find “ShodhChintan” highly useful document which can be referre to, again and again.

May God bless you all “Jai Jawan Jai Kisan, Jai Hindustan”

About ASM Foundation

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; organising 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 its aims and objectives, the Foundation organised it s first SwadeshPremJagritiSangosthi (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 Sangosthi which included the activities like inauguration of SmritiBhawan, 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 an annual feature of the activities of the foundation. Besides farmers, students and scientists, some prominent political personalities also attended the event. Since then the Foundation has organised 2nd Swadesh Prem Jagriti Sangosthi(SPJS) in 2010 and 3rdSPJS in 2011 in Bangalore and Dehradun respectively. Both these events were a great success. 4th Swadesh Prem Jagriti Sangosthi wasorganised from 27-31 May,2012 at QUAT, Bhubaneswar, and 5thSPJS wasorganisedw.e.f May 28-31, 2013, atJISL Jalgaon, Maharashtra. Now 6th SPJS is being organised at NAU, Navsari. 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 which include,AmitKrishi Rishi Award, Amit Padma Jagriti Award, AmitPrabudhManishi Award, AmitSwah Award,UdyanRatna Award, AmitAgrani Award, National Talent Award in Horticulture, Best All Rounder Awards (for school students), Lt. Amit Singh Memorial Best Performing Centre of AICRP on Vegetables, Lt. Amit Singh Memorial Best Performing Centre of AICRP on Palms, and Lt. Amit Singh Memorial Best Performing Centre of AICRP on Tropical fruits. The recipients of these awardsare 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 their respective 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.

Foundation is registered under the Indian Trust Act, and under section 12 A & 80G of Income Tax Act,1961. It is also registered with FCRA of Ministry of Home Affairs. During the year of foundation has been register for ISO900/I 2008. Currently, foundation has regional center at Nalanda /Patna besides head office in Delhi. During the last year, small office was also opened at Dubai. Now, the activities haveextended to implementation of programmes in collaboration with IRRI and Biodiversity International.

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

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

Bimala Singh
Managing Trustee

Neeta Singh
Trustee

Prof (Dr.) Babita Singh
Trustee

About the Organizers

Mrs. Bimla Singh
Managing Trustee

ASM Foundation, an ISO 9001:2008 certified organisations is committed to economic development and knowledge empowerment of people through various activities. It has headquarter 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 conferrers awards in various categories to recognise the contribution of individuals/ organisation.

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Dr. A. R. Pathak
Vice Chancellor

Navsari Agricultural University establish under integrated system of research, education and extension education caters to the needs for agricultural, horticultural and forestry, veterinary and agri-business management of south Gujarat with a intake capacity of 300 student annually and is in the forefront of technology development in India, particularly, in Gujarat. The students trained in NAU are catering to needs of technological upgradation and developments.

About the Collaborators

Dr. H. P. Singh
Chairman

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 having commitment for addressing global concern and providing innovative solutions. The aims of CHAI is 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, newsletter and books. To bring the competitiveness the CHAI has instituted various awards to motivate the innovators for the excellence in research, education, extension, teaching and farming.

Dr . B H Jain
Chairman

Jain Irrigation Systems Ltd. known as **JISL**, India, is an multinational organization with global presence in 120 countries, provides solution for efficient management of water, protection 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 awards and many International recognitions.

Horticultural Society of Gujarat (HSG), founded in April 1994, with the objective to advance the art and science of Horticulture in Gujarat as well as the country, is involved in organizing seminars, exhibitions, horticulture shows, framers meets and publications for communications in science. The HSG caters to needs of the horticulture community including research scientist, farmers and students.

Dr. N. L. Patel
President

Synergy Partners

Indian Society of Mycology and Plant Pathology(ISMPP), Udaipur established in 1969 publishes Indian Journal of Mycology and Plant Pathology quarterly. The other activities of the Society include organizing Annual Conferences. The Society has instituted many awards to encourage young scientists. More than 1500 members are contributing to the growth of the society by knowledge upgradation regarding protecting plants from diseases.

PHD Chamber of Commerce and Industry, established in 1905, is a proactive and dynamic multi-State apex organisation working at the grass-root level, with strong national and international linkages. The Chamber acts as a catalyst in the promotion of industry, trade and entrepreneurship and contributes significantly to socio-economic development and capacity building in several fields. through institutional linkages with over 60 important foreign Chambers of Commerce.The chamber has now, focused attention on agriculture and agribusines, under the Chairmanship of Shri N M Kejriwal, to generate awareness amongst the members about the potential and need for value addition to enhance the income of the farmers.

ASSOCHAM, established in 1920, has more than 300 Chambers and Trade Associations and is serving more than 4 lakh direct and indirect members from all over India and has been in the forefront to encourage knowledge sharing by way of facilitating interactions. operates through 90 Expert Committees that provide interactive platform in formulating policy recommendations to facilitate economic, industrial and social growth. Agriculture & Food Security committee the priority sec chaired by Shri Anil Jain, Managing Director, Jain Irrigation Systems Ltd, has been successful in sensitising the various stakeholders involved for boosting the growth of agricultural sector in the country by organising training programs, workshops and seminars.

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Horticulture Research, Education and Development in Historical Perspective- A Way Forward

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Horticulture, comes from the Latin word hortus, meaning, "garden" and cultūra meaning "cultivation" and it refers to plants, gardening, people working in the horticultural industries, which has impact on human activities. More precisely, horticulture indicates importance of plants, their cultivation and their uses for sustainable human existence. The horticulture is thus, the science and art of cultivation of gardens, orchards, flowers, fruits, vegetables, or ornamental plants resulting in the development of minds and emotions of individuals, the enrichment and health of communities, and the integration of the garden in the breadth of modern civilisation. Growing of perennial plants and trees for commercial purposes is referred to as orchard, while trees or herbs grown for aesthetic values or environmental services are referred to, as the garden. When orchards or tree plantation are continuously grown for commerce is referred as plantation crops.

Horticulture Beyond Gardening

Horticulture, primarily differs from agriculture in two ways, firstly, it generally encompasses a smaller scale of cultivation, using small plots of mixed crops rather than large fields of single crops. Secondly, horticultural cultivations, generally, include a wide variety of crops, even including fruit trees with ground crops and is grown in diverse ago-ecological situations. Appropriately, horticulture is the science, technology, and business involved in intensive plant cultivation for human use. It is practiced from the individual level in a garden up to the activities of a multinational corporation. Horticulture is very diverse in its activities, incorporating plants for food (fruits, vegetables, mushrooms, culinary herbs) and non-food crops (flowers, trees and shrubs, turf-grass, and medicinal herbs). It also includes related services in plant conservation, landscape restoration, landscape and garden design / construction / maintenance, arboriculture, horticultural therapy, and much more. This range of food, medicinal, environmental, and social products and services are all fundamental to developing and maintaining human health and well-being. Saying is true that the life starts with horticulture and ends with horticulture. Earlier the horticulture was largely confined to rural area and was hobby, but faster urbanisation, coupled with health consciousness has brought the horticulture on forefront, with advanced technologies, and now horticulture is a science and technology.

Horticulture Research and Development

Research is creation of knowledge and it's utilisation for the benefits of mankind is the development. Research brings the knowledge which is converted in to a technology and becomes a driver of growth with appropriate policy environment and needed investment. As the research in horticulture is concerned, it started with the turn of civilisation, largely to select useful plants and domesticate it for uses of mankind. As per the needs, new technologies for growing plant were developed, which became a family tradition to bring new knowledge, as at that time horticulture was a hobby. Many of cultivars, which are popular know also were selected, domesticated and were used for cultivation. Greenhouse technology was developed to grow vegetable and flowers out of season. Similarly propagation technique was developed to get true to type plants especially in perennial plants. However organised research was done under the schemes in mid of twenty century which was strengthened in eighties and subsequently. However, systematic development of horticulture started in 9th ninth plan with focus on investment and policy which has impacted the production, profitability, availability and above all environmental services. Details of research infrastructure and development are presented in subsequent chapter. Although, horticulture is fastest end growing sector in India, with growth rate of above seven per cent, challenges are much greater, to produce more for growing population from declining land and water in the scenario climate change. Therefore, to address the future challenges of, complimenting food, meeting nutritional needs, healthcare and providing environmental services research and development strategies have to be for Climate Smart Horticulture. Smart Horticulture is an integrated efforts of science and technology in consonance with socio-economics to address the issues related to food and nutrition, complimented with information technology. Thus, it is a challenge of technology coupled with human resource, necessitating strategic research, education and development.

Needs of Education in Horticulture

Growing population, rapid urbanisation, coupled with concern for human and environmental health are demanding rapid development of horticultural produces, engaging more work force and farmers to shift to horticultural crops, and adopt new tools techniques, to produces more, from less land and water, with new opportunities. In this content, not only the production, but efficient value chain management, addressing all the links in the chain of production to consumption, is inevitable, which will need highly skilled and trained human resources, who can take forward the development. Since, there is a shift to horticulture, as it has proved to be intellectually satisfying and economically rewarding, consequently, trend in youth is to adopt horticulture as their career, at the same times, new tools and technologies have seen its adoption in horticulture for enhanced efficiency. Traditional horticulture is no more relevant, necessitating science driven and technology-led development. Therefore, to keep pace with development of horticulture, required human resources have to be made available. Consequently, it is imperative to understand the status, the driver (developmental needs) and orient and reorient horticulture education to meet ever increasing demand of well trained and skilled human resources. These developments necessitate for the enhanced availability of skilled, efficient and knowledge empowered human resources through education and training. Accordingly, an attempt is made to analyse the status, needs, gaps and provide strategic direction to horticulture education, a way forward considering its relevance in changing dynamics and emerging challenges, as it need much more attention than before.

Horticulture Research, Education and Development-Historical Perspective

Origin and History of Horticulture

Origins of horticulture are intimately associated with the history of humanity. The study and science of horticulture dates all the way back to the times of Cyrus the Great of ancient Persia, and has been going on ever since, with present day horticulture. The practice of horticulture can be retraced for many thousands of years. The origins of horticulture lie in the transition of human communities from nomadic hunter-gatherers to sedentary or semi-sedentary horticultural communities, cultivating a variety of crops on a small scale around their dwellings or in specialised plots, visited occasionally during migrations from one area to the next. Mention of horticulture in all the ancient literature, *Ramayana, Mahabharata* and *Purana,* is a testimony for its association with history of humanity. A characteristic of horticultural communities is that, useful trees are often found planted around communities or specially retained from the natural ecosystem, and, it can be said that horticulture encompasses all life and bridges the gap between science, art and human beings. This broader vision of horticulture embraces plants, including the multitude of products and activities (oxygen, food, medicine, clothing, shelter, celebration or remembrance) essential for human survival, and people, whose active and passive involvement with "the garden" brings about benefits to them as individuals and, to the communities and cultures they encompass. Horticultural science encompasses all of the pure sciences – mathematics, physics, chemistry, geology, and biology – as well as related sciences and technologies that underpin horticulture, such as plant pathology, soil science, entomology, weed science, and many other scientific disciplines for knowledge, skills, technologies, education and commerce. It also includes the social sciences, such as education, commerce, marketing, healthcare and therapies that enhance contribution of horticulture to society.

A Historical Perspective of Indian Horticulture

In India too, horticulture profession is as old as civilisation but its development in the country has different phases of growth. The practicing horticulturists of the communities, in the past, were also differentiated with their trade, which they adopted, like gardening and vegetable cultivation, as they had specialisation. Kings and *Jamindar* promoted horticulture in the form of gardens and orchards for their pleasantry as hobby, which helped in conservation of plants and practices. While describing the current horticulture in India, we have to track it as pre-independence and post independence. Pre- independence horticulture is referred to as first phase development, characterised 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) is characterised 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 (2001-2011) is characterised by innovations, large scale adoption of technology like micro-irrigation, protected cultivation, precision farming –a way forward, 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 268 million tones, but challenges to produce more from limited land and water in the scenario of climate change has become a task demanding more innovations.

The Content of Horticulture Education

In horticultural education, which is infusion of knowledge and skills, the content must have relevance for the whole of the horticultural industry. In particular, concepts for the production of plants and plant-based products from the test tube to the field and to protected cultivation in greenhouses, or other closed production systems. The course must enable for an understanding of material and energy flows in horticultural cropping systems, a perception of external factors that have impact on crop quality. The horticultural education must have to focus on economic thinking and economic models, which intends to make possible an understanding of the market economy and behavior of businesses in horticulture. The founding principles of business management have to be taught ranging from production to marketing and distribution of products, which is generally referred as value chain management in horticulture. Therefore, horticulture education must have to provide innovative teaching, research, and outreach in the art and science of horticulture. These programs should encompass the basic biology, ecology, production and utilisation of horticultural products including fruits, vegetables, flowers, and landscape plants. The major goal of education should be to meet the changing challenges of a highly competitive and technological world, through, constant evaluation and adjustment of its programs and positions.

Employment Focus of Horticulture Education

Horticulturists must have the knowledge, skills, and technologies used for growing intensively produced plants for human food and non-food uses and for personal or social needs. Their work shall involve plant propagation and cultivation with the aim of improving plant growth, yields, quality, nutritional value, and resistance to insects, diseases, and environmental stresses. As they may have to work in different capacity, depending on the job requirement, gardeners, growers, therapists, designers, and technical advisors in the food and non-food sectors of horticulture. Thus, horticulture involves various areas of study. Two broad sections are: ornamentals and edible horticulture. Arboriculture is the study of plants and the selection, planting, care, and removal of individual trees, shrubs, vines, and other perennial woody plants, Landscape horticulture includes the production, marketing and maintenance of landscape plants including turf management, while, floriculture includes the production and marketing of floral crops and potted plants. Edible horticulture includes *Olericulture,* which are production and marketing of vegetables, *Pomology* which is the production and marketing of fruits. Post-harvest physiology involves maintaining the quality of edible horticulture and preventing the spoilage of plants and its products. As per the need environmental horticulture and health horticulture have also emerged as new sections in horticulture.

Horticulture in Trade and Business

A horticulturist could be systems engineers, wholesale or retail business managers, propagators and tissue culture specialists (fruits, vegetables, ornamentals, and turf), crop inspectors, crop production advisers, extension specialists, plant breeders and research scientists. They may have to work on genetics, physiology, computer science, communications, garden design, planting design and many more aspects related to horticulture. Thus horticulture courses include, plant materials, plant propagation, tissue culture, crop production, post-harvest handling, plant breeding, pollination management, crop nutrition, entomology, plant pathology, economics, and business. Manpower trained appropriately in horticulture can only take forward the horticulture for the benefit of mankind. Since, horticulture is the applied plant biology that encompasses the art and science of plant production and discipline's range is broad, making it a home for a diverse array of people, projects and possibilities. Hence, the mission of horticulture education should be to prepare students for careers with a broad base of horticultural knowledge, develop research-based knowledge for efficient and profitable horticultural production, improve the competitive position of horticultural industry, facilitate to increase the quality, variety, and availability of horticultural products; and deliver research-based knowledge about the ways horticulture improves the environment and serves as a source of personal enjoyment.

Indian Horticulture- Past, Present and Future

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. Globalisation of agriculture has opened 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, which 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.

Indian horticulture is the core sector of agriculture, 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.

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

Commodity	Production (million tons)			
	1991-92	2007-08	2010-11	2016-2017
Fruits	28.63	63.50	74.87	98.00
Vegetables	58.53	125.89	146.55	220.20
Spices	1.90	4. 10	5.35	5.50
Flowers	-	0.87	1.08	1.50
Plantation Crops	7.49	11.30	12.38	15.60
Total	96.95	207.01	240.5	333.8

Source: Singh, HP, 2007, Indian Horticulture, 52(4); NHB, 2013

Horticulture Development in Historical Perspective

The analysis for Horticulture development in India can be divided into five phases. The first phase involved the period prior to the independence of the country, second phase the period between 1948-1980, third phase between 1980- 1991 and fourth phase between 1991-2000 (Table 2) and fifth phase between 2000-2010.

The pre-independence horticulture was growing of flowers or fruits around house, characterised by selection of plants based on performance and conservation of few cultivars by vegetative methods of propagation. No science was involved in horticulture, but it was a profession of specific community. Growing of many horticulture crops was a household activity and crops were grown as pleasantry. Thus, during the period Kings, *Jamindars* and *Jagridars* adopted the enterprises as status symbol. Some of the horticultural crops especially yams & tubers continued to provide food for the poor. The second phase of the developmentof horticulture, covered the years which were influenced by indigenous thinking of sectoral growth of commodity, in the regions of importance, which included coconut, areca-nut and spices development through institutional support systems in coastal southern states. This phase also saw the emphasis on the development of fruits in tropical and subtropical regions, through the establishment of centres. This phase also witnessed the establishment of research institutions devoted to the horticulture. During the period only few crops were favoured and growth was limited to expansion of area. Use of fertiliser and chemicals were not known. The farmers were constrained for technology and resource availability. In this phase, with planned development of agriculture, few selected crops of horticulture got fillip, through the creation of infrastructure especially irrigation. During the period there were limited research supports but development process of horticulture started. Major emphasis continued on development of propagation techniques, identification of suitable crops, and rejuvenation of orchards. Since, achieving the self-sufficiency was focus of agriculture, thus limited efforts were made for the horticulture.

These smaller efforts and few success stories in horticulture during this period paved the way for planned development in horticulture both at central and state levels.

Table2: Phases of horticulture development in India

Phase	Time Period	Specific Characteristics
• First Phase	Pre-independence	Horticulture as a whole was not considered, but efforts were made to grow fruits, vegetables, flowers, spices in isolated manner
• Second Phase	1948-1980	No planned efforts, but specific problems were addressed. Technical support and development efforts were made for specific commodity like- spices, coconut, potato, citrus, onion etc.
• Third Phase	1980-1992	Consolation of institutional support and starting of plan process for the development of horticulture.
• Fourth Phase	1993—2000	Focused attention to horticulture with an enhancement of plan allocation, knowledge based technology driven efforts for the development, heralding the “Golden Revolution”
• Fifth Phase	2001-2010	Horticulture is seen as means of food and nutritional security, livelihood and health care. This phase is characterised by innovations, use of innovative technologies and improved investment for research and development.

Third phase is considered as a period of consolidation both for research and development. At central level, highest level positions in development (Horticulture Commissioner) and research (Deputy Director General) were created and efforts for development were triggered. Many states, provided attention to horticulture, recognizing its role in nutritional security, employment generation and enhancing the farm income. Central institute and directorates were established, which benefited farmers in adoption of improved technology. Seed policy introduced during the period triggered the use of improved varieties and technology. Efforts during the period which improved the income of farmers paved the way for strategically planned development of horticulture. Marked technological changes in **fourth phase of growth** recorded quantum jump in plan allocation, formation of association by farmers, unprecedented increase in production and enhanced availability of produce. During this period there has been a quantum jump in production and export of flower and introduction of new crops. This phase of development witnessed enhanced support for research and development, initiation of mission mode approach and adoption of newer technologies like micro-irrigation, fertigation, *in-vitro* propagated plants and growing of high value crop under greenhouse condition. The period served as transition from traditional horticulture to hi-tech horticulture and precision farming approach. Organic horticulture, quality management and safety also got the focus during the period.

The **fifth phase of horticulture** research and development is characterised by large scale adoption of innovations like micro-propagation, protected cultivation, use of *in vitro* propagated

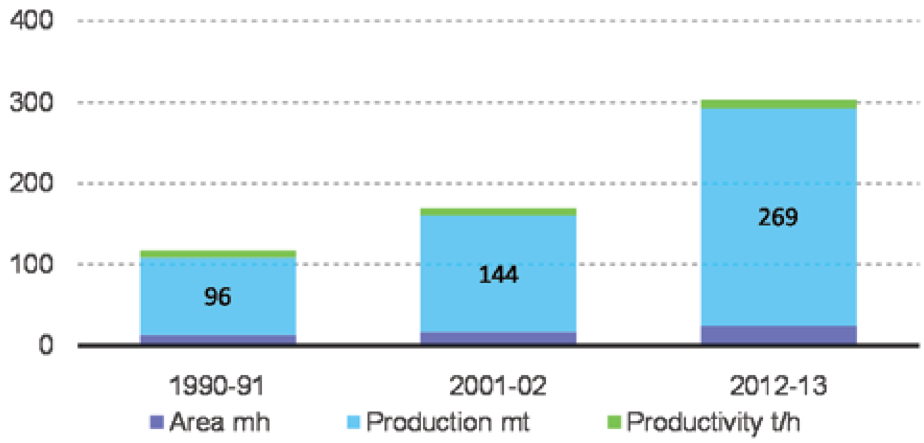

Fig. 1 Area, production, and productivity of horticultural produce

plants and diagnostics. The enhanced investment in mission mode through launching of various mission mode programme for development in research and development is also witnessed in this period. Research output supported by investment has made quantum jump in production (Fig. 1), productivity, availability and export and many newer crops were introduced, which were not known before. This trend of development has been marked as "Golden Revolution". This phase achieved the growth rate of 6.5% and contribution of horticulture to GDP of agriculture has increased to 30.4%. There is growing interest in horticulture, since it is considered intellectually satisfying and economically rewarding. Many new enterprises are noticeable in horticulture across the country including the sales of fruits and vegetables in super market.

History of 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 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 Agricultural 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, 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 Trawancore-Cochine State, systematic research through Ad-hoc project started in 1951, which got fillip with the establishment of Central Tuber Crops Research Institute 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 flavour 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 5 century old, which came to India in 1498. From Goa it spread to Konkan and then to Kerala, Karnataka, Tamil Nadu, Andhra Pradesh and Orrisa. 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 centres 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 Moughals in India during 16th and 17th 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.

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, there 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 utilisation of waste lands, employment generation and effective land use planning. Diversification, recognised 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 (Table3).

Contribution of horticulture to GDP of Agriculture, which was only 0.58 percent during 1952-53, with total production of 25 million tons increased to 18 percent from 6% area in 1991-92 and subsequently to 34.45 percent of agricultural GDP from 11.5 percent area in 2012-13 with production of 268.9 million tons from 23.69 million hectare area. Crop diversification to horticulture has also improved the employment opportunity, which increased sharply between 2000 and 2010. Among the horticulture crops, fruit crops recorded a two fold increase in area and three folds increase in production (Table 3). India emerged as second largest producer of fruits (81.28 million ton) obtained from 6.89 million ha area; contributing 14.2 per cent share in global fruit production. India occupies first place in the production of mango, banana, papaya, pomegranate, sapota and aonla. The productivity of grape is the highest in the world. Production and productivity of banana and sapota is the highest in world. However productivity in citrus, mango, apple, guava and pineapple continue to be lower than the world averages.

Table 3. Production of horticulture produce, fruits, vegetable, spices, plantation crops, nuts in time scale

Commodity	Production (million tons)								
	Area			Production			Productivity		
	1991-92	2002-03	2012-13	1991-92	2002-03	2012-13	1991-92	2002-03	2012-13
Fruits	2.87	3.79	6.89	28.63	45.20	81.28	9.97	11.93	11.79
Vegetables	5.59	6.09	9.21	58.53	84.81	162.18	10.47	13.92	17.60
Flowers	NA	0.07	0.23	NA	0.74	1.77 Loose 76.73 Cut	NA	10.57	7.69
Nuts	NA	0.12		NA	0.12	-	NA	1.00	-
Aroma. & Medi. Crop	NA	NA	0.56	NA	NA	0.92	NA	NA	1.64

Plantation	2.30	2.98	3.64	7.50	9.70	16.98	3.26	3.25	4.66
Spices	2.01	3.22	3.07	1.90	3.77	5.74	0.94	1.17	1.86
Mushroom	NA	NA		NA	0.04	-	NA	NA	NA
Honey	NA	NA		NA	0.01	-	NA	NA	NA
Grand Total	12.77	16.27	23.69	96.60	144.38	268.84	7.56	8.87	11.34

A=Area (in million ha), P=Production(in million metric tons), Source NHB, 2012-13: Indian Horticulture Data base

Production of vegetables has increased manifold to the tune of 162.18 million tons from 9.21m ha area (Table 3), contributing 11.50 percent to global vegetable production. Commercial floriculture have recorded faster pace of growth during the last decade. Medicinal and aromatic plants, which have immense potential got due recognition in the decade. India continues to be the largest producer, consumer and exporter of spices and spice products in the world, producing more than 50 spices. India is also a leading producer of plantation crops in the world and with contribution of 22.34% in coconut, 25% in cashewnut and 55% in arecanut. The diversification through horticulture has proved best option for the farmers to meet the need for food, nutrition, health care besides providing better returns on farm land and employment. The contribution of horticultural produce towards the value expressed in terms of per cent have increased from 18% in1991-92 to 34.45 in 2012-13 , while this contribution decreased for cereals and pulses. This sector has contributed significantly in generating employment opportunities, which has increased 7 fold from 100 man days in the year 1990-91 to more than 700 man days in the year 2007-08. Resultantly, horticulture has been 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 between 1991-2003, 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 labour became focus of development(Table4). 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 given in Table 4.

Table 4. List of technologies that transformed horticulture

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

Policy Changes for the Development of Horticulture

National Agriculture Policy 2000 has categorically emphasised on integrated development of horticulture, which should be knowledge based, technology driven and farmers' centric. The policy also emphasised 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.

Emerging Challenges to Horticulture Research and Development in India

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 1180 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

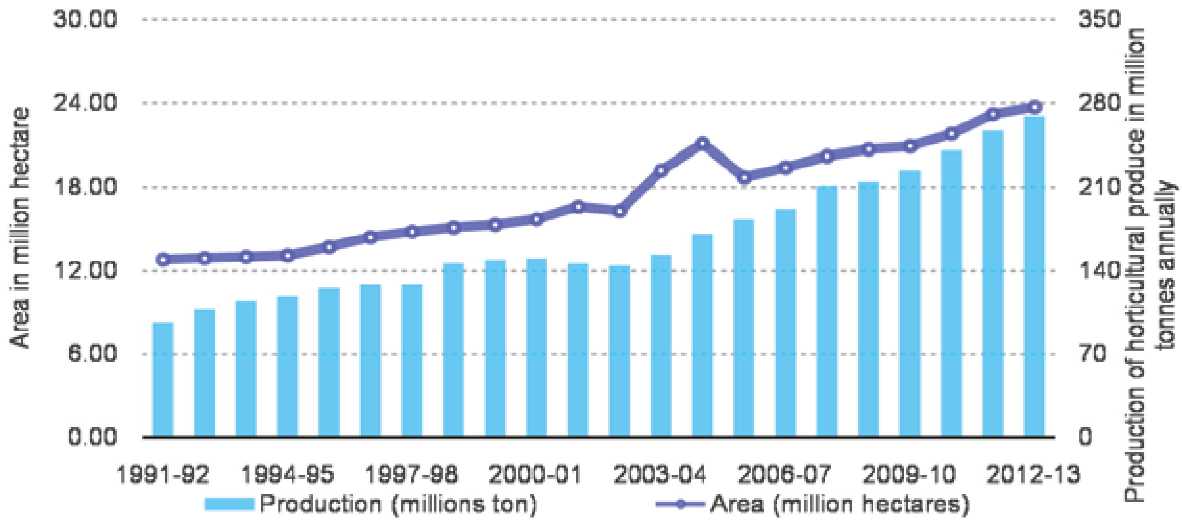

Fig. 2. Trend in area and production of horticultural produce in two decades

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 behaviour and nutritional requirements has to be addressed though the drive of science and technology, backed by enabling environments, resource utilisation 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.3).

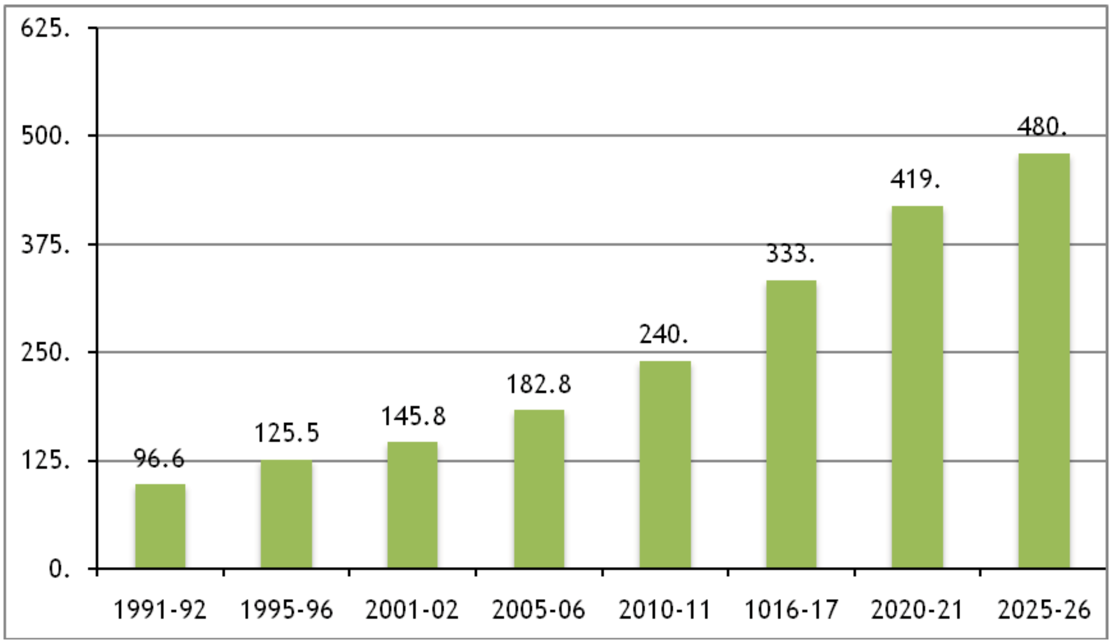

Fig. 3. Trend of horticulture production and future projections (Million tons)

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 percent vegetables and 15 percent fruits of the world, its penetration is global market is only 17 percent and 0.5 percent, respectively. Although we may have satisfaction of achieving above 6 percent growth rate and reaching to production level of 269 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.

Research and Development Initiatives Needed to Address the Changes of Horticulture

Most significant change in the last two decades has been in the use of technologies and private sector investment for production system management. Investment made in horticulture during plans have been highly productive in transforming an agrarian economy in many states, which has provided insight for reversing the trend of ever declining farmers' income and, above all addressing the nutritional security and environmental concerns. Impact of change in technologies like new cultivars and production system management is visible in terms of increased production and productivity, which has recorded ten-fold increase (268 million tons during 2012-13) from the level of 25 million tons in 1950-51. Undoubtedly, horticulture sector has moved dynamically despite numerous challenges and shortcomings, and is in crucial phase of development needing initiatives for sustainable development. To achieve the targeted production,stipulated in previous paragraphs, vertical growth, through the use of new cultivars, efficient water and nutrient management, effective plant health management coupled with strategies for reduced post-harvest losses with empowered human resources could be the approach, which would need appropriate innovations and investment. Protected cultivation has shown yield enhancement up to 4 times, but would need investment. Plant architectural engineering and management can mitigate the problem associated with seasonality in many crops and the enhanced efficiency in water management, utilising modern techniques, shall reduce water stress. Since, horticulture provides variability and has potential to adjust in different agro-climatic situation, technology-led development is inevitable, where in horticulture education to empower the youth with new knowledge become essential.

Research Infrastructure: The Indian Council of Agricultural Research (ICAR), as an apex organization in National Research System, has built research infrastructure for horticultural research and education. Currently, the country has 10 Central Institutes, 27 Regional Centres, 6 Directorates of Research and National Research Centres, 9 Multidisciplinary Institutes and 14 All India Coordinated Research Projects with 251 centres. There are 4 full fledged State Horticultural University. Besides these, work on horticultural crops, as per the project needs, is also done in CSIR laboratories, centres aided by Department of Biotechnology (DBT), Bhaba Atomic Research Centre (BARC) and Indian Space Research Organisation (ISRO).

Development Infrastructure: Undoubtedly, development of nation or sector is guided by technology, enabling policy environment and investment. In the country ICAR, is apex organisation for research purpose and education in horticulture, while Department of Agriculture and Cooperation (DAC) is changed with the responsibilities of development through dissemination of technology, investment and enabling policy environment. Besides, the Ministry of Agriculture, Ministry of Commerce with its Board, Agricultural Processed Food Products Export Development Authority (APEDA), New Delhi and Spices Board Kochi. Ministry of Food Processing and Industries are also supporting the development of Horticulture. DAC is apex for implementation of programmes in horticulture through, Horticulture Dependent in the states, National Horticulture Board (NHB), National Committee on Plasticulture Application in Horticulture. Coconut Development Board and Directories on horticultural commodities, with changed focus on horticulture, these have been an enhanced allocation for the development, which have attracted private investment with change in policy of storage, processing, marketing. 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.

After, implementation of mission programme for horticulture development, plan investment have increased many fold, which have impacted the Indian horticulture, as explained earlier, that, production has increase from 25 million tons in 1959-1951 to 268 million tones, in 2012-13. The trend of plan allocations in horticulture (Table 5), both for research and development clearly indicates that for plan expenditure has been rewarding. However, it pertinent to note that, changes in farmers occur through changes in technology, institution, trade and market, and policy environment. Expectedly next phase has to be predominated by skills of trade and value-addition and therefore all the efforts would be needed to have the development strategies which are knowledge-based, technology-driven and farmer-centric.

Table 5: Plan allocations and expenditure in horticulture research and development in India

Plan	ICAR Budget for horticulture Research (Rs. in crore)	DAC Budget of horticulture (Rs. in crore)
VII	3.5	25
VIII	31.9	789
IX	208.0	1453
X	321.7	4040
XI	629.8	8086
XII	1050.0	15946

In past decade development of horticulture had enhanced planned investment, which 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. Productivity of horticultural crops increased manifold and the sector sustained the growth rate of 6.5 percent. Technological support has played a key role in transforming Indian horticulture. However, many issues have emerged in the process of development and are being addressed.

Dynamics of Research, Education and Development in New Paradigm

Production of fruits, vegetables, flowers, spices and plantation crops has been success stories of the last decades, and to continue to build on success, sector has to face challenges. Therefore, there is a need to prioritise the action outlining the research, education, development and extension, to make this sector a key driver in rural and regional economic development. 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.

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 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 minimise 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 mimise the losses. Production systems that minimises wastes and maximises recycling will enhance resource efficiency. Plenty of wind and solar energy is available in the various ago-climatic zones, which can be utilised in mechanisation, 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, standardisation of recipes for various products, certification and marketing network etc. should be given priority.

Adoption of sustainable path for development to meet challenges in fruit production through proper technological innovations and interventions, specifically in areas like value chain management, is needed to improve global competitiveness. Inter institutional mechanisms to network and review the ongoing program of biotechnology, cost effective production technologies, post harvest technology, farm mechanisation, transfer of technology and organic farming is essential to provide strategic direction. Improving the understanding of interactions between native ecosystems and production systems and developing best practices to conserve biodiversity is essential. Understanding of social needs of communities and to build the capabilities for practice change, and for effective utilization of resources and adoption of technology would facilitate accelerated adoption of improved technologies and best practices and, respond to needs including bio-security threats.

Climate Smart Horticulture Development

The earth's climate system constantly adjusts so as to maintain the balance between the energy that reaches it from the sun and the energy that goes from earth back to space. This means that, even a small rise in temperature could mean accompanying changes in cloud cover and wind patterns. Some of these changes may enhance the warming, while others may counteract. Cooling effect may result from an increase in the levels of aerosols (small particles of matter or liquid that can be produced by natural or man-made activities). Positive feedback may result from an increase in water vapour due to high evaporation with rise in temperature and can further add to the warming effect. The significant change may impact /horticulture/ and consequently food supply. Climate change *per se* is not necessarily harmful, but the problems arise from extreme events that are difficult to predict, like more erratic rainfall pattern and unpredicted warm spells shall affect productivity. At the same time, more availability of CO_2 would help in improved yield of root crops and increased temperature may shorten the period.

Influence of Climate Change on Horticulture Crops

The vulnerability of horticultural crops to climate change depends on both the expected regional climate change and the sector's ability to adapt. The projected increases in temperature, variability in precipitation patterns, increase in frequency of extreme weather events such as heat, cold waves, frost days, droughts, floods would severely affect the production of horticultural commodities. These stresses at different crop developmental phases in varying intensities would ultimately determine productivity and quality. The emission of carbon dioxide due to anthropogenic activities has enriched the atmosphere. The carbon dioxide enrichment influences the carbon fixation and productivity of crops. The studies suggest a positive effect of increase in atmospheric carbon dioxide in C_3 photosynthetic pathway crops, promoting their growth and productivity. The studies also indicate the increase in water use efficiency (WUE) of crops due to reduction in transpiration rates. However, the adverse effects of associated excessive heat and drought stress might offset the positive effects of elevated CO_2. The interplay of all these factors associated with climate change would subsequently determine the extent of impact on different crops in different agro-ecological regions. It could bring about both adverse and beneficial impacts on crop production depending on the prevailing climatic conditions of the agro-ecological regions, crop species and season. It could affect the growth, development and quality of horticultural crops and alter the zones of crop adaptation.

Sensitivity of Horticultural Crops to Climate Change

In order to develop climate change smart horticultural crops, we need detailed information on physiological responses of the crops, effects on growth and development, quality and productivity. The various impacts need to be addressed in concerted and systematic manner in order to prepare the horticulture sector to face the imminent challenges of climate change. The rise in temperature would lead to higher respiration rate, alter photosynthesis rate and partitioning of photosynthates to economic parts. It could also alter the phenology, shorten the crop duration, days to flowering and fruiting, hasten fruit maturity, ripening and senescence. The sensitivity of individual crop to temperature depends on inherent tolerance and growing habits. Indeterminate crops are less sensitive to heat stress conditions due to extended flowering compared to determinate crops. The temperature rise may not be evenly distributed between day and night and between different seasons. In tropical regions even moderate warming may lead to disproportionate declines in yield. In high latitudes, crop yields may improve as a result of a small increase in temperatures. In developing countries, which are predominantly located in lower latitudes, temperatures are already closer to or beyond thresholds and further warming would reduce rather than increase productivity. The impact of climate change is likely to differ with region and type of the crop and climate variability.

High Temperature: The extreme weather events of hot and cold wave conditions have been reported to cause considerable damage to many fruit crops. In perennial crops like mango and guava, temperature is reported to have influence on flowering. The percentage of hermaphrodite flowers was greater in late emerging panicles, which coincided with higher temperatures.

Though grape originated in temperate regions, modifications in production system, taking up two pruning and one crop, has enabled it to adapt to tropical conditions. Under climate change conditions there would be changes in availability of growing degree-days leading to hastening of the phenological processes. Cashew, which is mostly grown under rainfed conditions, is vulnerable to climatic variability and drought conditions caused due to shifts in rainfall pattern and inter seasonal variability. The temperature rise will influence the survival and distribution of pest populations. Consequently, shifting equilibrium between host plants and pests. The rise in temperature will hasten nutrient mineralization in soils, decrease fertilizer use efficiency. Increase in temperature at fruit maturity lead to fruit cracking and burning in litchi and premature ripening of mango. Low fruit set is observed due to sudden rise in day time temperature (35ºC) during peak flowering in mango. Low temperature (4 to 11.5ºC) in the month of January, accompanied by high humidity (>80%) and cloudy weather delayed panicle emergence. During peak bloom period, high temperature (35ºC) accompanied by low relative humidity (49%) and long sunshine hours resulted in excessive transpiration and dehydration injury to panicles. Untimely winter rains promote vegetative flushes in citrus instead of flowering flushes. Dry spell during flower emergence and fruit set affects flower initiation and aggravates incidence of pest (*Psylla*).

In wine grapes anthocyanin development is influenced by difference between day and night temperatures with high variation (15-20 ºC) promoting colour development. In coconut, impact of climate change related events like consecutive droughts and cyclones adversely affected nut yields (like droughts in TN and Karnataka, cyclone in AP).

Many slow-growing fruit crops require heavy investment on establishment of orchards. Quick alteration/shifting of fruit species or varieties would be difficult and painful loss-bearing exercise under the impact of climate change, which may discourage the development. Recent studies have indicated that in Kullu district of Himachal Pradesh, farmers shifted from apple to vegetables, while in Shimla district at relatively higher altitude orchards have been replaced from high-chilling requiring apple cultivars of apple (Royal Delicious) to low-chilling requiring cultivars and other fruit crops like kiwi, pear, peach and plum and vegetables. In mid hills of Shimla district, trend is to shift from apple and potato cultivation totally. It is corroborated by declining trend in snowfall and apple productivity in Himachal Pradesh. Since many crops with chilling requirements are tree species, moving production areas is difficult. Thus in replanting orchards and plantations over the next decade, selection of lower-chilling requiring types may be advisable. This is just an example of impending impacts of global warming and climate change.

Grape being a temperate crop has very well adapted to tropical regions, under climate change scenario with increase in temperature there would be change in growing degree days (GDD), which has direct bearing on phenology of the crop. Hence, under such circumstances, we would have to identify varieties and regions suitable for production of quality fruits. Excessively high temperatures for extended periods of time in grapes generally result in delayed fruit maturation and reduction in fruit quality. At 35°C pigment development was completely inhibited in Tokay and reduced in Cardinal and Pinot Noir compared to 20 or 25°C. A linear reduction in per cent acid with increasing effective heat units was evident in Valencia and Navel orange varieties indicating the negative relationship of temperature with acid/brix ratios. Shift in varietal choice may become necessary in case of grapevines, banana, mango and other important horticultural crops. With global warming production areas for specific crops and/or timing of planting could be changed, but for many horticultural crops, market windows and infrastructure, such as availability of local packing and distribution facilities are critical components of the production system. Locations of important production areas are often defined as much by available land, markets and infrastructure as by climatic conditions per se. Thus, as horticulturists we have to ask ourselves and our clientele whether it is realistic to move production areas in response to climate change, or whether there are other production practices that can be adjusted to compensate climate change. Climate change and CO_2 are likely to alter important interactions between horticultural plants and pollinators, insect and disease, and pests and weeds.

In severe water stress causes reduction in leaf initiation, leaf size gets reduced and leaves become leathery and thick. Root growth is adversely affected by water stress. It may lead to increased rooting depth and higher proportion of feeder roots in citrus. In, water stress reduces inflorescence initiation in conjunction with reduced shoot growth. Water stress reduces the growth of grape berries, but does not influence the characteristic double sigmoid growth curve. Water deficit during stage I (when cell division is occurring) will generally reduce berry size more than water deficits during stages II and III (growth cell expansion). Water deficit positively affected polyphenol accumulation in berry skin and anthocyanin biosynthesis was strongly induced by water stress and the wines obtained from water-stressed plants had high anthocyanin concentration resulting in a more intense colour. Impact of water stress is more influenced by stage of growth, water stress before flowering is essential to get flowering while stress at the growth stage of fruit is detrimental.

We need quick and clear understanding of impact of climate change on horticultural crops for making sound action plan because horticulture based farming systems have high potential for sequestering carbon for mitigation of climate change. The perennial trees act as carbon sinks by sequestering the atmospheric carbon. The carbon credits could be earned under the clean development mechanism (CDM). The horticultural waste could be composted locally instead of dumping in the landfills, which can reduce the release of global warming methane that is involved in global warming. The organic waste could also be used for generating biogas as an alternate energy source. There are considerable uncertainties about agronomic implications of horticultural crops. Predicting impact of climate change on horticultural crops accurately on regional scale is a big problem. It can be accomplished only by a modeling approach through well-validated robust crop simulation models. These crop simulation models incorporate the effect of various factors of growth and yield in a mathematical model processed by computers to give results quickly for specific situation. Well-validated simulation tools developed for cereal crops have been helpful in predicting of impact of climate change.

In onion, warmer temperatures shorten the duration of growth leading to lower crop yields. Any soil warming would be advantageous for cucurbits, which are generally direct seeded and have a high heat requirement. The rise in temperature will influence survival and distribution of pest population; developing new equilibrium between alternate host crops and pests; hasten nutrient mineralization in soils; decrease fertilizer-use efficiency; and increase evapo-transpiration with reduced water-use efficiency. The net effect of climate change on horticultural crops will depend on interaction effects of rise in temperature and CO_2 concentration in atmosphere. In general, CO_2 enrichment does not appear to compensate for the detrimental effects of higher temperature on yield. Most importantly, the quality of produce of these horticultural crops is likely to be impacted severely.

Managing Climate Change for Climate Smart Horticulture

The issues of climate change and solution to the problems arising out of it requires local analysis, planning and management which could be managed through innovation, technology evaluation and refinement to provide effective solutions to the problems. Potential impacts of climate change depend not only on climate *per se*, but also on the system's ability to adapt to change. The potential depends on how well the crops adapt to the concomitant environmental stresses due to climate change. Depending on the vulnerability of individual crop in an agro-ecological region and the growing season, the crop based adaptation strategies need to be developed, integrating all available options to sustain the productivity. The scientists have already developed several technologies to cope with extreme events like high temperature, frost and limited and excess moisture stress conditions. These available technologies could be integrated and made use to reduce the adverse impacts of climate change and climate variability. Further emphasis need to be put on developing the crop, agro-ecological region and season-based technologies to reduce the impacts and increase the resilience of horticultural production systems to climate change. To address the adverse impacts of climate change on productivity and quality of horticultural crops we need to develop sound adaptation strategies.

In Climate Smart Horticulture is a production system for improved water-use efficiency and to adapt to the hot and dry conditions. Strategies like changing sowing or planting dates in order to combat the likely increase in temperature and water stress periods during the crop-growing season. Modifying fertilizer application to enhance nutrient availability and use of soil amendments to improve soil fertility and enhance nutrient uptake. Providing irrigation during critical stages of the crop growth and conservation of soil moisture reserves are the most important interventions. The crop management practices like mulching with crop residues and plastic mulches help in conserving soil moisture. In some instances excessive soil moisture due to heavy rain becomes major problem and it could be overcome by growing crops on raised beds. Production of vegetables could be taken up using clear plastic rain shelters, which can reduce the direct impact on developing fruits and also reduce the field water logging during rainy season. Planting of vegetables on raised beds during rainy season will increase the yield due to improved drainage and reduced anoxic stress to the root system. Use of rootstock tolerant would provide the scion cultivars with tolerance to soil related environmental stresses such as drought, salinity, low soil temperature and flooding.

In addition to employing modified crop management practices, the challenges posed by climate change could be tackled by developing tolerant varieties. Several institutions have evolved hybrids and varieties, which are tolerant to heat and drought stress conditions. They must be used very effectively to combat the effect of climate change depending upon their performance in a given agro-ecological region. Efforts should be intensified to develop new varieties suitable to different agro-ecological regions under changing climatic conditions. In comparison to annual crops, where the adaptation strategies can be realized relatively fast using a wide range of cultivars and species, changing planting dates or season, the planting and rearrangement of orchards requires a consideration of the more long-term aspects of climate change. Therefore, before resorting to any adaptation option, a detailed investigation on the impact of climate change on perennial crops is necessary.

The long-time horizon of perennial crops creates situations like; favourable areas may become unfavourable during the life of a single orchard. The choice of a variety is complicated by the risk that the best variety for the current climate may be poorly suited for future climates. Thus, while adaptations such as planting new varieties and shifting to new areas may reduce impacts in the long-term, short-term losses may largely be unavoidable. In wine grape, each grape variety grows in a range of temperatures and for each variety it is possible to define climates for premium wine production. The physiological and morphological differences between varieties (genotypes) enable production over a relatively large range of climates and depending upon the suitability to different growing areas the cultivars may be adopted. In situations, where there is a strong consumer preference for a select cultivar and also the suitable varieties are not available to adapt to the changing climate of a particular growing region, the option of using rootstocks for better performance of the scion cultivars could be explored.

An integrated approach with all available options of smart horticulture will be most effective in sustaining the productivity under climate change conditions. To achieve this end, efforts must be initiated at national and agro-ecological region level to assess the impact of climate change on different horticultural crops to develop a number of the combinations of adaptation options for horticulture sector, as a whole, in an integrated manner to tackle the impacts of climate change.

Technological Changes Needed for Climate Smart Horticulture

In a matter of fact, grape is a temperate fruit, which has been largely grown under cool climate, be it for table purposes or for wine-making. But the technological change in plant architecture and production system management has helped to produce grape in tropical situation, with highest productivity in the world. Likewise the chilling will not be enough to induce flowering in apple and high temperature in the mid hill agro-climatic conditions, may cause desiccation in pollen, shriveling of fruits resulting in reduced yield and more failure of the crops. These are the likely impact which causes the concerns. But, there are innumerable examples to cite that, climate has been changing and the technologies have helped in mitigating the problem. Salinity and alkalinity were a great problem for successful growing of grape but identification of suitable rootstocks has made it highly productive. If we look to potato, tomato, cauliflower and cabbage, these are thermo-sensitive crops and were productive only under long day conditions in temperate climate. But development of heat tolerant cultivars and adjustment in production system management has made it possible with very high productivity, even in subtropical and mild subtropical and warmer climates. These are the past experiences, which clearly brings home the point that through innovative research threat of climate change could be converted into the opportunity, but will need visualization of likely change, its impact and planning to mitigate it bad impact. Now, available tools of biotechnology could add for speedier delivery of research results.

Keeping in view the nature of crop, its sensitivity level and the agro-ecological region, the crop-based adaptation strategies need to be developed, integrating all available options to sustain the productivity. Developing strategies and tools to comprehensively understand the impact of climate change and evolve possible adaptation measures in horticultural crops is less understood. To enhance our preparedness for climate change and to formulate a sound action plan, we need to identify gaps in vital information, prioritize research issues from point of view of farmers, policy-planners, scientists, trade and industry. It is imperative to visualize likely changes which can happen in next 50–100 years, how these changes could affect growth, development and quality of horticultural crops, what are the technologies which shall help to mitigate the problem and what kind of innovative research should be done to overcome the challenges of climate change. Thus, policy issues, adaptation strategies and mitigation technologies could be worked out and challenges could be converted into opportunity.

Changing Dynamics of Horticulture

Change in dynamics of horticulture is now for health care through the use of horticultural produce for the treatment of many diseases, therapy, and environment services and above all to the improved quality of life of people living in rural as well as in urban area. Texas, university in USA, has integrated approach for horticulture to address the health of people. Similarly, environmental horticulture is emerging as new area to provide environmental services to mitigate and adapt to climate change. Urban and Peri-urban Horticulture is also seen to play a significant role in rapid urbanisation, taking place across the globe, to mitigate many of problems arising due to urbanisation, to meet the needs, utilise the waste and service the environment.

Horticulture as Protective food for Health Care

Household food insecurity is one of the three underlying causes of malnutrition, as physical, social and economic access to food by all people at all times to sufficient, safe and nutritious food which meets their dietary needs and food preferences for an active and healthy life is food security. Thus, food insecurity exists when people lack access to sufficient amounts of safe and nutritious food and is therefore not consuming the food required for normal growth and development, and for an active and healthy life. This may be due to the unavailability of food, insufficient purchasing power, inappropriate distribution, or inadequate utilization at household level. Food insecurity, poor conditions of health and sanitation, and inappropriate social and care environment are the major causes of poor nutritional status. Given below are name of the various vitamins and minerals that are required by the human body. Amount of these vitamins and mineral that is needed by the human body can be provided with diet having combination of fruits, vegetables, mushroom, spices, coconut and other. Even non- edible horticulture like plant and flowers have proved to be essential for good health. Aromas from flowers are used for therapy. Thus, horticulture is being now practiced as protective food and therapy.

Health care of people, at large, has been through modern medicine but still in Asia more than 80 percent people depend on herbs. Many of doctors now feel that modern medicine brings illness rather than wellness, and subscribe for balanced diet which protect against many disease by enhancing self protective mechanism through many immunological advantages. The fruits (aonla, bael, jamun, papaya), vegetables (carrot, cauliflower, onion, garlic, leafy vegetables), spices (ginger, turmeric, black pepper, fenugreek, ajowan) and ornamental plants (Ashoka, Ficus, catharanthus) protects against various kind of diseases. The spices like turmeric, chillies and cumin in the diet have been recognized to protect against cancer. Noni (*Morinda citrifolia*) with unique characteristics is recognized as best for health care, as it provides protection against various diseases including HIV. Virgin coconut oil protects from HIV and coconut water provides all nutrients to child apparently. Horticultural crops thus provide ample opportunities for health care. According to the Food and Nutrition Board of the National Research Council, man and women between 23 and 50 years eat about 2800 and 2,200 calories a day, respectively to maintain weight. The nutrient needs are liable to vary with gender, age, height, weight, physical condition, activity level and the climatic conditions where they live. Pregnant women and lactating mothers will need additional 300-500 calories per day than their usual needs. Thus, horticultural crops provide wider option (Table 6) for meeting the energy requirement for the human system.

Table 6 : Horticultural crops rich source of phytonutrients

Phytonutrients	Crops rich in these compounds
Carotenoids (Lycopene, Xanthophylls) -	Cruciferous Vegetables (Broccoli)
Lutein, and Carotene (Cryptoxanthine, Zeaxanthine) -	Allium Vegetables (Onion)
Flavonoids (Quercetin, Myricetin, Quercetagatin, Gossypetin) -	Green Leafy Vegetables (Spinach, Purslane)
Anthocyanins -	Coloured Fruits
Isoflavones -	Citrus Fruits
Phenolic Compounds (Catechin) -	Soyabean and Other Legumes
Indoles n-3 Fatty Acids-	Vegetable Oils, Nuts and Seeds

Cereals are the main staple food which lacks in various mineral and vitamins but to sustain and lead a healthy life, the food we eat should contain a wide range of nutrients in proper proportion i.e. it should be a well balanced diet. The nutrients include proteins, fat, carbohydrates, vitamins, fibre and minerals. Each nutrient has a definite function. No single fruit or vegetable can nourish the body with all the vital ingredients it requires. Hence it is important to consume a variety of fruits, vegetables, spices and condiments to derive required nutrition. Horticultural crops are meeting essential requirement for which these crops are rich source of energy, proteins, vitamins, minerals and antioxidants etc. for nourishment of our body.

Food as Prophylactic Medicine

Major shifts in dietary patterns are occurring throughout the world, even in the consumption of basic staples towards more diversified diets. Though cereals continue to remain the most important food source in the world, contributing 50 per cent of calories in developing countries, it is as much as 70 per cent of energy intake, in industrial countries, like UK and USA. While fruit and vegetables do not make a significant contribution to macronutrient intake, they make an important contribution to vitamins, minerals and dietary fibre. The legumes, especially the seed legumes, are of major nutritional significance, particularly in the developing world as they are the main source of proteins. Rising income levels in developing countries like China, India and Brazil coupled with increase in production of many foods of plant and animal origin have made food more accessible and affordable. A major shift in consumption pattern of animal food is being seen together with increased consumption of sugar, sweeteners and vegetable oil in many parts of the developing world. Besides these changes in food habits, a significant change in lifestyle is contributing to increased lifestyle disorders and nutrition related non-communicable and degenerative diseases (NR-NCD) like diabetes, CVD, obesity and intestinal diseases/ disorders.

When the oxidative stress is acute, an external supplementation of antioxidants (both water-soluble and lipid-soluble) can reduce the damage caused due to ROS (Reactive Oxygen Species) and free radicals. There are many substances that are protective in fruits and vegetables, so that the entire effect is not very likely to be due to any single nutrient or phytochemical. Steinmetz and Potter listed possible protective elements : dithiolthiones, isothiocyanates, indole-32-carbinol, allium compounds, isoflavones, protease inhibitors, saponins, phytosterols, inositol hexaphosphate, vitamin C, D-limonene, lutein, folic acid, beta carotene (and other carotenoids), lycopene, selenium, vitamin E, flavonoids, and dietary fiber . The most important mechanism by which these antioxidants act is likely to be by free radical scavenging in which the polyphenols can break the free radical chain reaction. A number of studies have been carried out on the structure and activity of flavonoids and their role in disease prevention.

India's history in health foods is one that is full of traditional and regionally ethnic foods. Cooking contains condiments, herbs, spices, whole foods, fruits, and vegetables, many of which are unique to Indian cuisine. In India, food containing healthy properties, beyond its nutritional value, has been documented throughout the ages, and many foods and medicinal plants have been used to treat common illnesses. Most of these foods were crude extracts and mixtures of naturally occurring substances of plant origin, widely referred in ancient Indian texts like 'Ayurveda (the science of longevity)'. New research shows that many of these foods, in fact, do have preventative properties. Since the mid 1980s, numerous studies have shown the relation between colorectal cancer and consumption of fruit and vegetables. The hypotheses, as to how fruit and vegetable intake may reduce the risk of colon or rectal cancer are numerous and involve independently or additively the many potential anti-carcinogenic compounds found in fruit and vegetables (eg, fiber, carotenoids, vitamin C, folate, glucosinolates, and allium compounds).

The antioxidants prevent the lipid per-oxidation by preventing the loss of membrane fluidity which in turn determines much of the protective functions of immune cells. The carotenes protect the immunity due to its capacity to quench antioxidants and single oxygen. Polyphenols, another antioxidant, acts by effectively scavenging free radicals. Recent studies have shown that flavonoids and polyphenols derived from fruits, avoid lymphocyte proliferation and IL-2 production. The prevention of proliferation of lymphocyte is associated with the inhibition of protein kinase C (PKC) activity, which is involved in cellular signal transduction. Most of the phyto-chemicals in the fruits and vegetables help in disease prevention through mechanism related to antioxidant activity, modulation of detoxification enzymes, stimulation of the immune system, decreased platelet aggregation, alterations of cholesterol metabolism, modulation of steroid hormone concentrations, hormone metabolism, blood pressure reduction, antibacterial and antiviral activity. Never before has the focus on the health benefits of commonly available foods including fruits and vegetables been so strong. The philosophy that food can be health promoting beyond its nutritional value is gaining acceptance within both the public arena and the scientific community. A balanced diet rich in fresh fruits and vegetables, is the single 'Mantra' being propagated world over for healthy living.

Horticultural produce being rich source of vitamins, minerals, proteins, and carbohydrates, which are essential in human nutrition are referred to as protective foods and assumes great importance. Thus, horticulture practices for heath through diet and therapy is emerging as a separate branch, in the science of horticulture. The emphasis on horticulture therefore, is the recognition of t needs for attaining nutritional security, and for a sustainable income. Healthier diets will improve the learning capacity of children and the working capacity of adults, leading to higher incomes and a reduction in poverty.

Urban and Peri-Urban Horticulture/ Environmental Horticulture

Trees, potted plants and flowers are not only valued for its aesthetically appealing entities of nature, but the research data have evidently proven that many kind of diseases including depression could be prevented if we are surrounded with plants and flowers. This is also proven that work efficiency is enhanced by 25-30 percent if workers have exposure to flowers. In the current context of climate change, landscape gardening, both interior and exterior, has become inevitable to service the environment. Recognising the importance of plants and flowers to the mankind, ancient culture has advocated the use of flowers, and the living styles have been interwoven with garden, plant and flower. Evidently, Love or sorrow is expressed with the colour of flowers. However, the quest for food during the development deviated us from the need of flowers for health. With the realisation, that plants and flowers are important, there is now a growing interest in urban and per-urban horticulture, since, and plants offer environmental and ecological services along with aesthetic values.

Trees and other ornamental plants are crucial to the sequestration of carbon form atmosphere and play an important role in reducing carbon foot print. Flowering /foliage plants in the garden not only add beauty but also help to improve the ecosystem. In the cities, environmental benefits and synergies can be achieved when horticulture is planned as a part of the urban landscape including safe recycling of solid waste and wastewater. The country has responded to the needs for effective urban and peri-urban horticulture with emphasis on green space, green building, development of parks and gardens, and promotion of peri-urban vegetables production, but there continue to be a gap in integration. Therefore, design of UPH must include an element of urban and peri-urban horticulture aimed at improving access to food and advancing the livelihoods of people living in and around cities besides servicing the environment.

Urban and peri-urban horticulture is a necessity rather than a demand. This has become a key component of the survival strategies. UPH could be a source of employment and has the potential to improve the nutritional security of urban residents. Horticultural products @400g/ person/day can prevent non-communicable diseases and improve the health. In urban and peri-urban area horticulture becomes a vital to address the challenges emerging owing to rapid urbanisation of cities and small towns. Initiatives of peri-urban vegetables production alone cannot be enough for the dimension of challenges, which is complex and high in proportion. This necessitates holistic approaches having vertical and horizontal integration of the efforts of all the stakeholders, which should address all the links in chain of UPH development concurrently.

Terrace gardening usually refers to the area in the immediate vicinity of a building. This is a raised ground space constructed around a dwelling house or on the sides of a hill. The terrace forms a link between the house and the rest of the outdoor living space and must, therefore, be designed in harmony with the plan of the house. Roof garden is one of popular alternatives in urban and peri-urban areas, because of the limited available space on the grounds of a house, particularly, in the big cities and towns. The only space left for garden enthusiasts is the roof of the house and the balcony. To ensure the success of roof garden, technical and developmental support is inevitable. Currently, a green space of 20m^{2}parkas minimum standard has been suggested. There are city-specific specifications are used toset standards .No dwelling should be more than 500 metres from a green area of at least 6,000 m2 .Green spaces in urban systems should essentially be developed as net works. There is no definite standard for green space in city based on scientific data. Therefore, standard for green space in the cities and tree coverage need necessitated for mitigation strategies, to climate change, which is expected to place increasing stress on urban and peri-urban areas. Green cities have become an option to mitigate the impact and adapt to climate change, as plants sequester the carbon dioxide and other gases. Well planned UPH could be an strategies to mitigate and adopt to the climate change. Therefore, all the initiatives must be taken for the development of UPH.

Higher Education in Horticulture

Education is a life line for any development, and needs utmost attention to empower the mankind with knowledge and skills to serve the community and nation. The education prepares the mindset for facing the challenges. It is not only a transfer of knowledge, but motivation and empowerment of nation. All the planners have to attach maximum to education because it takes generation to correct, if it get spoiled. Thus, education needs strategic planning well thought vision of the future needs in consonance with dynamically changing scenario, since educationist empowerment through knowledge synthesis, analysis and comprehension leading to skills development for social development to achieve economic development (Fig.4).Traditional horticulture nurtured the civilisation, but the modern horticulture is cradle of inventions, technologies and innovations with social responsibilities. Thus, graduate in horticulture must have ability to manage knowledge with skills of time management, team work and delivery of task with accurate attention to details. The learning and teaching effectiveness depend upon learner commitment, interest and dedication. The process that supports, the construction, and reconstruction of knowledge rather than infusion of information (Fig. 5) is horticulture education. Therefore, horticulture education has to be aimed to harness the emerging opportunities through utilisation of knowledge power and dynamic management, to build the manpower to make them assets to social responsibilities and serve the nation.

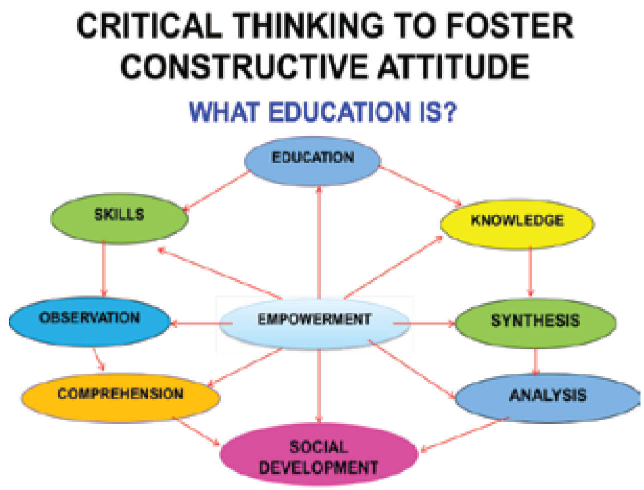

Fig.4. Empowerment through education

Fig. 5. Learners development strategies

Education in horticulture has to meet the twin needs. It has to meet the requirements of industries that employ horticulture educated personnel and secondly, it has to take into account the needs of the farmers and other grass-root level workers in the sector and has to play a critical role in view of large number of stakeholders. Re-assessment of the present system would be necessary in view of new challenges before the country. Higher education in horticulture is required for research, teaching, extension, and, there is a considerable need for skills development at the intermediary. Some of the new technologies, drip irrigation, greenhouse farming, tissue culture, nano-technology and other high-tech horticulture require well trained human resources to provide services to ever growing horticulture industries. Higher Education in horticulture is provided through State Agricultural University (SAUs), conceived as Farm University, to support technology-led development. First, such university was started at Pantnagar, in 1960, dedicated to the Nation by the First Prime Minister of India, Pandit Jawahar Lal Nehru. Subsequently each state established SAUs, which have now, swell to 68. Some SAUs have more than 3-4 agricultural university, beside horticultural, veterinary and fisheries universities. These Universities have very heavy reliance on funding from the public sector. Now there are 65 SAUs, one Central Agricultural University, four ICAR research institutes with the status of deemed to be universities and four central universities having agriculture faculty. Currently (2011), SAU/DU are having facilities for education in 13 disciplines at undergraduate level and more than 95 subjects at post graduate level through constituent and affiliated colleges/faculties. There are about 626 colleges, 360 in SAUs/DUs, 163 affiliated to SAUs and 103 colleges in general universities and others imparting education in agriculture/horticulture and allied sciences. With intake capacity of about 39,300 students, producing about 27,600 graduates and post graduates in various disciplines of agriculture and allied sciences, there is a growing trend for education in agriculture/horticulture. However, exclusively for horticulture, there are only, 4 SAUs and many college of horticulture are attached to SAUs.

To effectively address agricultural and rural development problems, equal emphasis has been given on theoretical as well as inductive reasoning skills so that students can interpret problems and devise solutions. A key feature of the curricula is, the importance accorded to practical and experiential learning. Some universities are also offering 2 years courses providing diploma and certificate and also short duration for skill development in horticulture. Although horticultural education has generally kept pace with scientific progress, yet it is behind the new developments for want of trained faculties and infrastructure. It is always experienced that the college educated graduates and post graduates students do not match appropriately to the needs of industry, as it has largely been isolated from the rest of the education system. This isolation has been leading to curricula irrelevance, falling teaching and learning standards, unattractive employment opportunities and, thus, decreasing investment support. Responses to such situations are mostly fragmented and inward looking. By disregarding the educational needs of all sectors, governments have built horticulture human resource pyramid, where the absence of a diffused general or specialized knowledge, limit national efforts to implement sustainable policies for agriculture/horticulture. Thus, p there is a need for institutions to develop ways of keeping in touch with the employment market and adapting education curricula accordingly. Ideally, institutions should set up permanent mechanisms for observation of the job-market and adaptation of courses, but it was acknowledged that institutional inflexibility and lack of resources would often make this difficult to achieve.

Infrastructure for Education in Horticulture

The first College of Horticulture was established in 1972, with the main objective of starting graduate programme in Horticulture and strengthening research and extension activities in horticultural crops. B.Sc. (Hort.) degree programme was started with an intake of 20 students d was increased to 30 in 1976 and then to 40 from 1979. The B.Sc. (Ag.) programme was also introduced from 1977 with an intake of 50 students. The syllabi for the B.Sc. (Hort.) and B.Sc. (Ag.) programme were then integrated and the B.Sc. (Ag.) programme alone was continued with the integrated syllabus.

First Horticulture University to be established in India is Dr. Yashwant Singh Parmar University of Horticulture and Forestry. This University has earned a unique distinction not only in the country, but also in whole of Asia to impart teaching, research and extension education in horticulture, forestry and allied disciplines with Himalayan perspective. Its milestones in teaching, research and extension education have strengthened the path of sustainable development of horticulture and forestry in Himachal Pradesh and have further presented a model of prosperity for eco-conscious development before Indian Himalayan states & entire region of Hindu Kush Himalayas. This University provided an insight for the establishment of horticultural University in the country, with its relevance in given agro-climatic situations. There are 4 horticultural University exclusively for the horticultural education. These are University of Horticultural Sciences Bagalkot, YSR Horticultural University, Venkataramannagudam, West Godavari, AP and Uttarakhand University of Horticulture, Bhasar, Uttarakhand. The main objectives of these Universities are, to enhance the growth of horticulture sector by providing leadership in teaching, research and extension services in horticulture and allied sciences through continuous innovations and assimilation of emerging. Paradigms, concepts and technology developments. Approaches are end to end, resolving inter-sectoral issues for addressing problem. These Universities promote multi-dimensional reforms in research, teaching, extension for production, processing, marketing and institution of time, and wish to accomplish the sense of urgency.

An important point to remember in regard to higher education in horticulture is that the courses at post-graduate and doctoral levels are open not only to the graduates' in horticulture but also to graduates from a number of other disciplines such as general life sciences and plant sciences. Currently (2011), horticulture education is offered at 57 colleges (42 in SAUs, 10 affiliated to SAUs and 5 others). Fourteen SAUs have facilities for education in this field at graduation level and 32 at post-graduation level. The intake capacity has sharply increased from about 1,100 in 2000-01 to about 3,000 in 2009-10 with expansion of intake in SAUs, including entry of private colleges affiliated to SAUs and other general universities. Against actual admitted strength of about 2,383 during 2009-10, a total of 1465 passed. The details of hoticultural college in different universities including central universities and affiliated colleges are presented in Annexure I.

Skill development for attending to demanding jobs in horticulture has given rise for starting of diploma, certificates and polytechniques courses in specific skills of horticulture, with aim to reduce the gap between demand and supply. The SAUs in Andhra Pradesh, Karnataka, Uttaranchal, Gujarat and Maharashtra have diploma courses. The VCGS college of Horticulture, in Uttarakhand has courses at certificate level and diploma levels in addition to undergraduate courses. In addition, short term training courses are also being organized in such skills as gardeners, garden supervision and horticulture entrepreneurship. Under the National Horticulture

Mission Programme, supervisory level, Gardener training, and entrepreneur development programme are supported, which has succeeded in increasing skilled manpower.

Human Capital Needs of Horticulture

The overall stocks of horticultural human resources required to meet the requirements of various segments of horticulture have been added up to give projections for various years upto 2019-20 (Table 7). The stock requirement of human capital in horticulture sector would grow from 62,583 in 2009-10 to about 95,902 by 2020. Hence, requirement is about 260 per annum. The required additional stock during 2010-20 would be about 3,300 per annum.

Table 7: Estimated human capital needs for horticulture research, education and development

Year	Diploma	UG	PG	PhD	UG & above
2009-10	146320	50005	9325	3254	62583
2019-20	175315	79731	11432	4738	95902

In 2010, the actual stock from supply is 14,179. Assuming the outturn levels will grow at the same growth rate, as observed during the last five years (i.e., about 15 per cent during 2006-10), the estimated demand-supply scenario in 2020 will be that demand (95,902) will far exceed the supply i.e. 26,030 leaving the gap of about 73 percent, if new facilities of horticultural education is not created .

Considering the current supply and experts opinions on graduates aspirations and employee organizations capacity to absorb graduates, the projections suggest that by 2020, the annual outturn from the horticultural education system should be about 8,400 diploma holders, 7300 under-graduates, 990 post-graduates and 330 doctorates. Current supply of about 1500 per year is far below the requirement of 8600. However, part of the requirement is met from other graduates – forestry, crop science and general science graduates, especially in the non-government sectors. While, on one hand, there is a need for technical advisers and business managers, on the other hand the sector needs skilled personnel at field level. Large numbers of retail companies are employing agri-business graduates. To meet the industry requirements, students need to understand the operations of collection centers, customer interface and pricing in the retail sector. This also entails skill in grading, storage, preservation, display, advertisement and marketing.

Enhanced activities in horticulture require specific skills with a course on Horticulture Business Management. At present a number of persons are joining the horticulture with other qualifications, i.e., graduates in agriculture and other general science subjects. Strengthening the extension services is extremely essential to cater to the needs of both the farmers and the industry. Seed industry needs more technical persons. There are number of activities in GoI in which need technical expertise for setting up of own enterprises as the guide others for innovations. The students coming out of the universities/colleges do lack professional skills and need help especially those, who are interested and have aptitude to start their own enterprises. ITI level training institutes should be established to focus on horticultural skill needs at micro-level. The courses are required in nursery management, seed production, post harvest and processing, hi-tech horticulture and protected cultivation. The issue of climate change, post harvest management and horticultural biotechnology are some of the emerging areas which require research, skill development and policy interventions.

Course Curricula for Education in Horticulture

Since horticulture, is a specialised field, that offers wide range of job opportunities and the course of B. Sc. horticulture is highly suitable for candidates who have great passion for gardening and plants. Horticulture offers job opportunities not only to candidates with Ph. D in horticulture, but even B. Sc. horticulture graduates can find job placements or they can also begin their own business as well. Professionals in the field of horticulture are called as horticulturists, and they can find employment opportunities. However, to enhance the job opportunity, course curricula should be relevant to dynamically changing horticulture. Further to enhance the competitiveness there is a need to enhance the knowledge. In this context it is essential that, B Tech in horticulture in horticulture. Tamil Nadu Agricultural University is first to start a B. Tech in Horticulture, as self finance course, which has encouraged many University to start such courses, as placement of student after graduation is much higher in industry, as well as an entrepreneur. Therefore, it is time to give a new dimension to horticulture education.

Bachelors of Science in horticulture are a degree level course being offered by many agricultural/ horticulture University, There are academic variations to total credit load for B.Sc. (Hort.) in various colleges ranging between 150-163 credit hours. While seven colleges were admitting students on the basis of common entrance test, four admitted on the basis of 10+2 examination marks alone. External and internal system of evaluation varied within the colleges, ranging from 100 per cent internal to 20 per cent internal and 80 per cent external. Credit hours assigned for RAWE varied from as low as 3 to as high as 21. Grading system was on 10-point scale in all the colleges. However, award of first division varied from 6.00/10 to 8.99/10 OGPA. Minimum attendance required in each course ranged from 70 per cent to 85 per cent amongst various colleges.

The courses are: Fruit Science: (total: 26 (16+10)), Fundamentals of Horticulture: 3 (2+1); Plant Propagation and Nursery management: 2 (1+1); Tropical and Subtropical Fruits: 3 (2+1); Temperate Fruits: 2 (1+1); Orchard Management: 2 (1+1), Plantation Crops: 3 (2+1), Weed management in Horticultural Crops: 2 (1+1), Principles of Genetics and Cytogenetic: 3 (2+1), Principles of Plant Breeding: 3 (2+1) , Breeding of Fruit and Plantation Crops : 3 (2+1); Vegetable Crops (total: 16 (10+6)), Tropical and Subtropical vegetables: 3 (2+1), Spices and Condiments: 3 (2+1) , Breeding of Vegetable Tuber and Spice Crops: 3 (2+1), Seed Production of Vegetables, Tuber and Spice Crops: 3 (2+1) , Temperate Vegetables: 2 (1+1) ,Potato and Tuber Crops: 2 (1+1); Post Harvest Technology (total: 8 (4+4)), Post Harvest Management of Horticultural Crops: 3 (2+1), Processing of Horticultural Crops: 3 (1+2); Fundamentals of Food Technology: 3 (2+1) Floriculture and Landscaping (total: 10 (6+4)), Ornamental Horticulture: 3(2+1), Breeding and Seed production of Ornamental Crops: 3 (2+1), Principles of Landscape Gardening: 1(0+1), Commercial Floriculture:3 (2+1); Plant Protection (total: 22 (13+9)), Fundamentals of Plant Pathology: 3(2+1), Mushroom Culture: 1(0+1), Diseases of Fruit, Plantation and Medicinal and Aromatic Crops: 3(2+1) , Diseases of Vegetable, Ornamental and Spice Crops: 3(2+1), Fundamentals of Entomology: 3(2+1), Nematode Pests of Horticultural Crops and their Management: 2(1+1),Insect pests of Fruit, Plantation, Medicinal and Aromatic Crops: 3(2+1), Apiculture: 1(0+1), Insect Pests of Vegetable, ornamental and Spice Crops: 3(2+1); Natural Resource Management (total: 16 (9+7)), Fundamentals of Soil Science: 2(1+1), Soil Fertility and Nutrient Management: 2(1+1), Environmental Science: 3(2+1), Soil and Plant

Analysis: 2(1+1), Farm Power and Machinery: 2(1+1), Water Management in Horticultural Crops: 2(1+1), Organic Farming: 3(2+1); Basic Sciences (total: 22 (14+8)), Elementary Statistics and Computer Application: 3(2+1), Elementary Plant Biochemistry & Biotechnology: 3(2+1), Introductory Crop Physiology: 2(1+1), Introductory Economics: 2(2+0), Horti-Business management: 2(2+0), Fundamentals of Extension Education: 2(1+1), Entrepreneurship Development and Communication Skill: 2(1+1); Growth and Development of Horticultural Crops: 2(1+1), Structural Grammar & Spoken English (NC) : 2(1+1), Introductory Microbiology: 2(1+1); Others: Introductory Agro-forestry: 2(1+1), Medicinal and Aromatic plants: 3(2+1), Introduction to major Field Crops: 2(1+1).

Experiential Learning in Horticulture

In order to provide adequate hands on experience to horticulture graduate on different aspects of horticulture, the final year students have to take programme which provide for six months of experiential learning and six months attachment with industry or modern horticulture farm. In experiential learning adequate infrastructure is being created through ICAR to provide entrepreneurship skills for taking up horticulture as a vocation. The experiential learning covers different aspects of horticulture, as many areas in horticulture has potential. At least two areas for hands-on training need to be selected by the student. The students have to prepare a work plan in the area selected with an end to end approach i.e., from purchasing the input to producing a product and marketing. This course also provides a skill of project development, monitoring and accounting. The students at the completion of project have to submit there report for evaluation. This approach for horticulture graduate had an excellent impact but many areas in horticulture is not covered for want of adequate infrastructure. Currently, available professional packages are: Protected cultivation of High Value Horticultural Crops: Visit to commercial poly houses, project preparation and planning, specialized lectures by commercial export house; Study of designs of green-house structures for cultivation of crops, land preparation and soil treatment, planting and production (cultural management including soil/media management in polyhouses, fertigation and irrigation management, Integrated Pest Management, harvesting and post harvest management, certification and distribution, cost of production); Visit to export houses, market intelligence, marketing of produce, cost analysis, institutional management, report writing and viva-voce; Nursery Production and Management: Project preparation, nursery registration, methodology and certification, establishment and management of plant propagation structures, establishment of progeny blocks, identification of mother plants and maintenance of bud wood bank, procurement of inputs (pots, polythene, FYM *etc.*,),techniques and environment management for large scale production, packaging and selling of plant materials, working out economics; Post Harvest Technology and Value addition: Design and project formulation, design and layout of pilot plant, cold store, grading-packing line, cool chain, pre harvest practices to extend shelf life, quality standards of fruits and vegetables for processing, procurement of raw material, inventory control, post harvest handling, grading, packaging, cool chain transportation and storage of fresh produce, processing (juice/pulp extraction, concentration, product preparation, dehydration, waste management, in-plant quality control), packaging (bottling, corking, sealing, labeling, aseptic packaging, storage), quality laboratory exercises, quality assurance, analytical tools, hygiene, machinery maintenance, HACCP, International standards, FPO Licence, PFA standards, codex laws, Sales promotion, certification, distribution and marketing, banking, finance and Institutional management, work experience in food processing plant; Floriculture and Landscape Gardening: Preparation of project report, soil and water analysis, preparation of land and layout, production and management of commercial flowers, harvesting and post harvest handling of produce, marketing of produce, cost analysis, Institutional management, visit to flower growing areas and Export House, attachment with private landscape agencies, planning and designing, site analysis, selection and use of plant material for landscaping, formal and informal garden, features, styles, principles and elements of landscaping, preparation of landscape plans of home gardens, farm complexes, public parks, institutions, highways, dams and avenues, making of lawns, use of software in landscape, making of bouquets, button hole, wreath, veni and gajras, car and marriage palaces, dry flower technology (identification of suitable species, drying, packaging and forwarding techniques); Others: Development of transgenic and biotic stress, organic production of fruits and vegetables, hybrid vegetable seed production, disease and pest management of horticultural crops, drying of flowers for export, extending shelf-life and management of flowers for export. Therefore, experiential learning for one year in two specific areas; increased practical skills through experiential learning; entrepreneurship development; inclusion of new courses on organic farming, farming systems, IPR, international treaties, communication skills development, horti-business management, biotechnology *etc.,* providing flexibility in the curriculum in the final year.

During the last two decades, horticultural crops have emerged as the second line of defence in the food domain, whereas cereals and legumes continue to be in the front line. The growing importance of horticulture lies in its significant support to food security; as major contributor to nutrition security; as promoter of health security and as an important source of employment and income generation. Horticulture supports significantly to food security, major contributor to nutrition security, promotes good health and is source of employment generation-all leading to livelihood security and economic growth. Awareness and education programme on food, nutrition and health security calls for augmentation in the university syllabus for its up gradation. Though efforts of ICAR efforts course curricula has been revised from time to time yet it do not satisfy the needed quality of human resources in horticulture. There is a success model of B Tech. In Horticulture, in TNAU, Coimbatore, which gives an insight that to make horticulture graduate employable and successful entrepreneur this course is essentially require to be persuaded. the quality. Appropriate policy and programmes to augment food, nutrition and health security and employment in income generation.

There is a need to establish strong linkages among countries and even among states of large countries by networking of institutes and organization for exchange of student, information and expertise in horticulture. Awareness and education programme on International Cooperation among Developing Countries require augmentation.

Distance Education in Horticulture

Distance education, a non-formal approach characterized mainly by correspondence and individual learning approach, is needed for extended reach of horticulture education in different categories of people to empower them with new knowledge and technologies of conventional system to fulfill the needs gave birth to the distance education concept. The distance education in general has a history of 100 years in UK, its initiation in India was made in the year1964, which started with subject of arts and has now extended to many science and technology courses/programmes. Poor socio-economic conditions, low level of entry behaviors and lack of accessibility to conventional system or unsuitability of learning schedules in agriculture, exponential growth in demand for higher education and limitations paves the way for distance education in horticulture. With online system of teaching, this has become more flexible, as even a class room environment can be created and hands on training could be imparted with attached study centres.

Distance education in agriculture was started with first Open University (OU) in Andhra Pradesh in 1982 and then BRAOU at Hyderabad. With the establishment of Distance Education Council (DEC) under Statute 28, Section 5(2) of IGNOU Act 1985 under the Parliamentary act. Indira Gandhi National Open University (IGNOU) which encompasses wide range of subjects, there have been accelerated growth in distance education in agriculture. Prominent open University which impart distance education in allied subjects of horticulture/ agriculture are: IGMOU, Nasik, Maharashtra, 1989; KOW, Kota, Rajasthan, 1987; NOU, Nalanda, Patna, Bihar, 1987; MPBOU, Bhopal, M.P., 1991; BAOU, Ahmadabad, Gujarat, 1994; KSOU, Mysore, Karnataka, 1996; NSOU, Calcutta, West Bengal, 1997; UPRTOU, Allahabad, U.P. 1998; TNOU, Chennai, Tamilnadu, 2003; COU, Raipur, Chhattisgarh, 2003. However, a few Open Universities are offering education programmes related to agriculture leading to various degrees. YCMOU, Nasik, Maharashtra, India is pioneer in distance agricultural education programmes.

The programmes covered are: Certificate course in Gardening, a) Principles and Practices of Gardening, b) Fruits, Vegetables & Flower Cultivation, c) Nursery Management, d) Landscape Gardening ; Foundation in Agricultural Sciences, a) Principles and Practices in Soil Science, b) Principles and Practices in Plant Sciences, c) Principles and Practices in Plant Protection, d) Principles and Practices in Crop Production ; Diploma in Fruit Production, a) Principles and Practices of Fruit Production, b) Commercial Fruit Production Part-I, c) Commercial Fruit Production Part-II, d) Post Harvest Technology of Fruits; Diploma in Vegetable Production, a) Principles and Practices of Vegetable Production, b) Commercial Vegetable Production Part-I, c) Commercial Vegetable Production Part-II, d) Post Harvest Technology of Vegetables; Diploma in Floriculture and Landscape Gardening, a) Principles and Practices of Floriculture, b) Commercial Flower Production Part-I, c) Commercial Flower Production Part-II, d) Post Harvest Technology of Flower and Landscaping; Diploma in Agri-business Management, a) Principles and Practices of Agribusiness Management, b) Agri business Management Part-I, c) Agribusiness Management Part-II, d) Principles and Practices of Agribusiness Communication; Bachelor of Science in Agriculture and Horticulture (B.Sc. Agri. and B.Sc. Hort.), for this 20 courses each are offered and the students have to pass entrance test and submit project report to qualify for the degree; Master of Science in Agricultural Communication, Agricultural Extension and Agricultural Development. a) Principle and Practices in Distance Education, b) Research Methods and Statistical Analysis, c) Agricultural Extension and Farm Journalism, d) Agricultural Communication and Mass Media, e) Dissertation/ Thesis and Ph.D. in Agricultural Communication/ Agriculture Extension/ Agriculture Development, a) Principle and Practices of Distance Education, b) Research Methods and Statistical Analysis, c) Agricultural Development and Multimedia Communication, d) Agricultural Information Technology, e) Dissertation / Thesis.

IGNOU offers PhD in Agriculture Education, Dairy Science and Technology; Diploma in value added products from fruits and vegetables, watershed management, dairy technology, fish products technology, meat technology, value added products from cereals, pulses and oilseeds; Certificate in Bee Keeping, Organic Farming, Poultry Farming, Sericulture and Water harvesting and management. PG Diploma in Food Science and Technology, Food safety and quality management and Plantation management. Also offers Post Graduate Certificate in

Agriculture Policy. Many of these courses cover many subjects of horticulture. However, the effectiveness of distance agricultural education with limited access to fieldwork and laboratory work and dependency on study centers for such facilities needs evaluation.

Instructional Methods for Distance Education

Distance Education in agriculture/ horticulture is characterized by relatively less interactive teaching/ learning programmes. The instructional programmes are mainly dominated by Printed Literature, Postal Correspondence, multi-media technologies and cyber technology. Subject matter and instructional programmes are mainly IT based. Obviously, the hands on experience are extremely less. Extensive use and development of programmed printed lessons, programmed audio and video lessons and computer aided instructional material is therefore eminent. Countrywide classroom of UGC and IGNOU on national TV network has become very effective over last several years. But the time slot is very inadequate and devoid of primetime opportunities. In fact, for distance education fulltime TV channel with 24 hours telecast is necessary. A large network of teleconferencing and internet networking facilities for learners at cooperative/ study centres is necessary. Distance education has to become techno-based and cyber based to cater to large information needs.

Distance education is, accessible, low cost educational opportunity for those out of conventional educational system. However, to be effective in horticulture more practical field based approach is essential. Higher education leading to Ph.D. needs to be more responsibly managed. There are several micro and macro issues before distance education system in general and horticulture in particular, in India. Need based training to faculty, service guarantee for academics, adequate and qualified human resources, funds, poor quality of instructional programmes, poor incentives to hired faculty, poor interaction with students and quality of guidance and high dropout rate, are some of the issues. Hence, to overcome these disabilities and strengthen distance education system, it is necessary to strengthen dual mode of distance education and through appropriate support system. OUs should not become degree distributing institutes but help beneficiaries to stand on their own feet. There are several vocational courses in horticulture sector which can be brought under distance education in future to take care of horticulture education which should not only benefit the students but horticulture professional.

A Way Forward

The decade has witnessed the emergence of horticulture as commercial enterprise moving from rural confine, owning to technological advancement, policy environment and investment in research, education and development. The production, productivity and export of horticultural produce have increased many folds. Despite achievements in horticulture sector, the challenges confronting are still many. With increase in per capita income and accelerated growth of health conscious population, coupled with rapid urbanisation, demand for horticultural produce is on increase, which is expected to further accelerate. But, the increased production has to achieved with declining land and water in changing climate. At the same time, growing competition in open economy, demand competitive price of standard quality produce. This opens up opportunity and challenges. Hence, the potentialities , which exist for horticulture has to be harnessed utilising power of knowledge and sustain the gains. Development of improved cultivars with high quality characteristics, productivity, resistance to pest and disease and tolerant to abiotic stresses and technologies for improving the efficiency of water and nutrients by reducing variability in yield, quality and reducing pre and post harvest crop losses are the priory to address the challenges.. The crop monitoring mechanism, ensuring timely availability of inputs, efficient delivery system and technical backstopping would be needed as integrated approach. Emerging challenges, thus, require sustained research and human capital to improve competitiveness, enhance efficiency of production system, assuring quality and safety and improved capability of community to manage the change. Consequently, technology driven horticulture will contribute significantly for economic development.In the context of threat of climate change, climate smart horticulture (CHS), has provided options for sustainability, but has many technological challenges and issues of human resource development. Climate change, which has been perceived as threat, will have likely impact on horticultural crops, due to erratic rainfall, more demand for water, and enhanced biotic and a biotic stresses. The changes will not be only harmful, as enhanced CO_2 concentration may enhance faster photosynthesis and increased temperature may hasten the process of maturity. However, measures to adapt to these climate change-induced changes are critical for sustainable production. Increased temperature will have more effect on reproductive biology and reduced water may affect the productivity but adaptive mechanism like time adjustment and productive use of water shall reduce the negative impact. The strategies must therefore, have to identify the gene tolerant to high temperature, flooding and drought, nutrient efficient cultivars and production system for efficient use of nutrient and water. Development of climate smart horticultural will need tolerant crops to high temperature, moisture stress and salinity. Genomics and biotechnology coupled with nanotechnology would be essentially required to develop genotype for climate smart horticulture. This would need highly prioritised research and education to address the impact of climate change. Enhancing the adaptation of tropical production system to changing climatic condition is a great challenge necessitating integrated efforts having an efficient and effective strategy to be able to deliver technologies that can mitigate the effects of climate change on diverse crops and production systems. This cannot be done with current level of human resource. Horticulture education therefore, must have to address all the strategies which can convert the challenges into the opportunities.

In order to achieve, vibrant, responsive and climate smart horticulture, which is eco-friendly, equitable, sustainable and economically productive, new frontiers of science and knowledge and human resource would be inevitable. Essentiality, the technologies must have potential to increase the value of production by reducing variability and increasing the marketability. The paradigm, necessitates for knowledge empowered human resource who can provide leadership in technology development and policy formulation to attract investment, and keep the pace of development. Horticulture education, relevant to needs therefore, have to play a crucial role.

In India, an emerging economy, a key challenge is to harness and sustain the strength and achievements in technologies developed in horticulture. While packing the way through capacity building and new modalities of training for traditional farmers as well as IT – Savy younger generation, it is essential that knowledge significant for the economy is imparted. Since, the path, ahead of Indian horticulture, is driving to Hi-tech horticulture, institutions and learning centres would be essentially required to serve as knowledge bank and evolve as an interactive learning centre backed by comprehensive research and hands on training. Such learning centre should provide superior learning opportunity along with perfect blend of practical training. Manpower and technology development through education and research has to be in accordance with the present day need; both qualitatively and quantitatively. Present day demand is influenced by the development in the recent past, such as nutritional security, food safety, environment safety, commercialisation and globalisation of horticulture and avoiding huge post-harvest losses have to be met through manpower and technological development. Accordingly, the course curriculums for graduate and post-graduate courses have to be redesigned. The course, programmes and the course contents have to be reformulated with modifications, in the changing scenario, to achieve science and technology-led horticulture development.

We wonder, why horticulture discipline is sub devided as, Fruit Science, Vegetable Sciences, Spices, Plantation Crops, Medicinal and Aromatic plants, Mushroom, Ornamental Horticulture, while in agriculture, crop commodity is not the concept of sub- sector. In some states vegetable and spices are the part of agriculture, ornamental horticulture as a part of tourism ministry, plantation crop especially, tea coffee and rubber as a part of commerce ministry and sericulture in the ministry of textiles. This approach has resulted in isolation, for the want of system approach of breeding, biotechnology, science of omics, soil and plant health management, and new frontiers like nanotechnology. This has also resulted in inbreeding of scientists in given discipline, creating a regional disparity. The phenomena, which have happened could be attributed to the facts that horticulture is still in transition phage, carved originally from the department of botany, and the transition has been guided by the whims and the fancy of people, who persuaded the horticulture research, education and development initially. Since, horticulture is now at the stage to take the challenges in the environment of enabling policy, improved infrastructure for research and education, it is time to give a well thought direction which attract the youth to take horticulture as a profession to serve the community and the nation. Worldwide, horticulture is seen as science, technology and business, accordingly, the sector has been consolidated to provide solution to emerging challenge, be it a biotechnology, plant and soil health, value addition, food safety, environment, and therapy for health and horti-business. Therefore, through national dialogue uniformity must be brought in commensuration with global developments.

It is also imperative to mention that, four years of degree course in agricultural engineering or general engineering is a terminal degree providing respectable job to graduates, as they are called technologist. But, horticulture graduate do not find respectable job opportunities after graduation, leaving, no option but to acquire masters degree. In the age of invention and innovation, horticulture is seen, highly technology driven, demanding the graduate with skill in IT and engineering, architectural skills and acumen for management, since emerging technology of growing plant is high-tech. Therefore, it would be wise to give 4 years degree course a terminal degree of B Tech in Horticulture by redesigning course curriculum and improving skills of faculty. Implementation, of this thought at TNU, as self financed course of B Tech in horticulture has been highly productive in terms of skills and employability, and many other universities, both in public and private sector, are coming forward for the start of B Tech (Hort).

Higher education leading to master in current discipline of horticulture has to be given a new direction, considering the needs and relevance. Instead of giving masters degree in vegetable sciences, fruit sciences and others it would be essential to redesign the courses as genetics and breeding of perennial, horticultural bio technology, soil health, plant health, food Technology, Environmental horticulture, urban and per- urban horticulture, horticulture therapy etc. This thought would need national dialogue to consolidate the issues to provide direction for making horticulture vibrant and responsive to the emerging needs.

Considering that the gap of available skills and needs will be widening rapidly, visualised in all the assessment of manpower requirement in horticulture, which may further widen with accelerated growth in horticulture. Therefore, an urgency is, for developing strategies to establish institutions for education and training having faculties with empowered knowledge and skills. This will also need more of horticulture universities. The concept of distance learning and e- learning with facilities for interactive practicals and hands on training involving private sectors, would be an options to address the emerging needs of horticulture education and skills development, to harness the potential of horticulture which exist in the country and provide a leadership role in horticulture research, education and development in the continent.

Summary

Horticulture, generally referred as gardening, has expanded in its scope and activities, moving from rural confine to commercialisation, and is providing best option for land use, nutritional security, employment opportunity, health care and above all environmental services. Historically, horticulture is as old as civilisation, but the present day horticulture has few decades of systematic and scientific approaches. I Indian, horticulture development has five phases of growth, characterised by, pleasantry an 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 269 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 behaviour and nutrition requirements, is demanding science and technology led development, backed by enabling environments, resource utilisation 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. In this context, horticulture education, relevant to needs, therefore, have to play a crucial role

The first College of Horticulture was established in 1972, with the main objective of starting graduate programme in Horticulture and strengthening research and extension activities. Dr.YSP University of Horticulture and Forestry Solan Himachal Pradesh is first university of horticulture. This University has earned a unique distinction, to impart teaching, research and extension education. In last five years, 3 new horticulture universities have been started. As many as 57 horticulture colleges have been established, under SAUs and central university, and few affiliated colleges are under private sector, to impart education in horticulture. However, available infrastructure and faculties are unable to provide needed manpower for horticulture. Assessment of human capital needs in horticulture under NAIP, suggested that additional stock needed during 2010-20 would be about 3,300 per annum, necessitating more infrastructure and linkages by networking of institutes and organizations for exchange of student, information and expertise in horticulture. In order to achieve, vibrant, responsive and climate smart horticulture,

which is eco-friendly, equitable, sustainable and economically productive, new frontiers of science and knowledge and human resource would be inevitable. Since, horticulture is highly technology driven, it would be wise to give 4 years degree course a terminal degree of B Tech in horticulture by redesigning course curriculum and improving skills of faculty. Considering that, the gap in supply and availability of skilled manpower in horticulture, is widening rapidly, which may further widen with accelerated growth, necessitates, an urgency for developing strategies to establish institutions for education and training having faculties with empowered knowledge and skills. The concept of distance learning and e- learning with facilities for interactive practicals, hands on training, involving private sectors would be an option to address the emerging needs of horticulture education and skills development. Well designed, horticulture education is essential for harnessing the potential of horticulture, which exists in the country, and provide a leadership role in research, education and development.

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Annexure I

List of Horticulture Colleges in India

A. Horticulture Colleges affiliated to State Agricultural Universities in India

State	University	College/faculty
Andhra Pradesh	Andhra Pradesh Horticultural University (APHU), Venkatrammanagudem, West Godavari	1. College of Horticulture, Anantharajupet, Kadapa District 2. College of Horticulture, Mojerla, Mahaboobnagar District 3. College of Horticulture, Rajendranagar, Hyderabad District 4. College of Horticulture, Venkataramannaguden, West Godavari District
Bihar	Rajendra Agricultural University, Pusa Samastipur	5. College of Horticulture, Noorsarai, Nalanda
Delhi	IARI, New Delhi	6. PG School of Horticulture, IARI
Gujarat	Navasari Agricultural University (NAU), Navsari	7. ASPEE College of Horticulture and Forestry, Navsari
	Sardar Krushinagar Dantiwada Agricultural University (SDAU), Sardar Krushinagar	8. Faculty of Horticulture, Dantiwada
Himachal Pradesh	Dr. Yashwant Singh Parmar University of Horticulture & Forest ry (YSPUHF), Solan, HP	9. College of Horticulture, Via Ochighat, Nauni, Solan
Karnataka	University of Horticulture Sciences, (UHS), Bagalkot	10. KRC College of Horticulture Arabhavi, Belgaum 11. College of Horticulture, Mudigere, Chikkamangalur 12. College of Horticulture, Bagalkot 13. College of Horticulture, Bidar 14. College of Horticulture, Kolar 15. College of Horticulture, Sirsi 16. College of Horticulture, Koppal 17. College of Horticulture, Hirriyur (Chitradurga) 18. College of Horticulture, Mysore 19. Centre for Post Graduate Studies, Bangalore

State	University	College/faculty
Kashmir	Sher-e-Kashmir University of Agricultural Sciences and Technology, Srinagar, Kashmir	20. Faculty of Agriculture, Wadura Sopore
Kerala	Kerala Agricultural University (KAU)	21. College of Horticulture, P.O. Vellanikkara, Thrissur
Madhya Pradesh	Rajmata Vijayraje Scindia, Krishi Vishwa Vidyalaya, Gwalior	22. College of Horticulture, Mandsaur
Maharashtra	Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth (BSKVV), Dapoli	23. College of Horticulture (KKV), Dapoli, Dist. Ratnagiri
	Marathwada Agricultural University (MAU), Parbhani	24. College of Horticulture (MAU), Krishi Nagar, Parbhani
	Mahatma Phule Krishi, Vidyapeeth, (MPKV), Rahuri, Ahmednagar	25. College of Horticulture (MPKV), Pune, Maharashtra
	Dr. Punjabrao Desmukh Krishi Vidyapeeth (PDKV), Akola, Maharashtra	26. College of Horticulture (PDKV), Akola, Maharashtra
Mizoram	Central Agricultural University, Imphal	27. College of Horticulture and Forestry (CAU), Pasighat
Orissa	Orissa University of Agriculture and Technology, Bhubaneswar	28. College of Horticulture, Chiplima
Rajasthan	Maharana Pratap Agriculture and Technology University, Udaipur	29. College of Horticulture and Forestry, Udaipur
Tamilnadu	Tamilnadu Agricultural University (TNAU), Coimbatore, Tamilnadu	30. Horticultural College and Research institute, Theni Dist., Periyakulam East 31. Horticultural College and Research Institute, Coimbatore 32. Horticultural College and Research Institute for Women, Trichy

State	University	College/faculty
Uttar Pradesh	Chandra Shekhar Azad University of Agriculture & Technology (CSAUT) Kanpur, Uttar Pradesh	33. Faculty of Horticulture, Kanpur, Uttar Pradesh
	Narendra Dev University of Agriculture and Technology, Faizabad, UP	34. College of Horticulture, Faizabad
Uttarakhand	G.B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand	35. VCSG College of Horticulture, Bharsar
West Bengal	Bidhan Chandra Krishi Vishva Vidyalaya (BCKVV), Nadia, West Bengal	36. Faculty of Horticulture, Mohanpur, Nadia
	Uttar Banga Krishi Vishwavidyalaya (UBKVV), Coochbihar, West Bengal	37. College of Horticulture, Pundibari, Coochbehar
B. Horticulture Colleges affiliated to Agricultural University		
Maharashtra	Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth (BSKKV), Dapoli	38. Sharadchandrajee Pawar College of Horticulture (Private-affiliated to BSKKV), Tal. Chiplun, Dist. Ratnagiri
	Mahatma Phule Krishi Vidyapeeth (MPKV), Rahuri	39. Shrimant Shivajiraje College of Horticulture (Private-affiliated to MPKV), Phaltan, Satara Dist.
	Dr. Punjabrao Deshmukh Krishi Vidyapeeth (PDKV), Akola, Maharashtra	40. Shivaji College of Horticulture (Private college-affiliated to PDKV), Amravati 41. Swatantrya Veer G.I. College of Horticulture, (Private college-affiliated to PDKV), Jalgaon Jamod, Dist. Budhana

State	University	College/faculty
Chhattisgarh	Indira Gandhi Krishi Viswavidyalaya, Raipur	42. Gayatri College of Horticulture, Dhamtari 43. K.L. College of Horticulture, Dhamtari 44. Rani Durgawati College of Horticulture, Pendra, Bilaspur 44. Danteshwari College of Horticulture, Raipur
C. Horticultural Colleges in General Universities		
West Bengal	Calcutta University, Kolkatta	45. Rev. William Carey Institute of Horticulture, Calcutta, University of Calcutta
Tamilnadu	Annamalai University	46. Faculty of Horticulture, Chidambaram, Tamilnadu
Uttarakhand	HNB Garhwal University, Srinagar	47. School of Horticulture, Srinagar, Pauri District, Uttarakhand
D. Horticultural Colleges in General Universities (Private)		
Uttar Pradesh	Amity University	48. Amity Institute of Horticulture Studies and Research
Punjab	Lovely Professional University	49. Faculty of Horticulture

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Research and Development on Climate Resilient Horticulture for Nutritional Security

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Abstract

Horticulture has been a key driver of economic development in India and virtually improved the economy in several states. In India, it contributes approximately 30.4 per cent to Agricultural GDP and during 2012-13, horticultural production (268.85 million tonnes from 23.69 million) has surpassed food production. It has been possible due to vast genetic diversity and potential gene pool of horticultural crops available in the country.

Globally, India is the second largest producer of fruits and vegetables. It is the largest producer of mango, banana, coconut, cashew, papaya, pomegranate and is the largest producer and exporter of spices. India ranks first in productivity of grapes, banana, cassava, peas, papaya etc. In monetary terms the growth in export of fresh fruits and vegetables is 14% while it is 16.27% in case of processed fruits and vegetables. Focused attention on horticulture has paid dividend and resulted in increased production and export. The production of horticultural produce has increased 7-fold which ensured nutritional security and employment opportunities. A total of 72,974 genetic resources holding 9240 accessions of fruits, 25,400 accessions of vegetables and tuber crops, 25,800 accessions of plantation and spices, 6250 accessions of medicinal and aromatic plants, 5300 accessions of ornamental plants and 984 accessions of mushroom have been conserved across the country. A total of 1,596 high yielding varieties and hybrids of horticultural crops (fruits – 134, vegetables – 485, ornamental plants – 115, plantation and spices – 467, medicinal and aromatic plants – 50 and mushrooms – 5) have been developed. As a result the productivity of horticultural crops viz. banana, grapes, potato, onion, cassava, cardamom, ginger, turmeric etc. has increased significantly. Although we are leading in production of many food items but Post harvest/ production losses in some of these commodities are cause of concern and need to be addressed appropriately. Our overall achievement on R&D of horticultural crops is laudable but the glass is only half full. We cannot be complacent given our demography and dwindling natural resources. The perceived threats on climate change pose greater challenge in achieving the targets in these crops now than ever before.

Horticultural crops suffer due to number of climate change factors. Human beings have always struggled for their survival. In this process, they have gained knowledge of complex phenomena operating in nature at various levels and suitably adjusted to the same. While gaining knowledge on different aspects of our environment and evolving strategies to face the adverse situations is important for our very existence, undue interference with Mother Nature may be equally deleterious. Conservation of genetic resources, diversification for widening of food basket, novel genes, efficient resource management, modified environment for crop production are some of the possible alternatives to mitigate the abiotic stresses. However, we will have to

strike a balance between our needs and the carrying capacity of the local environment to achieve sustainability in all its forms. An attempt has therefore, been made to briefly describe the climate change related abiotic stresses, their impact and remedial measures in some horticultural crops.

Horticulture comprising fruits (including nuts), vegetables (including potato, tuber crops and mushroom), ornamental plants, spices, plantation crops and medicinal and aromatic crops has been a key driver of economic development in India and virtually improved the economy in several states. In India, it contributes approximately 30.4 per cent to Agricultural GDP and at this stage it calls for technology-led development through requisite support for Research & Development with dynamic initiatives and vibrant policy on export promotion.

Scenario of Horticulture in India

For the first time in the history of India, horticultural production (268.85 million tonnes from 23.69 million ha in 2012-13) has surpassed food production (259.32 MT during 2011-12). It has been possible due to vast genetic diversity and potential gene pool of horticultural crops available in the country. However this genetic diversity is threatened in the wake of changing climate scenario and needs to be conserved.

Globally, India is the second largest producer of fruits and vegetables. It is the largest producer of mango, banana, coconut, cashew, papaya, pomegranate and is the largest producer and exporter of spices. India ranks first in productivity of grapes, banana, cassava, peas, papaya etc. In monetary terms the growth in export of fresh fruits and vegetables is 14% while it is 16.27% in case of processed fruits and vegetables.

The production of fruits has increased from 74.88 to 81.28 million tones and vegetables from 146.55 to 162.19 million tonnes from 2010-11 to 2012-13 (Table 1). Similarly, the productivity of fruits and vegetables during 2012-13 was 11.6 tons/ha and 17.6 tons/ha, respectively. Significantly higher productivity (t/ha) was recorded in papaya (40.7), banana (34.2), grapes (21.1), pineapple (14.9) and guava (13.6), tapioca (35), okra (27.5), cabbage (22.9), potato (22.8) and cauliflower (19.6).

Table 1: Indian Horticulture at a glance (2010-2011 to 2012-13)

Year	Fruits		Vegetables		Flowers		Medicinal & Aromatic crops		Plantation crops		Spices		Grand Total	
	A	P	A	P	A	P (loose)	A	P	A	P	A	P	A	P
2010-11	63.83	74.88	84.95	146.55	1.91	10.31	5.10	6.05	33.06	120.07	29.40	53.50	218.25	240.53
2011-12	67.05	76.42	89.89	156.32	2.54	16.52	5.06	5.66	35.77	163.59	32.12	59.51	232.42	257.28
2012-13	69.82	81.28	92.05	162.19	2.33	17.29	5.57	9.18	36.41	169.85	30.76	57.44	236.94	268.85

A= Area (00,000 ha); P= Production (00,000 tonnes)
Grand Total includes fruits, vegetables, flowers, nuts, aromatic & medicinal plants, spices, plantation crops, mushroom & honey.
Source: Indian Horticulture Database- 2013, National Horticulture Board.

Focused attention on horticulture has paid dividend and resulted in increased production and export. The production of horticultural produce has increased 7-fold which ensured nutritional security and employment opportunities. A total of 72,974 genetic resources holding 9240 accessions of fruits, 25,400 accessions of vegetables and tuber crops, 25,800 accessions of plantation and spices, 6250 accessions of medicinal and aromatic plants, 5300 accessions of ornamental plants and 984 accessions of mushroom have been conserved across the country. Molecular characterization of available germplasm has been done in several horticultural crops including mango, banana, citrus etc. A total of 1,596 high yielding varieties and hybrids of horticultural crops (fruits – 134, vegetables – 485, ornamental plants – 115, plantation and spices – 467, medicinal and aromatic plants – 50 and mushrooms – 5) were developed. As a result the productivity of horticultural crops viz. banana, grapes, potato, onion, cassava, cardamom, ginger, turmeric etc. has increased significantly. Although we are leading in production of many food items but Post harvest/ production losses in some of these commodities are cause of concern and need to be addressed appropriately. Our overall achievement R&D horticultural crops is laudable but the glass is only half full. We cannot be complacent given our demography and dwindling natural resources. The perceived threats on climate change pose greater challenge in achieving the targets in these crops now than ever before. It calls for constant monitoring of the research and development in horticulture sector.

Horticultural crops suffer due to number of climate change factors which cause abiotic stresses. An attempt has therefore, been made to briefly describe the climate change related abiotic stresses, their impact and remedial measures in horticultural crops. Abiotic stresses such as drought, heat, soil salinity, ozone and excess UV radiation are already causing significant yield losses and, are expected to become more prevalent in the coming decades due to worldwide climate change. Developing and adapting strategies that can cope with abiotic extremes is essential to meet the need of growing population and committed demand for export.

The abiotic stresses like temperature (heat, cold chilling/frost), water (drought, flooding/ hypoxia), radiation (UV, ionizing radiation), chemicals (mineral deficiency/excess, pollutants heavy metals/pesticides, toxic gases), mechanical (wind, soil movement, submergence), etc are responsible for reduction in agricultural production (Wang *et al.,* 2007). These comprise mostly of high temperature (40%), salinity (20%), drought (17%), low temperature (15%) and other forms of stresses (Ashraf *et al*., 2008). Only 9% of the world area is conducive for crop production, while 91% is affected by various stresses. As per the estimate (ICAR, 2010), 120.8 million ha (36.5 % of geographical area) in India are degraded due to soil erosion, salinity/alkalinity, soil acidity, water logging and other soil problems.

Table 2: Variables of abiotic stresses

i.	High temperature (heat stress)	vii.	UV-radiations
ii.	Low temperature (chilling & frost)	viii.	Nutrient deficiency in soil
iii.	Drought (water deficit)	ix.	Chemicals and pollutants (heavy metals, pesticides & aerosols)
iv.	Water logging/ flooding	x.	Oxidative stress (ROS, O3)
iv.	Salinity (salt stress)	xi.	Wind (high wind velocity, sand & dust particles)
vi.	Light (high/ low light intensity)	xii.	Extreme weather (avalanche, hail storm, thunder storm, dust storm, cyclones, tidal waves, etc.)

Temperature Stress

Both high and low temperatures (temporary or constant), can induce morpho-anatomical, physiological and biochemical changes in plants, leading to reduce horticulture production. IPCC (2007) has projected that the global annual temperature is likely to increase from 1.4 to 4.5°C by the end of this century resulting into 10-40% loss in crop production in India by 2080-2100, which need to be addressed through suitable strategies.

Heat Stress

Plants grow best at the higher end of their optimal temperature requirement. In the temperate zone, the minimum temperature for growth is about 4.4°C. Photosynthesis and respiration increase as temperatures rises until the energy used in respiration equals photosynthetic capacity, when growth ceases. For most plants, this temperature is around 35°C. For many cool-season crops, growth may cease at temperatures considerably lower than 35°C. Damage such as sunburns on leaves, branches and stems, anticipated leaf senescence and abscission, shoot and root growth inhibition and fruit discoloration and damage occur due to extremes of heat stress with maximum damage at reproductive stage in most plants. At very high temperatures, severe cellular injury or cell death may occur. protein denaturation and aggregation, and increased fluidity of membrane lipids are direct injuries whereas, inactivation of enzymes in chloroplast and mitochondria, inhibition of protein synthesis, protein degradation and loss of membrane integrity are indirect or slower heat injuries. High temperature can cause damage to components of leaf photosynthesis, thereby reducing CO_2 assimilation rates.

In apple, colour development occurs through biosynthesis of anthocyanines which it is reduced by high temperatures.

In banana, ideal temperature for optimum plant growth is 30°C and leaf emergence ceases below 10°C. The leaf production increases by one per month for every 3.3-3.7°C rise in minimum or mean temperature from 10-20°C or 13.5-25°C, respectively. The optimum temperature for bunch growth is 21-22°C and temperature above 30°C causes choking or rosetting in plant.

Mango grows best at 24-30°C; but can tolerate 48°C during fruit development and maturity.

Cashew requires relatively dry atmosphere and mild winter (15-20°C minimum temperature) coupled with moderate nights for optimum flowering. High temperature (34.4°C or more) and low RH (< 20%) during afternoon causes drying of flowers resulting in reduced yield.

In strawberry, high temperature stress adversely affects the inflorescences, flowers and fruits.

Cold Stress

Low temperature (chilling / freezing) injury can occur in all plants, but the mechanisms and types of damage vary considerably. Many horticultural crops of tropical origin experience physiological damage when subjected to temperatures below 12°C (well above freezing temperatures). Chilling injury is damage to plant parts caused by temperatures above the freezing point (0°C). Frost and freeze injury are closely related. Frost damage occurs during a *radiation freeze*, while freeze damage occurs during an *advection freeze*. In both cases, ice crystals form in plant tissues causing dehydration of cells and disruption of membranes. Tropical crops experience serious frost damage when exposed to sub-zero temperature, whereas temperate crops survive with little damage if the freeze event is not much severe.

Fruit plants can be affected either by winter injury, which occurs when the trees are dormant; and spring frost injury, which occurs when the trees are no longer dormant but in various stages of flower, fruit, and/or leaf development like the prevailing climatic condition during 2013-14 in most parts of Jammu & Kashmir, Himachal Pradesh and Uttarkhand.

Frost Injury in Some Horticultural Crops in Arid Zones of India

The arid zone ecosystem is very fragile and is prone to frost damage. Observations for the last 20 years at Bikaner indicated significant shift in minimum temperature. Maximum temperatures remained nearly constant for last 20 years, however, the spectrum of minimum temperature touched freezing point which had never been recorded before 2000AD and has now become a recurrent feature.

Table 3: Critical temperature (Tc; °C) for some temperate fruit trees

Fruit crop	Stage	10% kill	90% kill
Apple	Silver tip	-11.9	-17.6
	Green tip	-7.5	-15.7
	½" green	-5.6	-11.7
	Tight cluster	-3.9	-7.9
	Full pink	-2.7	-4.6
	Full bloom	-2.9	-4.7
	Post bloom	-1.9	-3.0
Apricot	Tip separates	-4.3	-14.1
	Red calyx	-6.2	-13.8
	First white	-4.9	-10.3
	Full bloom	-2.9	-6.4
	In shuck	-2.6	-4.7
	Green fruit	-2.3	-3.3
Peaches (Elberta)	First swell	-7.4	-17.9
	Caylx green	-6.1	-15.7
	Caylx red	-4.8	-14.2
	First pink	-4.1	-9.2
	First bloom	-3.3	-5.9
	Post bloom	-2.5	-3.9
Pears (Bartlett)	Scales separate	-8.6	-17.7
	Blossom buds exposed	-7.3	-15.4
	Tight cluster	-5.1	-12.6
	Full white	-3.1	-6.4
	First bloom	-3.2	-6.9
	Post bloom	-2.7	-4.0
Cherries (Bing)	First swell	-11.1	-17.2
	Green tip	-3.7	-10.3
	Tight cluster	-3.1	-7.9
	Open cluster	-2.7	-6.2
	First white	-2.7	-4.9
	First bloom	-2.8	-4.1
	Full bloom	-2.4	-3.9
	Post bloom	-2.2	-3.6

The 10% and 90% kill imply that 30 minutes at the indicated temperature is expected to cause 10% and 90% kill of the plant part affected during the indicated phonological stage.
Source : Proebsting and Mills (1978)

Table 4: Classification of some horticultural crops to severity of freezing injury (Wang and Wallace (2003), Caplan (1988)

Most susceptible	Moderately susceptible	Least susceptible/ Hardy
Apricot, Asparagus, Avocado, Balsam, Banana, Begonia, Cockscomb (*Celosia*), Cosmos, Cucumber, Eggplant, French bean, Lemons, Lettuce, Limes, Marigold, Melons, Okra, Peach, Phlox, Plums, Portulaca, Potato, Pumpkin, Salvia, Squashes, Sweet pepper, Sweet potato, Tomato	Apple, Aster, Broccoli, Carrot, Cauliflower, Grape, Grapefruit, Onion, Celery, Orange, Parsley, Pear, Petunia, Pea, Radish, Spinach, Sweet alyssum, Verbena	Beet, Brussels sprout, Bells of Ireland (*Molucella*), Cabbage, Calendula, Coreopsis, Cornflower, Dates, Dianthus, Endive, Kale, Kohlrabi, Pansy, Parsnip, Primrose, Rutabaga, Salsify, Snapdragon, Stock (*Matthiola incana*), Sweet pea, Turnip, Violet

In addition, the mean weekly minimum temperature revealed a drastic change in last 10 years. The mean weekly minimum temperature remained between 4.7 to 5.2°C up to 1999 but thereafter the area has experienced dip in mean weekly minimum temperature and recorded to be around 3°C in 2000 and 2001, around 2°C in 2003, 2004 and 2007 and lowest 1.8°C in 2006. The lowest temperature in Bikaner region is recorded mostly during January. In the year 2006 the minimum temperature dropped to sub- zero level and persisted continuously for 3 days. The same pattern was repeated two times in the first week of January and again by 20 January (-0.5° C for 2-3 days) in the year 2008. On the basis of observations on some of the important horticultural crops in Bikaner region immediately after the frost period, four distinct classes could be made on the basis of severity of damage (Table 5).

Table 5: Response of some arid horticultural crops to frost in hot arid regions of India

S.No.	Severely affected	Moderately affected	Less affected	Unaffected
1	Aonla	Bougainvillea	*Nerium*	Indian Aloe
2	Gonda	Alstonia	Neem	Gram
3	Ber	*Delonix regia*	Sapota	Date palm
4	Phalsa	Ashok	Rellia	Khejri
5	Marula nut	Pomegranate	Bael	Cactus pear
6	Ficus sp.			
7	Moringa			
8	Brinjal			

After the frost period, aonla plants did not recover whereas, ber, bael, karonda plants recovered within 1-2 months and put forth flowering and fruiting in next season.

Injury symptoms in edible part of vegetables exposed to freezing: Symptoms of injury in some of the vegetable crops due to exposure to freezing temperature are:

Broccoli: Youngest florets in center of curd turn brown and give off strong odours upon thawing.

Cabbage: Leaves become water-soaked, translucent and limp upon thawing; epidermis separates.

Carrot: Blistered appearance, jagged length-wise cracks. Interior becomes water-soaked and darkened upon thawing.

Cauliflower: Curds turn brown and have a strong off-odour after cooking.

Celery: Leaves and petioles appear wilted and water-soaked upon thawing. Petioles freeze more readily than leaves.

Garlic: Thawed cloves appear greyish-yellow and water-soaked.

Lettuce: Blistering; dead cells of the separated epidermis on outer leaves become tan; increased susceptibility to physical damage and decay.

Onion: Thawed bulbs are soft, greyish-yellow and water-soaked in cross-section; often limited to individual scales.

Potato: Freezing injury may not be externally evident, but shows as gray or bluish-gray patches beneath the skin. Thawed tubers become soft and watery.

Radish: Thawed tissues appear translucent; roots soften and shrivel.

Sweet potato: A yellowish-brown discoloration of vascular ring and a yellowish-green water-soaked appearance of other tissues. Roots soften and become very susceptible to decay.

Tomato: Water soaked and soft upon thawing. In partially frozen fruits, the margin between healthy and dead tissue is distinct, especially in green fruits.

Turnip: Small water-soaked spots or pitting on the surface. Injured tissues appear tan or gray and give off objectionable odour.

Water Stress

Water stress may be either scarcity (or drought) or excess (or flooding) as discussed further.

Drought Stress: Water is undoubtedly the single most important constituent, comprising more than 90% of the fresh weight of most herbaceous plants. Water availability is one of the major limitations to plant productivity. Erratic rainfall, high evaporative demand and severe drought, among others, contribute to the increasing water scarcity. Water deficit has been defined as the induction of turgor pressure below the maximal potential pressure. The magnitude of such stress is determined by the extent, stage and duration of the stress. Therefore, plant responses depend on the nature of the water shortage and may be classified as, (a) physiological responses to short-term changes, (b) acclimation to a certain level of water availability, and (c) adaptations to drought.

Short-term responses to water stress are primarily linked to stomatal regulation, thereby reducing water loss by transpiration and maximizing CO_2 intake. An optimum efficiency in this process would lead to a constant ratio of transpiration to photosynthesis. Mid-term responses (acclimation) include adjustment of the osmotic potential by solute accumulation, changes in cell wall elasticity and morphological changes whereas, long-term adaptation to drought includes genetically fixed patterns of biomass allocation, specific anatomical modifications, and sophisticated physiological mechanisms with an overall growth reduction to balance resource acquisition (Chapin, 1991).

Table 6: Physiological and biochemical changes in plants induced by drought stress

Physiological responses	Biochemical responses	Molecular responses
Recognition of root signals	Transient decrease in photochemical efficiency	Stress responsive gene expression
Loss of turgor and osmotic adjustment	Decrease efficiency of Rubisco	Increased expression in ABA biosynthetic genes
Reduced leaf water potential (ψ)	Accumulation of stress metabolites like MDHA, Glutathione, Glycinebetaine, proline, polyamines, and α-tocopherol	Synthesis of specific proteins like LEA, DSP, RAB, dehydrins
Decrease in stomatal conductance to CO_2	Increase in antioxidative enzyme like, SOD, CAT, APX, POD, GR and MDHAR	Drought stress tolerance
Decline in net photosynthesis	Reduced ROS accumulation	
Reduced growth rates		

Source: Shao *et al* (2008).
Abbreviation: SOD-Superoxide dismutase, CAT- Catalase, APX-Ascorbate peroxidise, POD-Peroxidase, GR-Glutathione reductase, MDHAR-Monodehydroascorbate reductase, LEA- Late embryogenesis abundant.

In vegetables, water deficit at critical growth stages reduce the production severely, besides hampering product quality (Table 7).

Table 7 : Critical stages of water deficit and its impact on vegetable crops (Bahadur, 2014)

Vegetables	Threshold soil moisture		Critical stage of water requirement	Impact of water deficit
	SWT[1](bars)	ASM[2]		
Tomato	-0.45	50%	Flowering and period of rapid fruit enlargement	Flower shedding, lack of fertilization, reduced fruit size, fruit splitting and development of calcium deficient disorder blossom end rot (BER).
Eggplant	-0.45	50%	Flowering and fruit development	Reduces yield with poor colour development in fruits.
Chilli and Capsicum	-0.45	50%	Flowering and fruit set	Shedding of flowers and young fruits, reduction in dry matter production and nutrient uptake.
Cabbage and cauliflower	-0.34	60%	Head/ curd formation and enlargement	Tip burning and splitting of head in cabbage; browning and buttoning in cauliflower.
Carrot, radish and turnip	-0.45	50%	Root enlargement	Distorted, rough and poor growth of roots, strong and pungent odour in carrot, accumulation of harmful nitrates in roots.

Cucumber	-0.45	50%	Flowering as well as throughout fruit development	Deformed and non-viable pollen grains, bitterness and deformity in fruits.
Onion	-0.25	70%	Bulb formation and enlargement	Splitting and doubling of bulb, poor storage life.
Okra	-0.70	40%	Flowering and pod development	Considerable yield loss, development of fibres in pods, high mite infestation.
Melons	-2.00	40%	Flowering and evenly throughout fruit development	Poor fruit quality in muskmelon due to decrease in TSS, reducing sugar and ascorbic acid; increase nitrate content in watermelon fruit.
Lettuce	-0.34	60%	Consistently throughout development	Toughness of leaves, poor plant growth, tip burning.
Pea	-070	40%	Flowering and pod filling	Reductions in root nodulation and plant growth; poor grain fill.
Leafy vegetables	-0.25	70%	Throughout growth and development of plant	Toughness of leaves, poor foliage growth, accumulation of nitrates.

[1]SWT= Soil water tension, [2]ASM= Available soil moisture at rooting depth (25-40 cm)

Strategies for Growing Horticultural Crops in Drought Prone Areas

Plants adapted to arid environments posses inherent drought escape or drought avoidance mechanisms and can be grown in drought hit areas. California poppy (*Escholtzia californica* Cham.) completes its life cycle in a few weeks before drought stress starts, while Coffee (*Coffea arabica* L.) and cacao (*Theobroma cacao* L.) flower and fruit when rains follow a drought period. However, some horticultural plants such as agave (*Agave deserti*) and cactus species store water in their buds, stems or leaves during water deficit period, utilize this stored water under severe drought. Other plant species avoid water stress by developing deep root system and/or mechanism involved in low transpiration loss. Among crops, arid legumes such as cluster bean (*Cyamopsis tetragonoloba*), dew bean (*Vigna aconitifolia*) and cowpea (*Vigna unguiculata*) are characterized by their deep taproot system with slow growth.

Table 8: Fruit and vegetables cultivars having tolerance against drought stress

Crops	Cultivars
Fruit	
Ber (*Ziziphus jujuba*)	Gola, Mundia, Kaithali, Banarasi Karaka, Umran
Aonla (*Phyllanthus emblica*)	Kanchan, Krishna, Balwant, NA -6, NA - 7
Pomegranate (*Punica granatum*)	P-23, P-26, IIHR Selection, Mridula, GKVK 1, Ganesh, Ruby
Custard apple (*Annona reticulata*)	Balanagar, Mammoth Red, Arka Sahan
Guava (*Psidium guajava*)	Allahabad Safeda, L-49, Kohir Safed, Safed Jam

Bael (*Aegle marmelos*)	NB-5, NB-9
Sapota (*Manilkara achras*)	Kalipatti, Cricket Ball
Fig (*Ficus carica*)	Poona, Black Ischia, Deanna, Excel
Mango (*Mangifera indica*)	Banglora, Neelam, Keshar, Bombay Green
Sweet orange (*Citrus sinensis*)	Blood Red, Malta, Mosambi, Pineapple, Valencia
Sour lime (*Citrus aurantiifolia*)	Kadayam, Promalini, Vikram, Sai Sarbati
Tamarind (*Tamarindus indica*)	PKM 1, No. 263, Pratisthan,Yogeshwari
Vegetable	
Tomato (*Solanum lycopersicum*)	Pusa Ruby, Pusa Early Dwarf, S-12, Sel. 7
Chilli (*Capsicum annuum*)	Pusa Jwala, Mathania, Sindhur, Pant C-1, Arka Mohini, Arka Gaurav, Arka Basant, Bharat, Indira, NP-46A, Titan (USA)
Cowpea (*Vigna unguiculata*)	Pusa Dofasali, Pusa Phalguni, Pusa Barsati, Pusa Rituraj, Kashi Kanchan, Kashi Shyamal, Kashi Gauri

Crops	Cultivars
Cluster bean (*Cyamopsis tetragonoloba*)	Pusa Sadabahar, Pusa Mausami, Pusa Navbahar, Durga Bahar
Brinjal (*Solanum melongena*)	Pusa Purple Long, Pusa Kranti, Pusa Anmol, Punjab Sadabahar, Arka Sheel, Arka Kusumakar, Arka Navneet, Arka Shirish
Okra (*Abelmoschus esculentus*)	Kashi Pragati, Kashi Vibhuti, Varsha Uphar, Hisar Unnat
Pumpkin (*Cucurbita maxima*)	Arka Chandan, Kashi Harit, Narendra Amrit, CO-1, CO-2
Amaranth (*Amaranthus spp.*)	Chhoti Chaulai, Badi Chaulai, CO-1,CO-2, CO-3
Muskmelon (*Cucumis melo*)	Pusa Sharbati, Pusa Madhuras, Hara Madhu, Punjab Sunehari, Durgapur Madhu, Kashi Madhu, Arka Rajhans, Arka Jeet
Watermelon (*Citrullus lanatus*)	Sugar Baby, Arka Manik, Arka Jyoti, Durgapur Meetha, Durgapur Kesar, Mateera
Ash gourd (*Benincasa hispida*)	Pusa Ujjwal, Kashi Dhawal
Pointed gourd (*Trichosanthes dioica*)	Narendra Parwal-260, Narendra Parwal-307, Rajendra Parwal-1, Rajendra Parwal-2
Snap melon (*Cucumis melo* var. momordica)	Pusa Shandar
Long melon (*Cucumis melo* var. utilissimus)	Arka Sheetal,Punjab Long Melon-1,Pant Kakri-1
Round melon (*Praecitrullus fistulosus*)	Arka Tinda, Hisar Tinda, Punjab Tinda
Drumstick (*Moringa oleifera*)	PKM-1, PKM-2, Kokan Ruchira

Water Logging

Waterlogging is important abiotic stress. Depending upon the moisture or water level in soil, waterlogging conditions can also be described as flood, submergence, soil saturation, anoxia and hypoxia. Normally plant roots are in contact with oxygen at a partial pressure equivalent to the gaseous atmosphere. The reduction of oxygen below optimal levels, termed *hypoxia*, is the most common form of stress in wet soils and occurs during short-term flooding when the roots are submerged under water but the shoot remains in the atmosphere. The complete lack of oxygen (*anoxia*), occurs in soils that experience long-term flooding and in plants with deep roots completely submerged in water. Water logging and flooding are common in rainfed ecosystems, especially in soils with poor drainage. In India, about 12 million ha is waterlogged and flood prone, where productivity of arable crops gets severely affected. Both flooding and water logging seriously reduce yield. Under flooded conditions transpiration is reduced due to closure of stomata, resulting in decreased water absorption by roots. As a consequence of disturbed physiological functioning, vegetative and reproductive growth of plants is negatively affected.

For most of the horticultural crops, soils should normally have 10 to 30% of their volume composed of larger pores that are filled with air, and 10% is considered the minimum air content for healthy root growth.

Table 9: Water logging tolerant rootstocks in some fruit crops

Crops/cultivars	Expression
Pear	
Pyrus betulaefolia	Extremely tolerant
P. calleryana	Very tolerant
Cydonia oblonga (Quince)	Very tolerant
P. communis (Bartlett)	Very tolerant
P. pyrifolia	Moderately tolerant
Apple	
M 1, M 3, M 7, M 13, M 15, M 16	Moderately tolerant
MM 106, M 111, M9, M 4	Moderately sensitive
MM 104, MM 109, M 2, MM 106	Sensitive
M26, Delicious Seedlings	Very sensitive
Northern Spy Seedlings	Extremely sensitive
Cherry	
Prunus cerasus; Stockton Morello	Sensitive
P. avium; Mazzard	Very sensitive
P. mahaleb	Extremely sensitive
Plum and Prune	
Prunus japonica	Moderately tolerant
P. cerasifera; GF 8-1	Moderately sensitive
P. domestica; Damas GF 1869	Moderately tolerant
P. domestica; Cirule 43, Brompton	Moderately sensitive
P. salicina; S37, S300, S2540	Sensitive
P. salicina; S573, 2508, 2514	Very sensitive
P. persica; Lovell, Halford Nemaguard	Extremely sensitive
Grape	Moderately tolerant
Fig	Intolerant
Trifoliate orange	Moderately tolerant
Rough lemon (*C. jambhiri*)	Moderately tolerant

Cleopatra mandarin	Moderately sensitive
Sweet orange	Moderately sensitive
Sour orange	Sensitive
Rangpur lime	Sensitive
Mango	Moderately tolerant
Guava	Moderately tolerant
Avocado	Sensitive
Loquat	Sensitive
Papaya	Sensitive

Source: Rowe and Beardsell (1973).

Light Stress

Sunlight is not only the energy source for photosynthesis, but also the most important factor affecting productivity in horticultural crops. Carbon exchange rate (CER) is strongly dependent on irradiance, absorption, and utilization of photon energy. Low irradiance or insufficient light penetration into the canopy, directly influences CER, thus decreasing productivity. Canopy management as a routine activity in horticultural crops should be aimed at increasing light interception and productivity, stabilizing yield and improving fruit quality.

Table 10: Optimum indoor light intensity some horticultural crops

Type of plant/ plant part	Required light (lux)
Cut flower	
Rose	4840-6450
Chrysanthemum	3760
Lilies	3760
Ornamental plant	
Begonia	3760
Cyclamen	3760
Orchids	4840
Nursery stocks	4840
Vegetable	
Lettuce	4840
Tomato	11000
Cucumber	10000-18000

Insufficient light causes plants to become unusually long. It increases inter-nodal length, leaves become broad and thin and; the plants have a loose, open structure. Reduced light intensity can also induce succulence and susceptibility to biotic stresses.

Table 11: Physiological response of plants to different wavelengths of light

Wavelength (nm)	Impact
720-1000	Stem elongation, inhibition seed germination, stimulation of onion bulbing
650-690	Suppression of onion bulbing, lycopene synthesis in tomato, flower initiation in long day plants, flower inhibition of short day plant, promotion of germination, promotion of anthocyanins

440-655	Photosynthesis occurs
445-660	Chlorophyll formation takes place
350-500	Phototropism response

Table 12: Light compensation and saturation values of some fruit crops (Restrepo-Díaz *et al*., 2010)

Crop	Light compensation point[1] ($\mu mol\ m^{-2}\ s^{-1}$)	Light saturation point[2] ($\mu mol\ m^{-2}\ s^{-1}$)	A max[3] ($\mu mol\ m^{-2}\ s^{-1}$)
Almond (*Prunus dulcis*)	60	1130-1330	15-20
Apple (*Malus domestica*)	57	1800-1900	16
Fig (*Ficus carica*)	49	1100	15
Grape (*Vitis vinifera*)	67	1800-1900	25
Orange (*Citrus sinensis*)	17	750-1000	15-22
Papaya (*Carica papaya*)	29	1900	25-30
Peach (*Prunus persica*)	40	1300	16-17

[1]The compensation point is the light intensity at which the rate of photosynthesis equals the rate of respiration. At this light intensity, the rate of net photosynthesis is zero.
[2]At the light saturation point, increasing the light no longer causes an increase in photosynthesis.
[3]A max is the maximum photosynthesis rate that occur an optimum light intensity.

Effects of excess shading on some horticultural crops

Muskmelon: Reduced photosynthe rate, fresh weight and flesh firmness. Low accumulation of sucrose. Accelerated formation of the 'water-soaked' symptom in pulp.

Sweet pepper: Enhanced flower abortion and thus reduced fruit yield.

Cauliflower: Growth and development of curd decreased with increasing shade levels.

Carrot: Reduced photosynthetic rate, stomatal conductance, transpiration and water use efficiency.

Lettuce: Decreased leaf thickness and leaf dry matter percentage.

Pear: Decreased area per spur leaf, specific leaf mass and fruit diameter.

Olive: Reduced percentage of inflorescence buds, number of fruits per tree, and fruit mass.

Grape: Affected dry-matter partitioning and photosynthesis.

Hazelnut: Reduced yield mainly by decrease in number and secondly by decrease in nut size.

Pecan: Diminished photosynthesis, stomatal and trichome density.

Salinity Stress

The adoption of modern crop growing practices in recent years has made salt stress an important problem in horticulture. Low rainfall, high evaporation, poor water management and the over usage of chemical fertilizers and over exploitation of underground water and surface water bodies has caused increase in area under salinity. Classification of vegetable crops as per tolerance/ susceptibility to salinity and its effect on yields has been shown in Fig. 1, and threshold salinity levels of vegetables, fruits, ornamental shrubs and trees under Table 13 and Table 14.

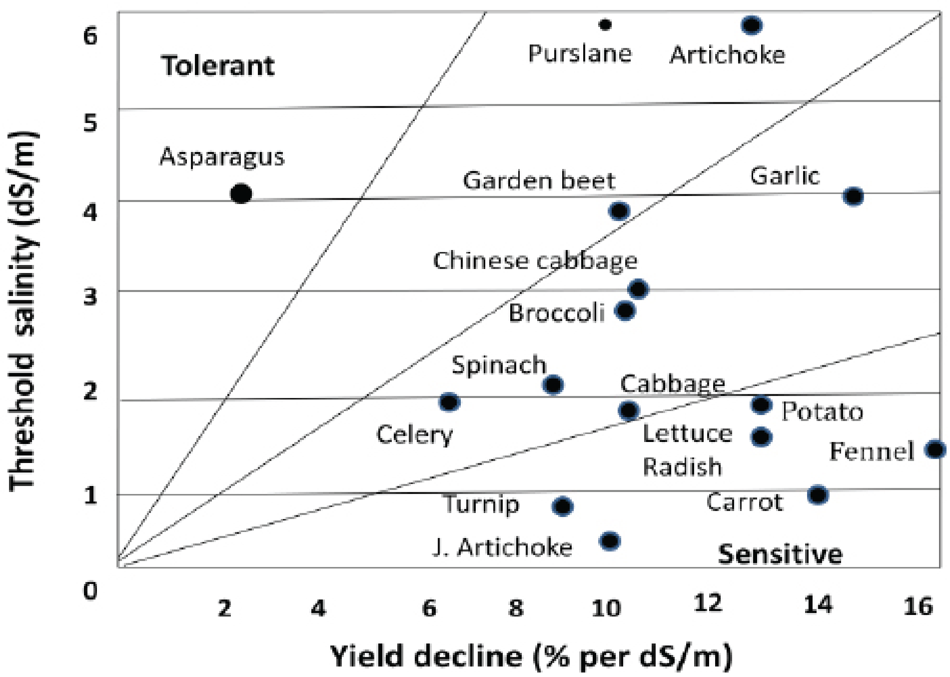

Fig.1: Effect of salinity on vegetable crops (Shannon and Grieve, 1999)

Increased concentration of salts causes several physical and chemical stress in plants, provoking complex responses like changes in plant morphology, physiology and metabolism. Growth inhibition by salt stress is associated with alterations in the water relationships within the plant, caused by osmotic effects with specific ionic consequences (excesses or deficits) or energy availability related to carbohydrate concentrations. Under natural conditions, higher plants encounter high concentrations of salts close to the seashore and in estuaries where seawater and freshwater mix or replace each other with the tides. Far inland, natural salt seepage from geologic marine deposits can wash into adjoining areas, rendering them unusable for agriculture. However, a much more extensive problem in agriculture is the accumulation of salts from irrigation water.

The harmful effects of salinity on plant growth are associated with i. low water potential of the root medium which causes a water deficit within the plant; ii. toxic effects of ions mainly Na^{+}, Cl^{-}, and SO_4^{2-}; iii. nutritional imbalance caused by reduced nutrient (e.g., K^{+}, Ca^{2+}, Mg^{2+}) uptake and/or transport to the shoot.

Salt Tolerance in Plant: The mechanisms of salinity tolerance can be grouped into Tolerance to osmotic stress, Na^{+} exclusion from leaf blades and Tolerance of tissues to accumulated Na^{+} or Cl^{-}categories (Munns and Tester, 2008). The chloride tolerance limit of rootstocks of some fruit crops has been given in Table 13.

Table 13: Salt tolerances of some horticultural crops (Pessarakli, 1999)

Crop		Salt tolerance parameters		
Common name	Botanical name	Threshold ECe (dS m^{-1})[a]	Slope (% per dS m^{-1})	Rating
VEGETABLES				
Sugar beet	*Beta vulgaris L.*	7.0	5.9	T
Broad bean	*Vicia faba L.*	1.6	9.6	MS
Labiab bean	*Lablab purpureus* (L.) Sweet	-	-	MS
Asparagus	*Asparagus officinalis L.*	4.1	2.0	T
Common bean	*Phaseolous vulgaris L.*	1.0	19	S
Lima bean	*P. lunatus L.*	-	-	MT*
Broccoli	*Brassica oleracea* L. (botrytis group)	2.8	9.2	MS
Brussels sprouts	B. *oleracea* L. (gemmifera group)	-	-	MS*
Cabbage	*B. oleracea* L. (capitata group)	1.8	9.7	MS
Carrot	*Daucus carota L.*	1.0	14	S
Cassava	*Manihot esculenta* Crantz	-	-	MS
Cauliflower	*Brassica oleracea* L. (botrytis group)	-	-	MS*
Celery	*Apium graveolens* L. var. dulce	1.8	6.2	MS
Cowpea	*Vigna unguiculata* (L.) Walp.	4.9	12	MT
Cucumber	*Cucumis sativus L*	2.5	13	MS
Eggplant	*Solanum melongena L.*	1.1	6.9	MS
Garlic	*Allium sativum L.*	1.7	10	MS
Lettuce	*Lactuca sativa L*	1.3	13	MS
Muskmelon	*Cucumis melo* L. (reticulatus group)	1.0	8.4	MS
Okra	*Abelmoschus esculentus* (L.) Moench	-	-	MS
Onion (bulb)	*Allium cepa L.*	1.2	16	S

Crop		Salt tolerance parameters		
Common name	Botanical name	Threshold ECe (dS m^{-1})[a]	Slope (% per dS m^{-1})	Rating
Pea	*Pisum sativum L.*	3.4	10.6	MS
Pepper	*Capsicum annuum L.*	1.5	14	MS
Potato	*Solanum tuberosum* L.	1.7	12	MS
Pumpkin	*Cucurbita pepo* L.var. Pepo	-	-	MS*
Radish	*Raphanus sativus L.*	1.2	13	MS
Spinach	*Spinacia oleracea L.*	2.0	7.6	MS
Tomato	*Lycopersicon lycopersicum* (L.) Karst. ex Farw.	2.5	9.9	MS
Turnip	*Brassica rapa* L. (rapifera group)	0.9	9.0	MS
Fruit Crops				
Almond	*Prunus duclis* (Mill.) D. A.	1.5	19	S
Apple	*Malus sylvestris* Mill.	-	-	S
Apricot	*Prunus armeniaca L.*	1.6	24	S
Banana	*Musa acuminata Colla*	-	-	S
Blackberry	*Rubus macropetalus* Doug.	1.5	22	S
Coconut	*Cocos nucifera L.*	-	-	MT
Date palm	*Phoenix dactylifera L.*	4.0	3.6	T
Grape	*Vitis vinifera L.*	1.5	9.6	MS
Guava	*Psidium guajava L.*	4.7	9.8	MT
Indian Jujube	*Ziziphus mauritiana* Lam.	-	-	MT
Lemon	*Citrus limon* (L.) Burm.	1.5	12.8	S
Lime	*Citrus aurantiifolia* (Swingle)	-	-	S
Mango	*Mangifera indica L.*	-	-	S
Orange	*Citrus sinensis* (L.) Osbeck	1.3	13.1	S
Papaya	*Carica papaya L.*	-	-	MS
Peach	*Prunus persica* (L.) Batsch	1.7	21	S
Pineapple	*Ananas comosus* (L.) Merrill	-	-	MT
Plum	*Prunus domestica L.*	2.6	31	MS
Pomegranate	*Punica granatum L.*	-	-	MS
Strawberry	*Fragaria x ananassa Duch.*	1.0	33	S
Walnut	*Juglans spp.*	-	-	S

S-sensitive; MS- moderately sensitive; MT- moderately tolerant; T- tolerant.
[a]In gypsiferous soils, plants tolerate ECe about 2 dS m^{-1} higher than indicated.

Table 14:Salt tolerance of ornamental shrubs and trees (Pessarakli, 1999)

Category	Example
Very sensitive (Maximum permissible soil salinity; ECe (1-2 dS m^{-1})	Star jasmine (*Trachelospermum jasminoides*), Pyrenees cotoneaster (*Cotoneaster congestus*), Oregon grape (*Mahonia aquifolium*)
Sensitive (Maximum permissible soil salinity; ECe (3-4 dS m^{-1})	Rosa spp., *Podocarpus macrophyllus, Hedera canariensis, Nandina domestica, Hibiscus rosa-sinensis, Lagerstroemia indica*
Moderately sensitive (Maximum permissible soil salinity; ECe (4-6 dS m^{-1})	*Lantana camara, Bauhinia purpurea, Magnolia grandiflora, Juniperus chinensis, Platycladus orientalis*
Moderately tolerant (Maximum permissible soil salinity; ECe (6-8 dS m^{-1})	*Callistemon viminalis, Nerium oleander, Cordyline indivisa, Chamaerops humilis, Rosmarinus officinalis*
Tolerant (Maximum permissible soil salinity; ECe (8-10 dS m^{-1})	*Syzygium paniculatum, Leucophyllum frutescens, Carissa grandiflora, Bougainvillea spectabilis, Pinus pinea*
Very tolerant (Maximum permissible soil salinity; ECe (>10 dS m^{-1})	White iceplant (*Delosperma alba*) Rosea iceplant (*Drosanthemum hispidum*) Purple iceplant (*Lampranthus productus*) Croceum iceplant (*Mesembryanthemum croceus*)

Table 15:Chloride tolerance limits of some fruit crop rootstocks (Maas, 1990)

Fruit crop	Rootstock	Maximum permissible Cl^- in soil water without leaf injury (mol m^{-3})
Citrus (*Citrus spp*.)	Mandarin (Sunki, Cleopatra), grapefruit, Rangpur lime	50
	Rough lemon, tangelo (Sampson, Minneola), sour orange, Ponkan mandarin	30
	Citrumelo 4475, Calamondin, sweet orange, trifoliate orange, Cuban shaddock, Citrange) (Savage, Rusk, Troyer)	20
Grape (*Vitis spp*.)	Salt Creek, 1613-3	80
	Dog Ridge	60
	Thompson Seedless, Perlette	40
	Cardinal, Black Rose	20
Stone fruit (*Prunus spp*.)	Marianna	50
	Lovell, Shalil	20
	Yunnan	15
Avocado (*Persea americana*)	West Indian	15
	Guatemalan	12
	Mexican	10

Strategies to Mitigate the Effect of Abiotic Stresses in Some Horticultural Crops

High Temperature Stress

i. Grafting Technique: Supra-optimal temperature causes many deleterious effects such as growth reduction, decrease in the photosynthetic rate and increase in respiration, assimilate partitioning towards the fruits, osmotic and oxidative damage, reduced water and ion uptake/movement, cellular dehydration. Since 1990, the grafting technology was initiated by the AVRDC for production of tomato and pepper in the Asian lowland tropics. Since eggplants are better adapted to hot climate and have better tolerance against supraoptimal soil temperature, use of eggplants as rootstocks for tomato at higher temperature is more promising. Although it was noted that eggplant rootstocks enhanced vegetative growth at 28°C, they had no advantage rather it decreases total fruit dry weight. The use of a heat-tolerant tomato (cv. Summerset) as a rootstock also failed to improve the yield. However, testing eggplants (*S. melongena* cv. Yuanqie) grafted onto a heat-tolerant rootstock (cv. Nianmaoquie) seemed to be promising and resulted in a prolonged growth stage and yield increase up to 10% (Wang *et al*., 2007). Comparing different lines of chilli pepper rootstocks (*C. chacoense, C. baccatum, C. frutescens, C. annuum*) confirmed highest yields under high-temperature conditions for rootstocks recommended by the AVRDC (*C. annuum* cv. Toom-1 and 9852-54). It is known that supraoptimal temperatures may develop multiple mineral deficiencies (P and Fe) in roots and shoots, which both can increase ethylene production. Grafting tomato onto a heat tolerant rootstock (*L. esculentum* cv. RX-335) result in a decreased hydrogen peroxide concentration indicating the lower oxidative stress. It has shown that grafting of tomato onto eggplants reduced electrolyte leakage under supra-optimal temperature stress, indicating less membrane damage and a higher ability to retain solutes and water. The tomato grafted onto eggplants exhibits lower proline but higher ascorbate content compared with self-grafted tomato.

ii. Use of Plant Growth Regulators: High temperature (HT) accelerates the most of the plant metabolic processes. The harmful effect of HT is usually aggravated by lack of available moisture. Applications of certain growth regulators can alleviate the harmful effect of HT in vegetable crops. In tomato fruit set under high temperature conditions can be achieved by spraying of sodium salt of PCPA (50 ppm) or NAA (10 ppm) at flowering. Similarly foliar spray of triacontanol (1-2 ppm) in chilli improves the fruit sets and reduces the flower and fruit drops at high temperature condition. Seed germination in lettuce at higher temperature can be enhanced by soaking seed ABA at 0.1 to 1ppm solution. Similarly seed germination in celery at higher temperature can be enhanced by imbibing the seeds in GA4+7 and subsequently in BA solution. Application of ABA, IAA and ethephon in tomato, capsicum, bean and cucumber, plant reduces the stomatal opening and water consumption.

iii. Shading Net: The harmful effect of heat and intense light intensities can be minimized by using shading devices. A screen made of fabric (polyester and poly propylene) is more convenient for shading a small part of greenhouse. They are available in different density of weave with degree of shading ranges from 20-90%, however 50% is more common. Shading nets in vegetables are known to reduce temperature, increase humidity and improve the appearance of some vegetables. The use of shade should be minimal in crops like tomato, which have a dense canopy. Besides, filter films such as fluorescent films, photochromic films and UV-blocking films are also used to reduce light intensity in commercial greenhouses.

Cold/ Low Temperature Stress

There are several options to protect horticultural crops from cold/ low temperatures.

i. Outdoor Heaters are also used as frost control method in fruit tree orchards, especially in European countries. It is often used in combination with wind machines. High fuel costs have reduced the use of this technique. About 86 heaters with oil burning capacity of 2-4 lit. h^{-1} are used to warm up for one hectare area. Heaters should be lit when orchard temperature reaches the critical point, particularly during flower bud development stage.

ii. Wind Machine is also used for warming orchards. Wind machines bring warm air down into an orchard from higher elevations during a temperature inversion and also stir the air to prevent cold air from settling into frost pockets are more practical. Wind machine is installed at N-W side with fan height of about 10 m, however it works well when wind speed is less than 1.3 m s^{-1}.

iii. Plastic Mulches have been shown to increase soil temperature and hasten early plant development. During the day, sunlight warms the soil. At night, the plastic traps the heat, keeping the warmth in the soil. Clear plastic allows greater soil warming than dark coloured (black, brown, gray) plastic (10°F to 20°F warming for clear, 5°F to 10°F for dark). This can increase the earliness of many vegetable crops by speeding up germination and early growth.

iv. Row Covers, which are often used in conjunction with plastic mulch to promote early crop growth while reducing heat loss at night. In newly established vegetable crops, row covers protect plants from temperatures 2° to 5°F below freezing for short durations. Row covers reduce the damage, but do not offer complete protection, when the temperature drops below 0°C. Therefore, slitted row covers (protect crops -0.5 to -1.0°C) and floating row covers (protect against frosts of -2.0 to -1.5°C) can suitably be used for this purpose.

v. Sprinkler Irrigation is sometimes followed to protect flowers and vegetables from cold injury. Saturating the soil early in the day may help protect plants, since the water will warm up during the day and release the heat slowly during the night. Sprinkling the plants during frosty nights can also help prevent injury. When water is sprinkled on plants as they cool, the heat of freezing will keep the plant surface at or near 0°C. This technique is often used in orchards during bloom time when frost or cold temperatures are predicted. The water application rate is usually varied between 0.20-0.60 inch/h depending upon ambient temperature and wind speed. The sprinklers should be setup to provide about 30 percent overlap to cover for a gentle breeze. It is observed that when sprinkler irrigation used in combination with row covers can extend frost protection to around -6.0°C. Vegetable and flower transplants should be hardened off before they are planted in the field. This slows the growth of the plants, decreasing the chance of cold injury. The plants should be gradually exposed to the lower temperatures. For cold protection, the plants can also be placed on wagons, which are brought outdoors during the day and returned to the barn at night.

vi. Chemical Frost Protectants, including surfactants and combinations of fungicides and antibiotics are other options of protecting crops from injury. Their application prevent formation of ice crystals, by destroying the bacteria that help cause ice crystals to form (called 'ice-nucleating bacteria'). These products provide some protection, at least for a few degrees below freezing. However, killing the bacteria will not prevent ice crystal formation caused by dust and other materials. These products should be used in conjunction with other protection measures, and should not be the only preventative measures used.

vii. Grafting on Tolerant Rootstock : Since the late sixties of the 20th century rootstocks have been used to enhance fruit yield in open-field and in unheated polythene greenhouses for cucurbits (cucumber, squash and melon) production during the cold seasons in Japan and Korea, when low soil temperatures seriously affect seedling performance. For cucumber, fig-leaf gourd (*Cucurbita ficifolia* Bouché) and bur cucumber (*Sicos angulatus* L.) are used as rootstocks. Fig-leaf gourd is unique among cucurbit species with an optimal root temperature at approximately 15°C, thus 6°C lower than that of cucumber roots. Studies demonstrated that these two rootstocks improved vegetative growth and early yield at suboptimal temperatures, and also when only the roots are subjected to chilling temperatures < 8°C (Ahn *et al*., 1999). For tomato, rootstocks of the high-altitude accession LA 1777 of *S. habrochaites* (synonym *L. hirsutum* Dunal), 'KNVF' (the inter-specific hybrid of *S. lycopersicum* × *S. habrochaites*), and chill-tolerant lines from backcrossed progeny of *S. habrochaites* LA 1778 × *S. lycopersicum* cv. T5 are able to alleviate low root-temperature stress for different scions. For watermelon, grafting onto Shin-tosa-type (an inter-specific squash hybrid, *Cucurbita maxima* × *C. moschata*) rootstocks is used to advance the planting date during cool periods. The same rootstocks can also be used to improve the vegetative growth rate of eggplants at suboptimal temperatures (Gao *et al*., 2008).

viii. Growth Regulators are known to increase cold hardiness in vegetable crops. Abscisic acid application has been found to increase cold hardiness in several vegetable crops. GA3 (25 ppm) have been found effective in tomato for overcoming damage caused by frost. Tomato plants sprays with CCC at 0.4-0.5% appreciably increase the cold hardiness. Spray of ethephon on tomato nursery 12 days prior to transplanting increase the frost tolerance in plant. In cucumber, ABA is reported to be involved in development of frost tolerance in plant. Gibberellic acid has been used to identify heat tolerance in Chinese cabbage at the seedling stage. Growth substances have also been used for induction of frost tolerance in lima bean, pole bean, snap bean, spinach, lettuce and tomato.

Drought or Water Deficit

i. Breeding Drought Tolerant Cultivars : The development of drought-resistant cultivars/lines of crops through selection and breeding is of considerable economic value for increasing crop production in areas with low precipitation or without any proper irrigation system. There are several genotypes/ cultivars that can tolerate up to some degree of drought stress may be used for growing in arid or drought prone areas (Table 16).

Table 16: Drought tolerant genotypes / cultivars in some vegetable crops

S.N.	Vegetable	Drought tolerant genotypes/species
1	Tomato	*S. habrochaites* (EC- 520061), *S. pennelli* (IIHR 14-1, IIHR 146-2, IIHR 383, IIHR 553, IIHR 555, K-14, EC-130042, EC-104395, Sel-28), *S. pimpinellifoloium* (PI- 205009, EC- 65992, Pan American, LA1579), *S. esculentum* var. cerasiforme, *S. hirsutum, S. cheesmanii, S. chilense, S. habrochaites,* Arka Vikas, RF- 4A, *L. pennellii* (LA0716), *L. chilense* (LA1958, LA1959, LA1972), *S. sitiens* (LA1974, LA2876, LA2877, LA2878, LA2885)
2	Brinjal	*Solanum microcarpon, S. gilo*, *S. macrosperma, S. integrifolium,* Bundelkhand Deshi, *S. sodomaeum* (syn. *S. linneanum*), SM- 1, SM- 19, SM- 30, Violette Round, Supreme
3	Chilli	*Capsicum chinense*, *C. baccatum* var. pendulum, *C. eximium*, Arka Lohit, IIHR -Sel. 132

4	Potato	*Solanum acaule*, *S. demissum, Solanum chacoense, S. stenotonum, S. ajanhuiri, S. curtilobum, S. xjuzepczukii*, Alpha, Bintje, Kufri Sheetman and Kufri Sindhuri
5	Okra	*Abelmoschus caillei, A. rugosus, A. tuberosus*
6	Onion	*Allium fistulosum, A. munzii,* Arka Kalyan, MST 42, MST 46
7	French bean	*Phaseolus acutifolius*
8	Water melon	*Citrullus colocynthis* (L.) Schrad
9	Cucumber	INGR-98018 (AHC-13)
10	Winter squash	*Cucurbita maxima*
11	*Cucumis spp.*	*Cucumis melo* var. momordica, *Cucumis pubescens*, *C. melo* var. callosus, *C. melo* var. chat Arya, *C. melo* (SC-15), VRSM-58, INGR-98015 (AHS-10), INGR-98016 (AHS-82), CU 159, CU 196, INGR-98013 (AHK-119), AHK-200, SKY/DR/RS-101
12	Cassava	CE-54, CE-534, CI-260, CI-308, CI-848, 129, 7, 16, TP White, Narukku-3, Ci-4, Ci-60, Ci-17, Ci-80
13	Sweet potato	VLS6, IGSP 10, IGSP 14, Sree Bhadra

ii. Grafting on Tolerant Rootstock: Under drought conditions, one way to reduce losses in production and to improve water use efficiency is grafting on rootstocks capable of reducing the effect of water stress. Grafting experiments on drought with fruit, such as kiwi and grapes, proof that drought tolerant rootstocks are available and may be utilized for drought stress condition on commercial scales. Now-a-days grafting technique is also being used for vegetable production in drought condition. Eggplant is more effective to water uptake than tomato and may be used under water-stress conditions. Grafted mini-watermelons onto a commercial rootstock (PS 1313: *Cucurbita maxima* Duch. × *Cucurbita moschata* Duch.) revealed a more than 60% higher marketable yield when grown under conditions of deficit irrigation compared with un-grafted melons (Rouphael *et al*., 2008). The higher marketable yield recorded with grafting was mainly due to an improvement in water and nutrient uptake, indicated by a higher N, K, and Mg concentration in the leaves, and higher CO_2 assimilation.

iii. **Transgenics:** The ongoing research on genetic engineering water stress tolerant plants is mainly based on transfer of one or several genes that are either involved in signaling and regulatory pathways, or that encode enzymes present in pathways leading to the synthesis of functional and structural protectants, such as osmolytes and antioxidants, or that encode stress tolerance conferring proteins. Most successful examples of transgenic crops for drought tolerance are transgenics of DREBs/CBFs transcription factors in tomato.

Waterlogging or Flood Stress

i. Foliar Sprays of Nutrients: Under flooded conditions, soil nitrate is less abundant, and soil N exists in the form of ammonium ($NH4^+$). Phosphate generally becomes more available during soil flooding. Under waterlogged conditions, elements such as Mn and Fe are reduced and may become toxic to flood sensitive plants. Under flooding or submerged condition root is unable to absorb plant nutrients. It is advice to spray low salt liquid fertilizer to supply about 2.0 kg N, 0.5 kg P_2O_5 and 0.5 kg K_2O per acre for instant relief to plant. Water soluble fertilizer mixture (such as 19:19:19 NPK) may be sprayed to plant @ 6 g/lit of water for instant supply of nutrients. Use of manures is considered beneficial in waterlogging-prone environments.

ii. Grafting on Tolerant Rootstocks: Grafting can provide tolerance to soil-related environmental stresses such as drought, salinity, low soil temperature and flooding if appropriate tolerant rootstocks are used. Grafting has been commercially utilized in some developed countries for eggplants, cucumbers and tomatoes. The cultivated area of grafted *Solanaceous* and *Cucurbitaceous* vegetables has increased tremendously in recent years. Problems caused by flooding may be solved by growing flood-tolerant crops or grafting in tolerant plants onto tolerant ones. For instance, grafting improved flooding tolerance of bitter melon (*Momordia charanthia* L. cv. New Known You 3) when grafted onto luffa (*Luffa cylindria* Roem cv. Cylinder 2). The reduction of the chlorophyll content in cucumber leaves induced by waterlogging may enhanced by grafting onto squash rootstocks. When grafting watermelon cv. 'Crimson Tide' onto bottle gourd SKP (Landrace) the decrease in chlorophyll content is less compared with non-grafted water melons. At the Indian Institute of Horticultural Research, Bengaluru and Indian Institute of Vegetable Research, Varanasi grafted tomato on eggplant has successfully been demonstrated and at AVRDC, in addition to tomato, pepper on chilli accessions like 'PP0237-7502', 'PP0242-62' and 'Lee B' lowland tropics has been successfully demonstrated, where flooding occurs also during the heat period. Water logging tolerant rootstocks in fruit crops has been given in Table 9.

Salinity Stress

Various strategies can be adopted to cope with salinity stress. However, two major strategies are adopted in salt affected lands, i.e., technological approach and biotic approach. In the technological approach, one can alter the salinity through reclamation and management practices which enable the plants to grow and produce a reasonable yield. Biotic approach has considerable promise in mitigating the problem of soil salinity world over. It is largely believed that the adverse effects of salt stress on plant growth are mainly due to its toxic and osmotic effects; therefore major focus is on selective ion accumulation or exclusion, control of sodium uptake and its distribution within the plant, compartmentalization of ions at cellular or at whole plant level.

i. Grafting onto Tolerant Rootstock: Grafting is an environment-friendly technique for avoiding or reducing losses in vegetable production caused by salinity, particularly in Solanaceous and Cucurbitaceous vegetable crops. Grafting onto tolerant rootstock is capable of ameliorating salt-induced damage to the shoot.

ii. Use of Growth Regulators: The physiological changes in plants under salt stress are caused by hormonal imbalance. Plant growth, photosynthetic activity and translocation of assimilates are inhibited under salt stress condition. Certain growth substances are known to alleviate the harmful effect of soluble salts on plant. In bean and tomato, application of Cycocel at 5-12 mg a.i./plant as soil application or as foliar spray at 0.3-0.1% improves considerable tolerance to salinity. Cycocel at 500ppm improves the salt tolerance and fruit yield in okra upto EC of 6 mmhos/cm; however seed treatment with 100ppm cycocel for 8 h is found more effective than the foliar spray with 500ppm. Dipping of tomato and onion seedling in 1% cycocel for 8 h induces salt tolerance in these crops.

Human beings have always struggled with existing environment for their survival. In the process of struggle, they have gained knowledge of complex phenomena operating in nature at various levels and suitably adjusted to the existing situations. While gaining knowledge on different aspects of our environment and evolving strategies to face the adverse situations is important for our existence, undue interference with Mother Nature may be equally deleterious. Conservation of genetic resources, diversification for widening of food basket, novel genes, efficient resources management, modified environment for crop production as discussed above are some of the possible alternatives to mitigate the abiotic stresses due to perceived threats of climate change. However, we will have to strike a balance between our needs and the carrying capacity of the local environment to achieve sustainability in all its forms.

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Fruits Based Milk and Whey Beverages for Better Nutrition

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Introduction

Last few decades India has witnessed a significant change in consumption trend of beverages. Indian beverage market which used to be dominated by aerated synthetic drinks has moved towards fruit and dairy based drinks. The growth rate of Indian beverages estimated to be around 18% percent which is quite impressive and positive factors contributing towards the growth include increasing middle class population, rapid urbanisation and higher disposable income. A substantial Indian population comprises of youth which is more conscious towards health and prefer any product which is healthy, nutritious and natural. A report from the Associated Chambers of Commerce and Industry (ASSOCHAM) in India reveals that current market of non-alcoholic beverages in India is US$ 1.2billion and it would grow to US$ 2.3 billion by 2015. Emerging beverage market is offering newer opportunities to food formulators and processors to deliver "functional beverages" as per the demand and need of consumers. It is now well established and accepted fact that majority of life threatening diseases are due to the lower consumption of fruits and vegetables resulting in poor status of antioxidant components in body. Fruits and vegetables are known to possess wide range of bioactive molecules often referred as phytochemicals, essential micronutrients and dietary fibres. Fruits and vegetables constitute the major source of antioxidants including carotenoids, polyphenols, flavonoids, phytosterols, phytoestrogens; glucosinolate and organosulphur compounds in our diet. However, fruits and vegetables possess functional proteins i.e. enzymes and lack vital proteins.

Milk and milk products as unique source of nutrients as well as physiologically active components require for normal growth and vitality. However, milk also lack certain key micronutrients (iron, copper and certain vitamins) and fiber. Therefore, there is obvious need for supplementing milk with necessary micronutrients as well as health promoting components form suitable sources. As regards the supplementary sources of nutrients and health factors for the milk several options including fruits & vegetables, cereals, millets, legumes and certain oilseed crops, could be adopted. The complementary role of milk and other commodities can be realized not only in nutrition and health terms but also in terms of products quality attributes like sensory and storage characteristics.

However, combining any commodity with milk often results in significant changes in physico-chemical characteristics and disturbs the equilibrium. A clear understanding of resultant phenomenon and strategies to overcome such problems is required to make the products stable. Several milk and fruits & vegetables based products are available in market, but there has been great opportunity for introducing many more.

Milk and Milk Products- Virtues and Limitations

Dairy based foods always have been an integral part of our rich cultural heritage and the nutritional advantages associated with consumption of these products is unparallel. Dairy products such as whey are excellent source of certain therapeutic components. Whey proteins are one of the highest quality food proteins with a high PER (3.6), biological value (104), NPU (95) and highest Protein Digestibility Corrected Amino Acid Score (PDCAAS) score that make then an ideal protein source for fortification of wide range of food stuffs. Dietary whey proteins have a number of putative, biological effects when ingested (Horton, 1995).Whey proteins are rich source of all essential amino-acids specially the sulphur containing amino-acids i.e. cysteine and methionine which make them superior to meat, soy and casein. Tryptophan, which acts as building block for niacin, is present in high amount in whey proteins. Liquid whey can be utilized as such or in concentrated form as whey powder for the production of higher value added products like lactose, whey protein concentrates (WPC) or whey protein isolates (WPI). Dairy ingredients also possess unique functional characteristics such as water binding, gelation, emulsification, whipping colour and flavour formation. Addition of dairy ingredients improves the quality characteristics of fruit based processed products such as yoghurt and beverages.

Issues Related to Quality of Milk and Fruits-Based Products

However, many technological problems may occur upon addition of fruits & vegetables into milk, mainly due to the numerous reactions of fruits and vegetable components with milk molecules. The addition of fruits in milk destabilizes the milk proteins by disturbing the salt balance. Some of the micronutrients like iron promote the oxidation of fat rich dairy products that may adversely affect flavour and storage stability of composite products. The interaction of polyphenols present in fruits with milk proteins has been investigated by number of researchers and form insoluble complex. These problems may be reflected in changes in texture, colour, sedimentation, flavour and/or the functional properties of the product. However, by adopting appropriate formulation and technological interventions these adverse effects can be avoided. In certain category of foods like fermented products and desserts the inclusion of milk or milk products enhances the acceptability of fruit based products. Milk and other dairy products are a part of the daily diet in almost all countries. Dairy products are also easily targeted for specific consumer groups like females and infants, allowing for the delivery of category specific functional ingredients.

Prospective Fruit Based Composite Dairy Foods

Fruit Based Milk Beverages

Milk based beverages have emerged as one of the most promising segment among value added dairy products. Dairy industry must exploit the opportunities to keep pace with the changing pattern of product consumption and increasing demand of health foods. Fruit juice based acidified milk beverages are an exciting and growing market in the beverage world. These beverages combine the tart flavor of fruit with the creamy texture of milk. This category includes mainly two types of beverages, Fermented Milk/Yogurt Drinks and) Directly Acidified Milk-Juice Drinks. The motivation for using dairy and fruit drinks is not just refreshment, but also issues such as healthy nutrition, functional ingredients, satisfaction and enjoyment. It is being the common practice to have milk shakes prepared freshly by blending milk and fruit pulps like mango, grape etc in India. Now, technological advances are being made to process these drinks commercially, and to extend their shelf life.

These beverages have lower pH compared to freshly made milk shakes. Lowering of pH helps in extension of shelf-life of the beverage from 90 to 120 days under ambient temperature storage. The pH of the product can be lowered by adding suitable acidifying agent viz., citric acid or lactic acid. Greater care should be exercised while adding the acidifying agent, otherwise, it leads to localised coagulation and causes gritty mouth feel in the product. Many stabilizing agents have been attempted to stabilize the fruit juice based acidified milk, the challenge still exist for higher percentage of milk protein incorporation into this kind of product. It is reported by various workers that the destabilization of milk protein at higher percentage of milk protein (more than 1. 5% of milk protein particularly casein) in the pH range of 3.8 to 4.2.

The addition of fruit components have been reported to enhance the micronutrient status of resultant products. Novel processing interventions such as pulsed electric field (PEF) and high pressure processing could be applied to deliver a shelf-stable product without affecting the sensory quality and food safety.

Fruit Based Whey Beverages

The ready-to-serve (RTS) type beverage may be prepared by mixing an appropriate fruit juice or concentrate and minimally processed whey along with other minor additives to improve the sensory characteristics and thermally processed to make it shelf-stable. In beverage formulation sugar content in the range of 7-10 percent was found optimum. However fruit juice content may vary from 5-30 percent and it depends on the nature of fruit. The processing technology for the manufacture of whey-fruit beverage is quite simple and can be adopted at any scale of production. In-package thermization above 80^0C and sterilization above 115^0C often results in shelf-life enhancement at ambient storage. UHT processing of such beverages increases the shelf-life up to a year at ambient storage conditions. The pH adjustment should always be compatible with typical flavour profile of the used fruit pulp/juice. For example pH level in the range of 3.6-3.8 maximizes the flavour perception of citrus fruit beverages. UHT processing of the finished product, especially while using direct-steam injected systems often results in loss of flavour. The tetra-pack paper (Laminates) based containers are mostly used for packaging of whey fruit based beverages in India. Metal cans, glass or rigid containers are rarely used for these products, because of the acidic pH and presence of minerals.

Despite its relative simplicity, finding a successful flavour combination to mask the unpleasant whey taste is difficult. Several workers have reported cheesiness or saltiness as two most dominant flavours in processed whey beverages. The presence of residual lipids also sometime pose flavour problem in whey beverages especially if the product is thermally processed at elevated temperature. The whey flavour was observed to be most compatible with citrus flavour and majority of commercially available whey-fruit beverages are based on citrus juices.Utilization of cheese whey often cause problem of cheesy and salty flavour due to the presence of residual rennet. Appropriate processing treatment is essential to overcome such problems including vacuum stripping of cheese whey. Lactose hydrolysis also enhanced the sweetness if whey is added above 50% level. Consumer prefer whey beverages that are sparkling clear, hence clarification of whey is essential to remove residual lipids, casein fines and partially denatured whey proteins. Acid whey possesses lesser proteins as compared to cheese whey and that make them more suitable base for beverages base. Major problems reported in whey beverages are turbidity and sedimentation after heat treatment and during subsequent storage. During thermal treatment whey proteins coagulate near their isoelectric point (at acidic pH) which causes development of turbidity and subsequent sedimentation in whey-fruit juice beverage. Such quality problems often lead to failure of these products in market. Several approaches have been tried to minimise these problems. Passing whey through a centrifugal classifies removed casein fines as well as residual fats and improved the clarity. Another approach could be homogenization of the beverage after pasteurization.

An attempt has been made at our Institute to develop sports beverage using whey. The hydrolyzed paneer whey was utilized for the preparation of lemon and pineapple based sports beverages. Acceptable lemon based sports drink can be made with 7.43% sugar, 3.1% lemon juice, 0.07% lemon flavour and 0.07% CMC. Addition of 0.35% salt enhanced the overall acceptability, but protein enrichment of the beverage using hydrolyzed whey protein resulted in lowering of product acceptability. The best formulation for pineapple sport beverage were 20% pineapple juice, 7.49% sugar, 0.15% stabilizer mix and 0.12% salt mix. The stored sports drink was acceptable up to 6 months. The formulation for the manufacture of "Panna" like beverage utilizing hydrolyzed whey permeates consisted of 15%, un-ripened mango pulp, 7% sugar, 1% salt mix, 0.2% commercial spice mix, 0.1% stabilizer and hydrolyzed whey permeate. However, these beverages suffered with heavy sedimentation during storage and homogenization was found to be effective in controlling this problem.

Utilization of Fruits in Fermented Dairy Products

At present around 7% of the milk produced in India is utilized for the manufacture of fermented dairy products. Dahi and dahi based products like *lassi* and shrikhand constitute the largest proportion of milk based fermented dairy products in the country. Recently fruit based yoghurt has also been introduced in Indian market which is also becoming popular day-by-day. Addition of fruits as pulp or juice in dahi or yoghurt improves the quality and acceptability of resultant products. For the manufacture of fruit yoghurt, fruit pulp or juice is used typically in the range of 4-20%. Addition of mango pulp above 4.0 percent was reported to adversely affect the delicate yoghurt flavour and also the body and texture despite using homogenization pressure. However homogenization pressure up to 200 bars may help in producing yoghurt with smoother consistency and also minimize the whey separation. Fruit dahi was prepared by suing mango, banana, pineapple and strawberry @ 6, 8, 6 and 4 percent levels and among them mango dahi was found to be most acceptable.

Shrikhand, a popular protein and sugar-rich fermented dairy product is also blended traditionally with mango pulp to prepare '*Amrakahnd*". The product is quite popular in western part of the country. Successful attempts were made to add cocoa powder and papaya pulp in *shrikhand*. It was reported that addition of cocoa powder at the rate of 5% in *shrikhand* resulted in pleasing taste and flavour, smooth body and texture, colour and appearance. Use of papaya pulp at the rate of 60% increased the nutritional value of *shrikhand* and also increased the total solid content of *shrikhand.* Similar results were obtained with natural fruit juices to get the desired taste, flavour, colour, body and texture development in the *shrikhand*. The nutritional value of shrikhand is also increased by incorporating apple pulp and *Celosia argentea* (flower part only). *Celosia argentea* is used as the colouring agent for *shrikhand*. After addition of apple pulp the protein, fat and ash content decreased while the moisture content increased slightly. Innovations in terms of reducing the sugar and fat levels in shrikhand could be a strategy followed by addition of fruit pulp to enhance the nutritional image of the product.

Published literature on probiotic fruit and vegetable containing fermented dairy products showed that fruit and vegetable constituents not only assist in development of desirable sensory attributes but also enhance the survivability of probiotic cultures. Most probably the cell wall constituents or polysaccharides present in fruit pulp act as prebiotic substance and also as encapsulating agent.

Summary

Trends indicate the growing awareness among consumers and manufacturers alike for the enormous potential offered for diversifying product profile using combination of milk solids and fruits & vegetables. Milk nutrients are considered essential components of diets among all age groups. The capacity of India to penetrate world markets depends on its ability to meet various emerging challenges both at production and processing levels. It could only be possible through research initiatives for storage and processing of food raw materials, novel food product development, development of indigenous processing equipments, appropriate packaging materials and techniques and rapid and reliable quality control methods.

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Biotech, Advancing Towards Another Green Revolution

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The knowledge of resources and education in the application of new biotechnological know-how is most important necessity for the development of rural and tribal sector worldwide. This effort will certainly bring the most desired development and prosperity in the backward areas of our country side.

Twenty first century belongs to the Biotechnology and hence, let us all pledge to use its immense potentialities for the benefit of mankind and sustainable development of our society, with due regards to our planet earth and all its ecosystems.

With the advent of molecular cellular biology, powerful tools and means to play with natural DNA have become available. These techniques are being improved at a rapid pace making recombinant DNA technology almost a new avatar of biology, an avatar that can touch the lives of billions of people positively. Originally, the term "Biotechnology" simply meant consciously manipulating and using processes of life for the benefit of humankind. But gradually the scope of the definition has become so enormous that all the new discoveries in any area of biology are accredited to biotechnology. The newer field of nanotechnology too, is part of this new, all inclusive definition of biotechnology. The advent of nanotechnology and a galloping progress in understanding the fundamentals of life processes and devising of newer more sophisticated technologies have resulted in an unsurpassed boom in the field that we are currently witnessing. It is now the general feeling that biotechnological innovations are poised to sweep the entire Globe influencing every aspect of human ecospheric life.

While biotechnology touches virtually every aspect of human life today, one can try and divide the impact of biotechnology on human beings into the following categories:

- The medicinal field which includes development of new targeted drugs, development of new diagnostic and preventive technologies, gene therapy, exploitation of plants and microbes as vehicles and factories for producing drugs and, in general, development of technologies that make human health better.
- Development of transgenic traits in plants that make them produce more and sustain adverse climatic conditions such as drought, salinity, aridity etc. Evolution of bio-fertilizers and bio-pesticides that reduce our dependence on counterproductive chemical moieties is also another cherished goal that impacts us. The question of higher food production is also included in this category.
- Addressing the question of environmentally sustainable technologies that will allow us to carry on with our activities with least damage to the environment or, conversely, allow us to restore the environmental conditions to their earlier, pristine nature. Included in this category is the development of alternative sources of energy since it is the exploitation of fossil fuels mainly that is responsible for the state in which the environment is today.
- Bioinformatics which includes management of data created by galloping genomics and proteomics studies and in silico development of drugs and enzyme inhibition studies.

The above categorization is not watertight since each field impacts the other field. However, such categorization has become necessary so as to summarize and classify the numerous developments that have taken place in the field of biotechnology in the last decade or so.

The biotechnology industry is getting more globalised with companies from all over the world joining the race. Though the core work of the human genome sequencing project was done in the US and the UK, the availability of genome sequences and software tools on the internet has made it possible for scientists anywhere in the world to participate in contemporary research. However, for such reasons as the availability of finance, the size of the market, government funding for research projects, and the intellectual property rights regime, the United States is expected to continue to be at the centre of the biotechnology industry for the foreseeable future. For example, the budget of the National Institutes of Health of the United States alone was about $27 billion in 2003 with the life sciences research budget of the whole of the European Union being less than half of this. Compare this with what Biocon India has to say. As per Biocon India, quoted in "The Economist", Sept. 2001, the biotechnology market in India is estimated at US $2325million at the end of 2005 in various sectors such as Animal and Health-care product (vaccines, antibiotics and other ($925million); Agricultural products i.e. high yielding and genetically modified seeds and other ($850million); Industrial products i.e. enzymes, amino acids, organic acids, yeast products ($550million). In view of this, the globalization of biotech companies in the U.S. is mainly in terms of pushing their products into other markets and limited research collaborations where very specialized pockets of expertise exist.

The biotechnology industry is booming. The United States biotech sector generated revenues of US$25 billion in 2001 from 1,379 companies. There is a boom in development of new drug molecules. From 1995 to 2000, nearly three times as many biotech drugs were approved than in the previous 13 years combined. In 2001, there were 117 biotechnology drug products and vaccines approved by the U.S. FDA and of these, three fourths were approved in the preceding 6 years; another 350 biotech drug products and vaccines were in advanced clinical trials at that time (Biotechnology Industry Organization, 2001). Before 1995, the number of biotechnology patents granted in the United States had not crossed 4,000 per year but in 1998 it touched 9,000 (Biotechnology Industry Organization, 2001, quoting U.S. Patent and Trademark Office). The number of biotechnology drugs and vaccine approvals never exceeded 7 per year till 1994, but was as many as 32 in 2000.

Impact of Biotechnology on Agriculture and Food Production

Challenges and Expectations from Biotechnology

Plant biotechnology is expected and predicted to have direct impact in improving health, primarily by making more food available to meet basic dietary needs and also by making better foods that are high in vitamins and have other healthy traits. In the developing world, where 840 million are chronically malnourished, the challenge often is just getting people enough calories. Biotech crop advances hardier crops that can ward off insect pests and viruses could have far reaching impact in helping farmers in Southern Africa and Asia. Such are the lofty expectations from biotechnology. To come true to these expectations, we need a 2nd green revolution, no less.

Need for a 2nd Green Revolution: The world needs a 2nd Green Revolution to feed its ever growing population, as stated by UN Food Agency. A cumulative international effort is required to feed the world as its population soars from the current six billion to nine billion, the agency

Director General Jacquest Diouf stated. While addressing the World Affairs Council of Northern California in San Francisco, Diouf stressed on the need for preserving the natural resources and environment while increasing the food production. The earlier Green Revolution relied on the lavish use of inputs such as water, chemical fertilizers and pesticides. Diouf suggested an additional requirement to grow an extra one billion metric tons of cereals a year by 2050. For this, the cultivators need a base of land and water in many of the world's regions. The present environment is increasingly deteriorating the land by global warming and climatic changes. The indiscriminate use of chemical fertilizers and pesticides adds to this deterioration. So, the need of the hour is spelt out clearly: to increase the food production without worsening the environment.

There are diverse ways in which biotechnology is addressing these problems and summarized below:

- Develop new plant varieties which give higher yield of food per hectare.
- Increase the content of nutrients in the plants.
- Increase the shelf life of food so that one saves on the losses due to spoilage and thus, indirectly adds to the amount of food available.
- Develop more effective biofertilizers and biopesticides to save the environment and soil from degradation and again indirectly adds to the food store.
- To spread awareness among the farmers about the newer objectives and the ways available to achieve them.

Recent Advances Relating to the Above Points: While speaking on 'Recent advances in plant biotechnology for human welfare', G. Madhava Reddy stated that plant molecular biology techniques like isolation of specific genes, synthesis of chimeric genes, etc., have been used for developing transgenic for more than 250 traits in more than 1000 plant varieties. As examples, he cited the case of transgenic tomatoes possessing qualities such as delayed ripening, high lycopene content, and also potatoes modified with high starch content, under commercial cultivation. Ultimately, gene manipulation through biotechnology provides an unlimited opportunity to solve problems of hunger, food security, diseases and also environmental pollution amongst the growing population in developing countries like India.

A gene that produces a plant hormone to counteract ageing and keeps fruits and vegetables fresh longer was recently discovered at the University of Leeds in the United Kingdom. Researchers currently are investigating practical applications for the commercial food marketplace that would help lengthening the shelf life of fruits and vegetables and ensure that they reach consumers.

As important as plant biotechnology is for the production of more food for a growing population, researchers are also developing healthier foods that can improve human health. Scientists today can use biotechnology to improve food by introducing health-enhancing traits, it otherwise wouldn't have. Field tests are underway on a cancer-fighting tomato with three times more lycopene, an antioxidant that protects human tissue and could help prevent breast and prostate cancers as well as heart disease. In India, mustard seeds have been improved so as to contain more beta carotene. These could help alleviate vitamin A deficiencies. Several research teams are working to improve rice by putting more nutrition into each grain. Enhanced Golden Rice may help reduce childhood blindness, while new iron-rich rice could have a truly global impact on one in three people worldwide who do not get enough of the nutrient. Researchers working with cassava, a staple food in many poorer parts of the world, have boosted protein levels by 35 to 45 percent and increased the levels of essential amino acids. Other members joining the group of functional food include vitamin E-enriched corn and canola oil, soybeans with higher levels of healthy monounsaturated fats and vitamin A-enriched rice.

Various biotechnological tools are utilized in improving the fertility of soil especially N and P content, through nitrogen fixing and phosphorus solubilizing bacteria thereby, reducing the inorganic source of these nutrients resulting in economizing the crop production. Though efforts have been made successfully in popularizing these bacterial, inoculants as biofertilizers, little has been done in improving their bioefficacy in the soil. Application of beneficial bacteria, fungi & actinomycetes as biocontrol agent against fungal phytopathogens is an emerging eco-friendly alternative to chemical pesticides. Soil reaction, deficiency and toxicity of nutrient elements and their balance in the soil are few important factors that determine their efficiency.

The biopesticidal genes from *Bacillus thuringiensis* (Bt) have been transferred into pigeonpea *(Cajanus cajan),* brinjal *(Solanum melanogena),* tomato, potato, rice, sorghum, cauliflower, cabbage, mustard and chickpea *(Cicer arietinum),* and are at different stages of testing. Several groups are working on the manipulation of fatty acid content in oil crops, or improving protein content in rice and potato by transgenic methods, or on delaying fruit ripening in tomato and banana using antisense technology. Although most of the transgenic varieties have yet to be cultivated on a commercial scale, hopefully these efforts would produce various transgenic plant varieties and provide them at affordable costs to the farmers, helping to prevent private-sector monopolies. Many plant genetic engineering efforts to develop fungal resistance involve pathogenesis-related (PR) protein genes. Among the PR proteins, chitinase (PR-3) and beta-1, 3-glucanase (PR-2) are efficient in the lysis of chitin and glucan polymers in the fungal cell wall.

The possibility to transfer genes across almost all taxonomic borders by molecular techniques has expanded the potential resources available to plant breeders enormously. The need of the hour is that the differences between transgenic and non-transgenic crops should become irrelevant when the *focus* of plant breeding is on achieving maximal production in a sustainable way to feed the growing human population. Dubbed 'the Green Phoenix', transgenic plant technology offers both challenges and opportunities for growth and development of mankind. This technology should be used to complement the traditional methods for enhancing productivity and quality, rather than replace the conventional methods. To adopt this technology, GM crops and their products, awareness has to be created among the farming and consumer communities regarding their benefits and effects on human life, by the scientific communities and national leaders.

The aesthetics of food is almost as important as the food itself. In food plaza, colour of food is one of the most vital elements in determining acceptance, besides making it attractive and appetizing. Historically, natural or "biocolours" were used extensively till the end of 19th century, when synthetic colours called 'coaltar dyes' were developed and acquired a widespread acceptability. Unfortunately, many of these have proved themselves to be allergens, or worse, to be carcinogens. Biocolours like anthrocyanins, betalaines, carotenoids. chlorophylls, xanthophylls etc. occur widely in nature. Among these, carotenoids are responsible for many of the brilliant red, orange and yellow colors of edible fruits (ripe mango, orange, papaya), vegetables (agathi, amaranth, colocasia leaves, carrot and mushroom). Carotenoids have vitamin-A activity and are associated with an array of biological functions like antioxidant, anticancer, modulation of detoxifying enzyme, enhancing immune system, all requiring intestinal uptake.

Thus, the use of biocolour is of immense significance from health point of view. Due to the hazardous nature of synthetic dyes, there is an increased commercial interest in using microorganisms as a colour source. Fungal systems are considered to be the best alternative, as they can grow and produce colour within a short period of time in a limited space. Many of the plant sources also are useful for biocolour production.

Farmers have been educated mostly on the use of biofertilizers and biopesticides but they have not been enlightened on the soil management to reap the maximum benefit of theses biofertilizers. In this regard, the Govt. policies require effective implementation by means of scientific local dialects communication by providing know-how and regular training programme among rural and tribal farming community, thus improving the national production and their socio-economic condition as well.

Rajiv Gandhi Biotechnology Centre, Nagpur (India) has been instrumental in addressing some of the issues raised above in Central India. It has developed nano-probiotics, biofertilizers and biopesticides and has popularized them at the rural level. The centre has also done yeoman's service in spreading awareness among farmers about the manner in which they can harness biotechnology in addressing the need for better farming.

Biotechnology and its Impact on Environment

An indiscriminate fossil fuel consumption, a lack of desire to develop alternative energy sources due to reasons mainly economic and/or political, lack of sophisticated models that predicted global warming till recently, use of CFC chemicals, initially due to ignorance and later wantonly, an uneducated and uninformed rampant use of fertilizers and chemical pesticides, wanton destruction of animals and plants for economic or supposedly aesthetic reasons are all reasons for the environmental degradation that we see today and that threatens to uproot whole populations from their traditional homes and play havoc with the food supply of the globe. Biotechnology is supposed to address these momentous problems. Let us try and believe that it is not too late in the day and that biotechnology may just be able to address these cantankerous issues.

Biodiversity is a major key to the environment protection. The tiger in India faces extinction mainly because its visceral parts are of medicinal use in traditional Chinese medicine and that its skin is of ornamental use. The cheetah is on the verge of extinction in Africa mainly owing to a limited genetic pool and problems that have arisen in that pool. Many other animals, small and big, are in danger of extinction. So is the fate of plants. To clear the land for building activities, for organized farming or merely for timber has created the condition whereby we will lose plants and many undiscovered medicinal molecules with them. Biotechnology is trying to address these problems by addressing and correcting the gene pools of the Cheetah, improving the reproductive traits of the tigers and by protecting the germplasm of plants and by devising ever new micropropagation techniques and by various other methods. We are also trying to save the eagles by establishing that diclofenac sodium, a drug used in cattle is responsible for their plight and then banning this drug. According to IUCN : " The major proximate causes of species extinction are habitat loss and degradation".

The primary causes of habitat loss are agricultural activities, mining, fishing, logging and harvesting and development of human settlements, industry and associated infrastructure. The pressure on the land and rivers lead to the loss of habitat and prey base. Another important reason for the loss of species is poaching. The global market for animal products stands at an alarming $2.5 billion. In the past decade, poaching has emerged as an organized crime and has become virtually impossible to control. Unlike the mega species, the smaller ones are victim of their low-priority conservation status, No census is done on them. The major roadblock seems to be the lack of funding. According to a World Resource report, the planet is on the verge of an episode of major species extinction. This phenomenon, during which a significant portion of global flora and fauna were wiped out, has happened five times over the last half-billion years.

The United Nations Environment Protection (UNEP) agency believes that ecotourism can cause the loss of the biodiversity, thus, leading to loss of tourism potential. Tourists often unknowingly cause enormous disruption, and even destruction of ecosystems by destroying the species (insects, wild and cultivated plants etc.) that are not native to a local environment. The destruction and disturbance caused by the tourism industry, especially over the last few decades, when access to remote areas improved greatly, has led to questions being asked about its sustainability.

Need for Newer Agricultural Technologies: Development and Research Strategies

The development of small farms depends upon a number of factors and it is a complex phenomenon. One of the important factors is, the development and transfer of new agricultural technologies. In the past agricultural research did not pay more attention to develop technologies suiting to the conditions of small farmers, however increased attention is paid to this aspect in recent times. Studies have also pointed out that with the available new technologies, the level of production and productivity could be considerably improved in the fields of small cultivators. The idea that small farmers are traditional and not motivated to adopt modern technologies is not correct according to the results of many research studies. What is needed is to transfer presently available and suitable technologies as well as developing appropriate technologies. Also, there is a need to identify and remove the constraints in adoption of technologies.

Although the new agricultural technology has helped in raising farm production, productivity and income of the farmers in developing countries, in recent decades, a majority of small farmers in these countries remain poor and operate largely traditional methods of farming at little above subsistence level. The big and wealthier farmers have adopted modern farm innovations while the small and poor farmers are unable to make use of the same. The past development strategies, research priorities and extension efforts have failed to distributethe fruits of agricultural development efforts to the majority to small farmers. Realising the need for reaching the small farmers with modern approaches, extensive efforts have been initiated in several countries.

If we agree that small farmers can be helped by modern technology. The next important thing we have to do is to make available the viable technology to the farmers. At present, the main criterion for evaluating agricultural innovation is whether it is agronomical successful and cost effective. Thus, if our research is to help our small farmers, our priorities and emphasis should be tailored to produce technology appropriate for small farmers. While generating technology, we have to keep in mind various problems of small farmers such as small size of farm, poor financial resources, lack of irrigation facilities, poor marketing facilities and the like. The technology should also be cheap and simple to the understood and used by the farmers.

Today, transfer of technology is more important than other functiona1 areas, may it be research or education. There are a large number of farm technologies which have not yet reached the farmers, more so the small and marginal farmers and agricultural labourers. No doubt, the benefits of Green Revolution in India have gone to the rich farmers, for they have relatively easy access to extension agencies, as well as have resources to backup their production plans. They could also take risk and experiments.

Critical Appraisal for Dissemination of Technologies

Basically, small farmers have favorable attitude towards new technology and they have selectively adopted the same with suitable changes or modifications.The adoption of new technology is sometime hindered by a number of constraints. Some of these are technological, socio-cultural, economic, physical, administrative and the like. Hence, there is a need for close interaction between scientists and small farmers to reduce technology application gap and develop appropriate technologies. This includes learning about small farmers and integration of small farm family's circumstances into the project process.

Overall, there has to be a sound technical advisory system to be linked with the mobilized group which can plan and advise marginal farmers for increased agricultural production and productivity. For this purpose, the following critical suggestions are:

i. Identification of farmer's problems through base line survey and preparation of resource inventory.

ii. Formation of farmer's group and discussions with members of groups about the identified problems.

iii. Formulation of agricultural production plans through participatory planning for homogeneous groups.

iv. Training of farmers in the improved practices and organization of large scale demonstrations based on production plans.

v. Linkage of farmers groups with developmental agencies (credit and inputs).

vi. Adaptive trials must be conducted on the field of small farms before the experimental recommendations are released for adoption to these farmers.

vii. All the inputs and credit needs of small farmers should be routed through single agency and a single window approach is suggested for this purpose.

viii. Mixed farming must be encouraged among small farmers. Training should be given to small farmers on subsidiary enterprises like dairying, goat rearing, sheep rearing, poultry keeping etc.

ix. Aproper rural communication policy and strategy has to be evolved with emphasis on reaching small farmers with modern technologies.

x. The extension organizations should be reoriented to the needs of small farmers. Greater extension efforts have to be directed towards small farmers.

The Rajiv Gandhi Biotechnology Centre established at R. T.M. Nagpur University (M. S.), India and School of Life Sciences, North Maharashtra University, Jalgaon, India has taken up the above mentioned issues. It makes various bioinput products that are of tremendous use to the farmers and other natural producers in the villages of the region. Our scientists and faculty members fan out into the fields and understand the difficulties encountered by the farmers and try to address these in our labs. Knowledge of the local dialect by our scientists is of big help here. From the past many years, we have been developing the most appropriate sustainable, eco-friendly, low cost, viable biotechnology solutions with special emphasis on nano-probiotics, biopesticides and biofertilizers useful for rural and tribal areas. We sincerely hope that there must be many more institutions in India and other developing countries striving hard so that the benefits of biotechnology trickle down to the masses.

We believe that the best lies ahead of us and the successes achieved by the centre and North Maharashtra University, Jalgaon, India so far are just pointers to the road ahead. We also believe that a replication of our path-breaking initiatives, particularly with respect to our services to the villages, “Lab to Land” will go a long way in not just nurturing the imperiled lives of peasants and common folks but also in lessening the opposition to the biotech products and hence, boosting the usage of biotech products to give a fillip to the biotech Industry, leading to the prosperity of the nation.

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Climate Smart Horticulture for Addressing Food, Nutritional Security and Climate Challenges

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Horticulture is an essential driver for growth of agriculture in India and includes fruits, vegetables, flowers, potato and tuber crops, spices, mushrooms, medicinal and aromatic plants and plantation crops. It has become an outsmart option for diversification to meet the need for food, nutrition, health care besides providing better returns on farm land and better opportunity for employment. Little investment made in horticulture has been rewarding in terms of increased production, productivity and export and emergence of India as second largest producer of fruits and vegetables. This changing scenario is attributed to technological interventions and efforts for development. 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. The issue of climate change and climate variability has thrown up greater uncertainties and risks, further imposing constraints on horticultural 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 climate-smart interventions which are highly location-specific and knowledge-intensive for improving production in the challenged environment.

Standing Situation of Horticulture

Most significant change in the last two decades have been that horticulture has moved from rural confine to commercial production leading to use of technologies and private sector investment in production system management. Investment made in horticulture during IX, X and XI Plants have been highly productive in transforming an agrarian economy in many states, which has provided insight for reversing the trend of ever declining farmers' income and, above all addressing the nutritional security and environmental concerns. Impact of change in technologies like new cultivars and production system management is visible in terms of increased production and productivity, which has recorded more than nine-fold increase to 268.2 million tonnes during 2012-13 (NHB, 2013) from the level of 25 million tonnes in 1950-51. Undoubtedly, horticulture sector has moved dynamically despite numerous challenges and shortcomings, and is in crucial phase of development needing initiatives for sustainable development. To achieve the targeted production of 340 million tonnes of horticultural crops by end of XII Plan (2012-17), vertical growth, through the use of new cultivars, efficient water and nutrient management, effective plant health management coupled with strategies for reduced post-harvest losses could be the approach, which would need appropriate innovation and investment. Protected cultivation has shown yield enhancement up to 4 times, but would need investment. Plant architectural engineering and management can mitigate the problem associated with seasonality in many crops and will enhance efficiency of irrigation utilizing modern techniques to reduce water stress. Since, horticulture provides variability and has potential to adjust in different agro-climatic situation technology-led development is inevitable.

Sagacity of Climate Change

Significant variation in either mean state of climate or in its variability, persisting for an extended period (typically decades or longer) is referred as climate change, which may be due to natural internal processes or external forcing, or to persistent anthropogenic changes in the composition of the atmosphere or in land use. The earth is the only planet in our solar system that supports life, because of unique environmental conditions that are present - water, an oxygen-rich atmosphere, and a suitable surface temperature. It has an atmosphere of proper depth and chemical composition. About 30% of incoming energy from the sun is reflected back to space while the rest reaches the earth, warming the air, oceans, and land, maintaining an average surface temperature of about 15 ^{o}C. The chemical concentration in atmosphere for nitrogen is 78%; about 21% is oxygen, which all animals needs to survive; and only a small (0.036%) is made up of carbon dioxide which plants require for photosynthesis. In atmosphere, energy is absorbed by the land, seas, mountains, etc., and simultaneously released in the form of infrared waves. All this released heat is not lost to space, but is partly absorbed by some gases present in very small quantities in atmosphere, called greenhouse gases consisting of carbon dioxide, methane, nitrous oxide, water vapour, ozone and a few others. In absence of emission of heat imbalances are created. Thus, increased concentration of greenhouse gases leads to increased temperature which in turn has impact on the world climate, leading to the phenomena known as climate change (IPCC 2001, Singh, 2010).

The earth's climate system constantly adjusts so as to maintain the balance between the energy that reaches it from the sun and the energy that goes from earth back to space. This means that, even a small rise in temperature could mean accompanying changes in cloud cover and wind patterns. Some of these changes may enhance the warming, while others may counteract. Cooling effect may result from an increase in the levels of aerosols from small particles of matter or liquid that can be produced by natural or man-made activities. Positive feedback may result from an increase in water vapour due to high evaporation with rise in temperature and can further add to the warming effect. The significant change may impact agriculture/horticulture/fish/livestock and consequently food supply. Climate change per se is not necessarily harmful, but the problems arise from extreme events that are difficult to predict, like more erratic rainfall pattern and unpredicted warm spells shall affect productivity. At the same time, more availability of CO_2 would help in improved yield of root crops and increased temperature may shorten the period. For the last few years, various institutions, Government organizations and also the Indian Council of Agricultural Research (ICAR) have been deliberating upon the likely change in climate and its adverse impact on agriculture, and there have been clear conclusion that climate is changing, which needs public intervention and also preparedness to face the challenges.

Climate Change in Asia

The increase in temperature due to global warming is 0.76 ^{o}C since 1850. The rate of warming in the last 50 years is double than that for the last century. As many as 11 of the past 12 years were warmest since 1850, when records began. The likely increase in temperature is 1.8-4 °C by next century. The threshold value of temperature rise is 2 °C for devastating, dangerous and irreversible consequences of warming to manifest world over (IPCC, 2007). Global warming is occurring along with shifting pattern of rainfall and increasing incident of extreme weather events like floods, droughts and frosting. Recent studies suggest clear evidence of reduction in light intensity, rapid melting of glaciers and rise in sea-level. The estimates of Indian Institute of Tropical Meteorology, Pune, indicate similar trends in India with slightly higher magnitude. It is projected that rainfall over India will increase by 15-40%, and the mean annual temperature will increase by 3-6 ^{o}C by the end of 21st century (IPCC, 2001, Singh, 2010). Warming is likely to be more pronounced over land areas with the maximum increase over northern India. The winter and post-monsoon seasons are likely to be more affected by warming. Beside, there would be more fluctuation in temperature and water availability may decline.

The South Asian region is projected to be one of the most vulnerable to climate change. It is attributed to increasing population pressure, extreme poverty, and predominance of agriculture and resource crunch in the region. It is projected that by 2020, food requirement in South Asia would be 50% more than the current demand. The challenge is to produce the same from constant or even shrinking land resources due to competition for land from other sectors like infrastructure, industry and housing. Poverty alleviation and food security for teeming millions in India under adverse climate change scenario would be a daunting task. These changes in global environment will have profound effects and serious consequences for agriculture, horticulture, arable eco-system and society as a whole.

Direct and Indirect Effects of Climate Change

Global climate change is expected to affect agricultural/horticultural crops through its direct and indirect effects. Scientific evidence suggests a positive effect of increase in atmospheric carbon dioxide in C_3 photosynthetic pathway promoting their growth and productivity (Kimball, 1983; Poorter, 1993; Acock and Allen, 1985). Increased CO_2 will reduce evapo-transpiration and thus increase water-use efficiency. However, positive effects will be counteracted by increase in temperatures. Rise in temperature will reduce crop duration, increase respiration rate, alter photosynthate partitioning to economic product, alter phenology, particularly flowering, fruiting and reduce chilling unit accumulation, hasten senescence, fruit ripening and maturity. Cauliflower grows best in cool to warm conditions (15–25 °C) with high humidity. Though, some varieties can grow with temperatures over 30 °C, most varieties are very sensitive to higher temperature. Delayed curd initiation in cauliflower is reported due to increased temperature. Temperature above 30 ºC induce maximum flower and fruit drop and high temperatures after pollen release decrease fruit setting, fruit yield and seed setting in tomato (Singh, 2010).

The sensitivity of individual crop to temperature depends on inherent tolerance and growing habits. Indeterminate crops are less sensitive to periods of heat stress because the time of flowering is extended compared with determinate crops (Hall and Allen, 1993). In onion, warmer temperatures shorten the duration of growth leading to lower crop yields. Any soil warming would be advantageous for cucurbits, which are generally direct seeded and have a high heat requirement. The rise in temperature will influence survival and distribution of pest population; developing new equilibrium between alternate host crops and pests; hasten nutrient mineralization in soils; decrease fertilizer-use efficiency; and increase evapo-transpiration with reduced water-use efficiency. The net effect of climate change on horticultural crops will depend on interaction effects of rise in temperature and CO_2 concentration in atmosphere. In general, CO_2 enrichment does not appear to compensate for the detrimental effects of higher temperature on yield (Srinivas Rao et al, 2010). The interplay of all these factors associated with climate change would subsequently determine the extent of impact on different crops in different agro-ecological regions. It could bring about both adverse and beneficial impacts on crop production depending on the prevailing climatic conditions of the agro-ecological regions, crop species and season. It could affect the growth, development and quality of horticultural crops and alter the zones of crop adaptation.Most importantly, the quality of produce of these horticultural crops is likely to be impacted severely.

Sensitivity of Horticultural Crops

To quantify the impacts of climate change on horticultural crops, we need detailed information on physiological responses of the crops, effects on growth and development, quality and productivity. The various impacts need to be addressed in concerted and systematic manner in order to prepare the horticulture sector to face the imminent challenges of climate change. The rise in temperature would lead to higher respiration rate, alter photosynthesis rate and partitioning of photosynthates to economic parts. It could also alter the phenology, shorten the crop duration, days to flowering and fruiting, hasten fruit maturity, ripening and senescence. The sensitivity of individual crop to temperature depends on inherent tolerance and growing habits. Indeterminate crops are less sensitive to heat stress conditions due to extended flowering compared to determinate crops. The temperature rise may not be evenly distributed between day and night and between different seasons (Srinivas Rao, 2010). In tropical regions even moderate warming may lead to disproportionate declines in yield. In high latitudes, crop yields may improve as a result of a small increase in temperatures. In developing countries, which are predominantly located in lower latitudes, temperatures are already closer to or beyond thresholds and further warming would reduce rather than increase productivity. The impact of climate change is likely to differ with region and type of the crop (Abdalla and Verkerk, 1968).

Tropical/Subtropical Fruits and Plantation Crops

High Temperature: The extreme weather events of hot and cold wave conditions have been reported to cause considerable damage to many fruit crops. In perennial crops like mango and guava, temperature is reported to have influence on flowering. The percentage of hermaphrodite flowers was greater in late emerging panicles, which coincided with higher temperatures (Ramaswamy and Vijay Kumar, 1992). Though grape originated in temperate regions, modifications in production system, taking up two pruning and one crop, has enabled it to adapt to tropical conditions. Under climate change conditions there would be changes in availability of growing degree-days leading to hastening of the phenological processes (Laxman and Srinivas

Rao, 2010). Cashew, which is mostly grown under rainfed conditions, is vulnerable to climatic variability and drought conditions caused due to shifts in rainfall pattern and inter seasonal variability (Yadukumar *et al*, 2010). The temperature rise will influence the survival and distribution of pest populations. Consequently shifting equilibrium between host plants and pests. The rise in temperature will hasten nutrient mineralization in soils, decrease fertilizer use efficiency. Increase in temperature at fruit maturity lead to fruit cracking and burning in litchi and premature ripening of mango. Low fruit set is observed due to sudden rise in day time temperature (35 ºC) during peak flowering in mango (Singh, 2010). Low temperature (4 to 11.5ºC) in the month of January, accompanied by high humidity (>80%) and cloudy weather delayed panicle emergence. During peak bloom period, high temperature (35ºC) accompanied by low relative humidity (49%) and long sunshine hours resulted in excessive transpiration and dehydration injury to panicles. Untimely winter rains promote vegetative flushes in citrus instead of flowering flushes. Dry spell during flower emergence and fruit set affects flower initiation and aggravates incidence of pest (*Psylla*). In wine grapes anthocyanin development is influenced by difference between day and night temperatures with high variation (15-20 ºC) promoting colour development. In coconut, impact of climate change related events like consecutive droughts and cyclones adversely affected nut yields (like droughts in TN and Karnataka, cyclone in AP) (Bhriguvanshi, 2010; Laxman *et al*., 2010).

Many slow-growing fruit crops require heavy investment on establishment of orchards. Quick alteration/shifting of fruit species or varieties would be difficult and painful loss-bearing exercise under the impact of climate change, which may discourage the development. Recent studies have indicated that in Kullu district of Himachal Pradesh, farmers shifted from apple to vegetables, while in Shimla district at relatively higher altitude orchards have been replaced from high-chilling requiring apple cultivars of apple (Royal Delicious) to low-chilling requiring cultivars and other fruit crops like kiwi, pear, peach and plum and vegetables. In mid hills of Shimla district, trend is to shift from apple and potato cultivation totally. It is corroborated by declining trend in snowfall and apple productivity in Himachal Pradesh. Since many crops with chilling requirements are tree species, moving production areas is difficult. Thus in replanting orchards and plantations over the next decade, selection of lower-chilling requiring types may be advisable. This is just an example of impending impacts of global warming and climate change.

Grape being a temperate crop has very well adapted to tropical regions, under climate change scenario with increase in temperature there would be change in growing degree days (GDD), which has direct bearing on phenology of the crop. Hence, under such circumstances, we would have to identify varieties and regions suitable for production of quality fruits. Excessively high temperatures for extended periods of time in grapes generally result in delayed fruit maturation and reduction in fruit quality. At 35°C pigment development was completely inhibited in Tokay and reduced in Cardinal and Pinot Noir compared to 20 or 25°C. A linear reduction in per cent acid with increasing effective heat units was evident in Valencia and Navel orange varieties indicating the negative relationship of temperature with acid/brix ratios. Shift in varietal choice may become necessary in case of grapevines, banana, mango and other important horticultural crops (Laxman and Srinivas Rao, 2005; Laxman *et al.*, 2010).

With global warming production areas for specific crops and/or timing of planting could be changed, but for many horticultural crops, market windows and infrastructure, such as availability of local packing and distribution facilities are critical components of the production system. Locations of important production areas are often defined as much by available land, markets and infrastructure as by climatic conditions per se. Thus, as horticulturists we have to ask ourselves and our clientele whether it is realistic to move production areas in response to climate change, or whether there are other production practices that can be adjusted to compensate climate change. Climate change and CO_2 are likely to alter important interactions between horticultural plants and pollinators, insect and disease, and pests and weeds.

Water Stress: In citrus severe water stress causes reduction in leaf initiation, leaf size gets reduced and leaves become leathery and thick. Root growth is adversely affected by water stress. It may lead to increased rooting depth and higher proportion of feeder roots in citrus. In grape vine, developing water stress reduced inflorescence initiation in conjunction with reduced shoot growth. Water stress reduces the growth of grape berries, but does not influence the characteristic double sigmoid growth curve. Water deficit during stage I (when cell division is occurring) will generally reduce berry size more than water deficits during stages II and III (growth cell expansion). Water deficit positively affected polyphenol accumulation in berry skin and anthocyanin biosynthesis was strongly induced by water stress and the wines obtained from water-stressed plants had high anthocyanin concentration resulting in a more intense colour (Hucheche *et a*l., 2010; Downton, 2007; Idso and Kimbell, 2003). In papaya, water stress imposed by suspending irrigation for 34 days arrested plant growth, induced leaf abscission and drastically decreased photosynthetic rate. Thus, it is evident that impact of water stress is more influenced by stage of growth, water stress before flowering is essential to get flowering while stress at the growth stage of fruit is detrimental.

Flooding: In mango flooding simultaneously reduced net CO_2 assimilation and stomatal conductance after 2-3 days. However, flooding did not affect leaf water potential, shoot extension growth, or shoot dry weight, but stem radial growth and root dry weight were reduced. Mortality of flooded trees ranged from 0 to 45%. Hypertrophied lenticels were observed on trees that survived flooding but not on trees that died. The reductions in gas exchange, vegetative growth, and the variable tree mortality indicate that mango is not highly flood-tolerant but appears to possess certain adaptations to flooded soil conditions (Bhriguvanshu, 2011 and Laxman *et al*., 2010).

The studies conducted in apple show that, the productivity will continue to decline up to 1500 m msl to the tune of 40-50 % due to warmer climate and lack of chilling requirement during winter and warmer summers in lower elevations resulting into shifting of apple production to higher elevation (2700 m msl). Winter snowfall affects flowering. In spring, low fluctuating temperatures during bloom results in poor fruit set while warm temperatures result in desiccation of floral parts. Mild winter temperatures followed by warmer springs advanced bud burst and exposing buds to frost damage in almond and apricot. High temperature and moisture stress increased sunburn and cracking in apples, apricot and cherries (Singh, 2010).

Research Efforts for Understanding the Impact of Climate Change

These studies conducted by various institutes indicate the likely impact of climate change on various horticultural crops. To quantify the impacts of climate change on horticulture sector concerted efforts are needed to study and assess the impacts on individual crops under the major agro-ecological regions and growing seasons. We need to set new research priorities to have a detailed understanding of the impact of climate change on horticulture sector as a whole. The quantification of impacts of variations in temperature, excess and limited moisture conditions is the first step to prepare the horticulture sector for developing adaptation strategies under climate change scenarios.

We need quick and clear understanding of impact of climate change on horticultural crops for making sound action plan because horticulture based farming systems have high potential for sequestering carbon for mitigation of climate change. The perennial trees act as carbon sinks by sequestering the atmospheric carbon. The carbon credits could be earned under the clean development mechanism (CDM). The horticultural waste could be composted locally instead of dumping in the landfills, which can reduce the release of global warming methane that is involved in global warming. The organic waste could also be used for generating biogas as an alternate energy source. There are considerable uncertainties about agronomic implications of horticultural crops. Predicting impact of climate change on horticultural crops accurately on regional scale is a big problem. It can be accomplished only by a modeling approach through well-validated robust crop simulation models. These crop simulation models incorporate the effect of various factors of growth and yield in a mathematical model processed by computers to give results quickly for specific situation. Well-validated simulation tools developed for cereal crops have been helpful in predicting of impact of climate change.

Impact of Climate Change on Vegetables and Other Horticulture Crops

Indian climate is dominated by the monsoon, responsible for most of the region's precipitation, poses excess and limited water stress conditions. Vegetables being succulent are generally sensitive to environmental extremes and high temperature, limited and excess moisture stresses are the major causes of low yields. Under climate change scenarios the impact of these stresses would be compounded. In tomato high temperatures can cause significant losses in productivity due to reduced fruit set, smaller size and low quality fruits. Optimum daily mean temperature for fruit set in tomato has been reported to be 21-24 ºC. The pre-anthesis stage is more sensitive in tomato (Geisenberg and Stewart, 1986. Post pollination exposure to high temperature inhibits fruit set in pepper, indicating sensitivity of fertilization process (Erickson and Markhart, 2002). In cucumber sex expression is affected by temperature. Low temperatures favours female flower production, which is desirable and high temperatures lead to production of more male flowers (Wien, 1997). The duration of onion gets shortened due to high temperature leading to reduced yields (Daymond *et al*., 1997). Cauliflower performs well in the temperature range of 15-25 ºC with high humidity. Though some varieties have adapted to temperatures over 30 ºC, most varieties are sensitive to higher temperatures and delayed curd initiation is observed (Singh, 2010). The quality of horticultural commodities is likely to be most affected by heat and water stresses. In onion temperature increase above 40 ºC reduced the bulb size and increase of about 3.5ºC above 38ºC reduced yield (Lawande *et al*.,2010; Srinivasa Rao, 2010). In potato, reduction in marketable grade tuber yield to the extent of 10-20% is observed due to high temperature and frost damage reduced tuber yield by 10-50%, depending upon intensity and stage of occurrence. Advancement in appearance of aphids by two weeks with increase in 1ºC and also the reduced growing period of potato seed crop. Temperature increase beyond 20 ºC during winter affects cultivation of seasonal button mushroom and increased incidence of diseases. Occurrence of frost during January in Rajasthan affects cumin resulting in total crop failure. Temperature raise from 20 to 22 ºC will increase the incidence of pest and diseases in case of cymbidium orchid (Peet and Wolfe, 2000; Reynolds *et al*., 1990).

The horticultural crops having C3 photosynthetic metabolism have shown beneficial effects due to elevated CO_2. Studies conducted under controlled open top chambers indicated the increase in onion yield by 25-30% mainly due to increases in bulb size at 530 ppm CO_2 (Wurr *et al*.,1998; Wheeler,1996; Daymond *et al*., 1997). Tomato also showed 24% higher yield at 550 ppm CO_2 due to increase in number of fruits (Srinivas Rao, 2010). In perennial crops like coconut studies indicate the increase in shoot height, leaf area and shoot dry matter due to elevated CO_2 to the tune of 36% over chamber control (Naresh Kumar, 2008).

In onion, warmer temperatures shorten the duration of growth leading to lower crop yields (Wheeler *et al.*, 1996). Any soil warming would be advantageous for cucurbits, which are generally direct seeded and have a high heat requirement. The rise in temperature will influence survival and distribution of pest population; developing new equilibrium between alternate host crops and pests; hasten nutrient mineralization in soils; decrease fertilizer-use efficiency; and increase evapo-transpiration with reduced water-use efficiency. The net effect of climate change on horticultural crops will depend on interaction effects of rise in temperature and CO_2 concentration in atmosphere (Srinivas Rao, 2010). In general, CO_2 enrichment does not appear to compensate for the detrimental effects of higher temperature on yield. Most importantly, the quality of produce of these horticultural crops is likely to be impacted severely.

Climate Smart Horticulture and Policy Requirements

In broad sense climate-smart agriculture/horticulture should contribute for achieving the goal of sustainable agriculture. It has an integration of three dimensions of sustainable development (economic, social and environmental) for jointly addressing food security and climate challenges. Such three dimensions are sustainably increasing agricultural productivity and incomes; adapting and building resilience to climate change and reducing and/or removing greenhouse gases emissions, where possible. Climate smart horticulture should primarily aim to improve food and nutritional security helps people to adapt to climate change and contribute to climate change mitigation by adopting appropriate practices, developing enabling policies and institutions and mobilizing needed finances. It requires comprehensive policies at every level, adequate institutions and proper governance to make the necessary choices. It also requires new financing to address the needs in terms of investments and research and to enable the farmers to overcome barriers to adoption of new practices including up-front costs and income foregone during the transition period.

Climate Smart Horticulture- An Approach.

Climate smart horticulture is not a single specific agricultural technology or practice that can be universally applied. It is an approach that requires site-specific assessments to identify suitable production technologies and practices to address multiple challenges faced by agriculture and food systems simultaneously and holistically. The major characteristics of climate smart horticulture are that it is a location-specific and knowledge-intensive, identifies integrated options that create synergies and reduce trade-offs, identifies barriers to adoption and provides appropriate solutions, strives to achieve multiple objectives while prioritizing benefits and trade-offs, identifies barriers to adoption and provides appropriate solutions, strengthens livelihoods by improving access to services, resources and markets, addresses adaptation and builds resilience to shocks, considers climate change mitigation as a potential co-benefit, integrates climate financing with traditional sources of agricultural investment and it brings together practices, policies and institutions that are not necessarily new but are used in the context of climate change.

Addressing Climate Change

Climate change is global, but its nature, extent and magnitude are variable in different regions and locations. Hence, the issues of climate change and solution to the problems arising out of it requires local analysis, planning and management. There is need to analyze and understand about climate change at regional levels in relation to both annual and perennial horticultural crops, which could be managed through innovation, technology evaluation and refinement to provide effective solutions to the problems.

Simulation Models for Impact Assessment

In the event of working out adaptation and mitigation strategy, it will be appropriate to utilize modelling tools for impact analysis for various horticultural crops. Availability and development of good simulation models for horticultural crops (fruit and vegetables) is lacking in India probably with exception of potato and coconut. In tomato and onion crops, the Info Crop model has been adapted and the model is being validated for different agro-ecological regions (Naresh Kumar *et al.*, 2008). Perennial nature of large-sized fruit trees and shrubs are problematic in study of direct effect of various factors of growth, development and yield in controlled environment. Innovative methods are required to develop simulation models for important horticultural crops like mango, grape, apple, orange, citrus, litchi, guava, etc., on priority. Similarly, annual vegetable crops like capsicum, cucurbits, cauliflower and root and tubers, and flower crops urgently need crop simulation models (Srinivas Rao, 2010). Once these simulation models are available, prediction of vulnerability of existing areas under these horticultural crops to climate change scenario can be examined and new target areas for possible shifting of species and varieties for cultivation can be identified. Possible adaptation measures to reduce the impact of climate change are also possible to study through simulation models for suggesting changes in management practices. Development of crop simulation models for horticultural crops in India is now a priority area of research.

Adaptation Strategies

Potential impacts of climate change depend not only on climate *per se*, but also on the system's ability to adapt to change. The potential depends on how well the crops adapt to the concomitant environmental stresses due to climate change. Depending on the vulnerability of individual crop in an agro-ecological region and the growing season, the crop based adaptation strategies need to be developed, integrating all available options to sustain the productivity. The scientists have already developed several technologies to cope with extreme events like high temperature, frost and limited and excess moisture stress conditions (Naresh Kumar, 2010; Srinivas Rao and Bhatt, 1992; Laxman and Srinivas Rao, 2005). These available technologies could be integrated and made use to reduce the adverse impacts of climate change and climate variability. Further emphasis need to be put on developing the crop, agro-ecological region and season-based technologies to reduce the impacts and increase the resilience of horticultural production systems to climate change. To address the adverse impacts of climate change on productivity and quality of horticultural crops we need to develop sound adaptation strategies.

Production System Management: The emphasis should be on development of production systems for improved water-use efficiency and to adapt to the hot and dry conditions. Strategies like changing sowing or planting dates in order to combat the likely increase in temperature and water stress periods during the crop-growing season. Modifying fertilizer application to enhance nutrient availability and use of soil amendments to improve soil fertility and enhance nutrient uptake. Providing irrigation during critical stages of the crop growth and conservation of soil moisture reserves are the most important interventions. The crop management practices like mulching with crop residues and plastic mulches help in conserving soil moisture. In some instances excessive soil moisture due to heavy rain becomes major problem and it could be overcome by growing crops on raised beds. Production of vegetables could be taken up using clear plastic rain shelters, which can reduce the direct impact on developing fruits and also reduce the field water logging during rainy season. Planting of vegetables on raised beds during rainy season will increase the yield due to improved drainage and reduced anoxic stress to the root system. Grafting of vegetables on tolerant rootstocks would provide the scion cultivars with tolerance to soil related environmental stresses such as drought, salinity, low soil temperature and flooding. Efforts initiated by AVRDC in improving flood tolerance in tomato using eggplant rootstocks for grafting could be extended to impart water stress and temperature stress tolerance (AVRDC, 1990). More heat tolerant cultivars are required under climate change conditions and these cultivars need to perform at par with the conventional varieties under non-stress conditions.

Gene Manipulation for a Biotic Stresses: In addition to employing modified crop management practices, the challenges posed by climate change could be tackled by developing tolerant varieties. Several institutions have evolved hybrids and varieties, which are tolerant to heat and drought stress conditions. They must be used very effectively to combat the effect of climate change depending upon their performance in a given agro-ecological region. Efforts should be intensified to develop new varieties suitable to different agro-ecological regions under changing climatic conditions. In comparison to annual crops, where the adaptation strategies can be realized relatively fast using a wide range of cultivars and species, changing planting dates or season, the planting and rearrangement of orchards requires a consideration of the more long-term aspects of climate change. Therefore, before resorting to any adaptation option, a detailed investigation on the impact of climate change on perennial crops is necessary.

The long-time horizon of perennial crops creates situations like; favourable areas may become unfavourable during the life of a single orchard. The choice of a variety is complicated by the risk that the best variety for the current climate may be poorly suited for future climates. Thus, while adaptations such as planting new varieties and shifting to new areas may reduce impacts in the long-term, short-term losses may largely be unavoidable. In wine grape, each grape variety grows in a range of temperatures and for each variety it is possible to define climates for premium wine production. The physiological and morphological differences between varieties (genotypes) enable production over a relatively large range of climates and depending upon the suitability to different growing areas the cultivars may be adopted. In situations, where there is a strong consumer preference for a select cultivar and also the suitable varieties are not available to adapt to the changing climate of a particular growing region, the option of using rootstocks for better performance of the scion cultivars could be explored.

An integrated approach with all available options will be most effective in sustaining the productivity under climate change conditions. To achieve this end, efforts must be initiated at national and agro-ecological region level to assess the impact of climate change on different horticultural crops and to develop combinations of adaptation options for horticulture sector as a whole in an integrated manner to tackle the impacts of climate change.

Mitigation Strategies

Climate change is a reality and there is enough evidence to show that the emission of green house gasses has caused global warming and associated climate change. In addition to adapting the horticultural production systems to adverse impacts of climate change, horticulture sector can considerably contribute to the mitigation. Mitigation is referred to the process in which the emission of green house gases are either reduced or sequestered. The improved crop management practices can considerably reduce the emission of green house gasses due to reduced dependence on energy needs and intensification of perennial horticultural crops will help in sequestering carbon dioxide from the atmosphere.

Carbon Sequestration Potential

Mitigation measures in the agriculture and forestry sectors are generating much interest as a potential source for additional income to otherwise weak rural areas and as a means of fueling adaptation to climate change. Mitigation efforts through carbon sequestration help to reduce the adverse impacts of climate change. The information about carbon sequestration potential of fruit trees is scanty though they contribute significantly. In a study using PRO-COMAP model at IISC, Bangalore estimated the mitigation potential of farm forestry fruit orchard block planting with 75% of area proposed under *Mangifera indica*, *Tamarindus indica*, *Achras sapota*, *Artocarpus*, Neem and Guava. The carbon stock change under baseline and mitigation scenario (excluding harvested wood products) and the carbon increment per ha for various project activities for the 30-year period (2005-2035) worked out to be 47.42 t C/ha. The overall mitigation potential for farm forestry with an area of 5,381 ha is 81,750 t C. fruit orchards farm forestry is found to be most profitable at 29.92 % IRR (Ravindranath *et al*, 2007; Laxman *et al*, 2010).

Call for Technological Change for Mitigating Affect

In a matter of fact, grape is a temperate fruit, which has been largely grown under cool climate, be it for table purposes or for wine-making. But the technological change in plant architecture and production system management has helped to produce grape in tropical situation, with highest productivity in the world. Likewise the chilling will not be enough to induce flowering in apple and high temperature in the mid hill agro-climatic conditions, may cause desiccationin pollen, shrivelling of fruits resulting in reduced yield and more failure of the crops. These are the likely impact which causes the concerns. But, there are innumerable examples to cite that, climate has been changing and the technologies have helped in mitigating the problem. Salinity and alkalinity were a great problem for successful growing of grape but identification of suitable rootstocks has made it highly productive. If we look to potato, tomato, cauliflower and cabbage, these are thermo-sensitive crops and were productive only under long day conditions in temperate climate. But development of heat tolerant cultivars and adjustment in production system management has made it possible with very high productivity, even in subtropical and mild subtropical and warmer climates. These are the past experiences, which clearly brings home the point that through innovative research threat of climate change could be converted into the opportunity, but will need visualization of likely change, its impact and planning to mitigate it bad impact. Now, available tools of biotechnology could add for speedier delivery of research results. Mitigation efforts could be intensified in the following ways.

1. Estimation of carbon sequestration potential of perennial crops and different horticultural based land use systems. Though currently most of the horticultural crops do not fall under clean development mechanism, they have high sequestration potential.
2. Development of Green House Gas (GHG) emission inventories from all the activities of horticulture sector.
3. Development and implementation of eco-friendly and green technologies during the entire cycle of production, storage and retailing to reduce the GHG emissions.
4. Improved agronomic practices such as increasing nitrogen and water use efficiency to reduce the emission of green house gasses due to over dependence on energy needs.
5. Development of eco-friendly production, disease and pest management strategies.
6. Commodity wise assessment of GHG emission during production, processing, post harvest packaging and handling and development of suitable mitigation technologies.

Summary

Keeping in view the nature of crop, its sensitivity level and the agro-ecological region, the crop-based adaptation strategies need to be developed, integrating all available options to sustain the productivity. Developing strategies and tools to comprehensively understand the impact of climate change and evolve possible adaptation measures in horticultural crops is less understood. To enhance our preparedness for climate change and to formulate a sound action plan, we need to identify gaps in vital information, prioritize research issues from point of view of farmers, policy-planners, scientists, trade and industry. It is imperative to visualize likely changes which can happen in next 50-100 years, how these changes could affect growth, development and quality of horticultural crops, what are the technologies which shall help to mitigate the problem and what kind of innovative research should be done to overcome the challenges of climate change. Thus, policy issues, adaptation strategies and mitigation technologies could be worked out and challenges could be converted into opportunity. Considerable efforts are required to develop the knowledge and capacities to make climate smart horticulture a reality.

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Nanotechnology for Ensuring High Quality Foods and Enhanced Use Efficiency

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Nanotechnology is a fascinating field of science dealing with a manipulation of atom by atom and thus processes and products evolved from nano science are the most précised ones that are impossible to achieve by the conventional systems. Despite nanotechnology being exploited in the fields of electronics, energy and health sectors, agricultural science is just beginning to scratch the surface. It is anemerging field of science capable of resolving issues and problems that are unresolved in engineering and biological sciences. Nanotechnology is being visualized as a rapidly evolving field that has potential to revolutionize agriculture and food systems and improve the condition of the poor. Nano Mission in Agriculture is quite appropriate in India in the context of changing scenarios in agricultural production systems and in the verge of transforming traditional farming to precision agriculture.

Indian agriculture isfacing a wide spectrum of challenges in crop production systems such as crop yield stagnation, declining organic matter, multi-nutrient deficiencies, climate change, shrinking arable land and water availability, resistance to GMOs and shortage of labour. Despite the fact that our research efforts for the past fifty years have helped us to achieve self-sufficiency in food grain output, Indian agriculture begins to feel the pain of fatigue of green revolution recently and yields of many crops started stagnating. To address all the challenges ahead, we should think of an alternate technology such as “nanotechnology” to precisely detect and deliver the correct quantity of nutrients or other inputs required by crops in suitable proportion that promote productivity while ensuring environmental safety.

The Indian government is looking towards nanotechnology as a means of boosting agricultural productivity in the country. Recently, the Planning Commission of India recommended nanotechnology research and development (R&D) as one of six areas for investment. The report was written by a subgroup of the commission, and incorporated into India's eleventh five-year plan, for 2007–2012. In order to harness the benefits of nanotechnology, biotechnology and bioinformatics to transform Indian agriculture, an exclusive National Institute of Nanotechnology in Agriculture has to be established. The report says nanotechnology such as nano-sensors and nano-based smart delivery systems could help ensure effective utilization of natural resources. Nano-barcodes and nano-processing could also help monitor the quality of agricultural produce. Applications of nanotechnology in agriculture include smart delivery of agri-inputs, food processing, food packaging and food supplement.

Nano-Agriculture

Nano-Seed Science

Seed is a basic input deciding the fate of productivity of any crop. Conventionally, seeds are analyzed for their germination and distributed to farmers for sowing. Despite germination percentage registered in the seed testing laboratory is about 80-90%, it hardly happens in the field due to the inadequacy or non-availability of sufficient moisture under rainfed system. Recently, in Tamil Nadu Agricultural University, Coimbatore, have shown that the accelerated aged pulses seeds treated with ZnO nano-particles had 9 times higher germination (90%) as against the untreated seeds (10%). Seeds that are stored for a long time generate reactive oxygen species (ROS) that are being quenched by the action of donating electrons from ZnO nano-particles. This technology is very appropriate for rainfed agriculture. There are strong evidence indicating nanotechnology can be exploited for seed invigoration that ensure crop productivity in rainfed system.

Nano Fertilizers

Fertilizers are indispensable factor to achieve the crop productivity. In fact, fertilizers were squarely responsible for the phenomenal grain output of 243 million tonnes in 2011 which was just 55 million tonnes in 1960's and this figure closely coincides with the fertilizer consumption of 0.5 million tonnes in 1960's and 23 million tonnes in 2011. Our country is investing more than 1,25,000 Crores of rupees in importing fertilizers with a sizeable subsidy amount of over Rs. 60,000 Crores. If nanotechnology can push the fertilizer use efficiency by few percentages it will be the greatest economic benefit to the country. The laboratory studies have shown that the nutrient release from the nano-formulations is about 60 days while the nutrient release ceased to exist from the conventional fertilizers in 10-12 days. The ^{15}N tracer studies have indicated that the nitrogen use efficiency can be doubled by nano-fertilizers (35% in conventional to 72% in nanofertilizer). The fate of nano-fertilizers in soil-water-plant continuum is yet to be determined. Nano-fertilizers may be used as a strategy to regulate the smart release of nutrients for an extended period of time that may commensurate with crop requirement. The impact of nano-fertilizer products on physiological, biochemical, nutritional and morphological changes in plants and the fate of nano-products in soil and plant systems are yet to be studied. In addition, the effects of nano-fertilizer products on rhizosphere microorganisms and biogeocycling of nutrients have to be explored.

Nano Herbicides

Weeds are menace in agricultural production system. Since two-third of Indian agriculture is rainfed farming where usage of herbicide is very limited, weeds have the potential to jeopardize the total harvest in the delicate agro-ecosystems. Herbicides available in the market are designed to control or kill the growing above ground part of the weed plants. None of the herbicides inhibits activity of viable belowground plant parts like rhizomes or tubers, which act as a source for new plants in the ensuing season. Since no soil applied herbicides are available to kill the underground propagating material of perennial weeds, one must wait for the appearance of plants and apply the foliar herbicides. Lack of selective herbicides for perennial weeds, herbicides should be applied in the absence of crops or keep field without crop for season or less by compromising the growing season. Tilling operation many times worsen problem of perennial weed population build up. The Tamil Nadu Agricultural University, Coimbatore, has successfully encapsulated the herbicide molecules (Pentimethalin and metalachlor) with polymers such as PSS (poly styrene sulphonate) and PAH (poly alylamine hydrochloride) that breaks open only the soil moisture is present. Encapsulated herbicides possess thermal and hydro stability besides sustained release of active ingredients that ensure effective weed control.

Nano Pesticides

Persistence of insecticides in the initial stage of crop growth helps in bringing down the pest population below economic threshold level and to have an effective control for a longer period. Hence, the use of residues in the applied surface remains one of the most cost-effective and versatile means of controlling insect pests. In order to protect the active ingredient from the environmental conditions and to promote persistence, a nanotechnology approach "microencapsulation" can be used to improve the insecticidal value. Microencapsulation comprises nano-sized particles of the active ingredients being sealed by a thin-walled sac or shell (protective coating). Microcapsules generally measure from 5 to 500 microns in size. In Tamil Nadu agricultural University, neem-based microemulsion (198 nm) developed has been found effective in controlling sucking pests such as thrips, aphids and mites. Recently, several research papers have been published on the encapsulation of insecticides. Nano-encapsuation of insecticides, fungicides or nematicides will help in producing a formulation which offers effective control of pests while preventing residues in soil.

Smart Delivery System

Nanoscale devices are envisioned that would have the capability to detect and treat diseases, nutrient deficiencies or any other maladies in crops long before symptoms were visually exhibited. "Smart Delivery Systems" for agriculture can possess timely controlled, spatially targeted, self-regulated, remotely regulated, pre-programmed, or multi-functional characteristics to avoid biological barriers to successful targeting. Smart delivery systems can monitor the effects of delivery of nutrients or bioactive molecules or any pesticide molecules. This is widely used in health sciences wherein nanoparticles are exploited to deliver required quantities of medicine to the place of need in human system. In the smart delivery system, a small sealed package carries the drug which opens up only when the desirable location or infection site of the human or animal system is reached. This would allow judicious use of antibiotics than otherwise would be possible. A molecular-coded "address label" on the outside of the package could allow the package to be delivered to the correct site in the body. Similarly, implanting nano-particles in the plants could determine the nutrient status in plants and take up suitable remedial measures well before the malady causes yield reduction in crops. The fertilizer or irrigation requirement of crops can be scouted by nanotechnology. The exciting possibility of combining agricultural science and nanoscale technology into sensors holds the potential of increased sensitivity and therefore a significantly reduced response-time to sense field problems. "Smart" delivery systems could contain on-board chemical detection and decision making capability for self-regulation that could deliver active chemical molecules or nutrients as needed. Remote activation and monitoring of intelligent delivery systems can assist agricultural growers of the future to minimize antibiotic and pesticide use.

Nano Remediation

A strong influence of nano-chemistry on waste water treatment, air purification and energy storage devices is to be expected. The scientists of Banaras Hindu University have devised a simple method to produce carbon nanotube filters that efficiently remove micro to nano-scale contaminants from water and heavy hydrocarbons from petroleum. The filters are carbon cylinders several centimeters long and 1-2 cm wide with walls just one-third to one-half of a mm thick. They are produced by spraying benzene into a tube shaped quartz mold and heating the mold to 900^{o}C. The nanotube makes the filters strong, reusable and heat resistant and they can be cleansed easily for reuse. They can remove 25 nano-meter sized polio viruses from water as well as larger pathogens such as *Escherichia coli* and *Staphylococcus aureus* bacteria. If it is used widely, we shall minimize the water borne diseases. Magnetic nanoparticles offer an effective and reliable method to remove heavy metal contaminations from waste water by making use of magnetic separation technique. Nanotechnology can introduce new methods for the treatments and purification of water from pollutants, as well as new techniques for wastewater management and water desalinization. In TNAU, efforts are being undertaken to use Fe^{o} nanoparticle to decontaminate soil and aquatic systems.

Precision Farming

Precision farming has been a long-desired goal to maximize output (i.e. crop yields) while minimizing input (i.e. fertilizers, pesticides, herbicides etc.) through monitoring environmental variables and applying targeted action. One of the major roles for nanotechnology-enabled devices will be the increased use of autonomous sensors linked into a GPS system for real-time monitoring. These nano-sensors could be distributed throughout the field where they can monitor soil conditions and crop growth. **Nanosensors** are can be developed to determine nutrient, moisture and physiological status of plants. This assists in taking up appropriate and timely corrective measures. Nano-particles are mini laboratories having the potential to precisely monitor temporal and seasonal changes in the soil-plant system. Nanosensors detect the availability of nutrients and water precisely which is very much essential to achieve the mission of precision agriculture. Nanosensors utilizing carbon nanotubes or nano-cantilevers are small enough to trap and measure individual proteins or even small molecules. Ultimately, precision farming, with the help of smart sensors, will allow enhanced productivity in agriculture by providing accurate information, thus helping farmers to make better decisions. The nano-agriculture should consider the following:

- Single molecule detection to detect enzyme substrate interactions
- Nano-capsules for delivery of agri-inputs
- Delivery of growth hormones in a controlled fashion
- Growth monitoring sensors
- Nano-chips for in identity preservation tracking
- Sensors for detecting pathogens in plants and animals
- Nano-capsules to deliver vaccines
- Nano-particles to deliver genes to plants (targeted genetic engineering)

Food Processing

During last three years, food industries have witnessed that the nanotechnology has been really integrated in a number of food and food packaging products. There are now over 300 nanofood products available on the market worldwide. These exciting achievements have encouraged a large increase of R&D investments in nanofood. Today, the nanotechnology is no longer an empty buzzword, but an indispensable reality in the food industry. Any food company who wants to keep its leadership in food industries must begin to work with nanotechnology right now. The impact of nanotechnology is huge, ranging from basic food to food processing, from nutrition delivery to intelligent packaging. It is estimated that the nanotechnology and nano-bio-info convergence will influence over 40% of the food industries up to 2015. The risk for the food companies lies in not entering the nanotechnology, but entering too late. The nanofood market has been soaring from 2.6 bn. US dollars 2003 to 5.3 bn. US dollars in 2005 and has reached 20.4 bn. US dollars in 2010. Nano-featured food packaging market grew up from US$ 1.1 bn. 2005 to US$ 3.7 bn up to 2010. More than 400 Companies around the world are today active in research and development and production.

India plays a pivotal role in fruits and vegetables production ranking second in the world next to Brazil and China, respectively. But, per capita availability in India hardly exceeds 50% of daily requirement for human consumption (fruits demand 120g; availability 60g; vegetables demand 280g; availability 140 g). The wide gap is primarily attributed to the post harvest losses of perishables to the tune of 35-40% amounting to a huge sum of Rs. 40,000 crores.Further, more than 98% of the fruits and vegetables produced are consumed as such and a meager less than 2% get processed. Nanotechnology can be employed to prevent post harvest losses besides improving the availability of functional foods through encapsulation. Nano-encapsulation is defined as a technology of packaging solids, liquids or gaseous materials in miniature, sealed capsules that can release their contents at controlled rates under specific conditions.Microencapsulation is the technique by which one material or a mixture of materials is coated with or entrapped within another material or system. The coated material is called active or core material, and the coating material is called shell, wall material, carrier or encapsulant.

Nano-encapsulation is a technique that can be successfully used to improve the survival of microorganisms in dairy products, protect sensitive food components, ensure against nutritional loss and incorporate unusual or time-release mechanisms into the formulation.In microencapsulation, usually a material or a mixture of materials is coated with or entrapped within another material or system. Commonly, food constituents likefats, oils, aroma compounds, oleoresins, vitamins, minerals, colorants and enzymes are used for the encapsulation purpose.Spray-drying is a unit operation by which a liquid product is atomized in hot air to instantaneously obtain its powder. The initial liquid feed is in the form of solution, emulsion or a suspension. Spray-drying depends upon the feed material and operating conditions to produce a very fine powder (10–50 μm) or large sized particles (2–3 mm). In Tamil Nadu Agricultural University, Coimbatore, encapsulation of functional foods such as anthocyanins from grapes skins, lycopene from tomato, oleoresins from turmeric and carotenoids from carrot has been successfully demonstrated.

Nano encapsulation of functional foods and bioactive compounds has thrown a new challenge in nutrition.A feasibility study was under taken by DFRL Lab of DRDO for the development of micronutrients; iron and vitamins incorporated liposomes using nanotechnology. Milk has also been fortified with vitamins and minerals using nanotechnology principles.Considering the accomplishments made already in the fascinating field of science, it has envisioned initiating new avenues of research in agriculture, horticulture, dairy science, poultry production and fisheries. In all the array of disciplines, encapsulation can be used as a tool to preserve the functional qualities of foods, to extend the shelf-life and to deliver the inputs at the right spot with right quantity and in desirable proportions. The encapsulation technique has been highly exploited in medical field and this can be extended in agricultural sciences that will add value to the crop besides facilitating in achieving nutritional security.

Food processing industry should consider the following:

- Nano-capsules to improve the bioavailability of neutraceuticals in food ingredients
- Nano-encapsulated flavor enhancers
- Nano-particles as gelatin and viscosifying agents
- Nano-capsule infusion of plant based steroids to replace a meat's cholesterol
- Nano-particles to selectively bind and remove chemicals and pathogens from food
- Nano-emulsions to improve the efficacy of pesticides and nutrient carriers

Food Packaging

Food packaging is a critical technology addressing the ever-increasing demands for convenience, freshness, ease, shelf-life, safety and security of food products. The main purpose of food packaging is to protect the food from microbial and chemical contamination, oxygen, water vapor and light. The type of packaging used therefore has an important role in determining the shelf-life of the food. Nanotechnology can be intervened to achieve the purpose of food packaging and it will become one of the most powerful forces for innovation in the food packaging industry. About 400-500 nano-packaging products are estimated to be in commercial use at the moment, while nanotechnology is predicted to be used in the manufacture of 25 percent of all food packaging within the next decade. Food industries have witnessed the real strength of nanotechnology in a number of food and food packaging products. There are now over 300 nano-food products available in the market worldwide. These exciting achievements have encouraged a large increase of R&D investments in nano-food. The nano-food market has shown a phenomenal increase of four-fold in five years (from 5.3 in 2005 to 20.4 billion USD in 2010).

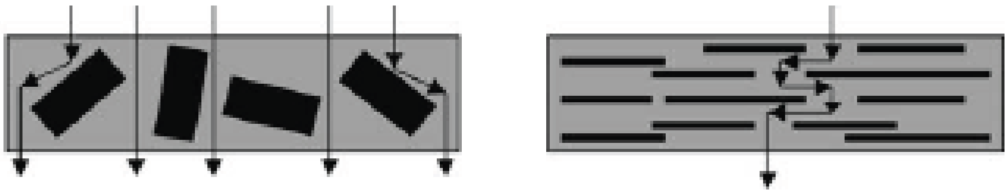
Polymer Composites with Nanoclay

These are among the first nanocomposites to emerge on the market as improved materials for packaging (including food packaging). Nanoclay has a natural nanoscaled layer structure, which when incorporated into polymer composite restricts the permeation of gases. Nanoclay–polymer composites have been made from a thermoset or thermoplastic polymer reinforced with nanoparticles of clay. These include polyamides (PA), nylons, polyolefins, polystyrene (PS), ethylene-vinylacetate (EVA) co-polymer, epoxy resins, polyurethane, polyimides and polyethyleneterephthalate (PET).

Preparations methods of nano-films are solution included intercalation, in-situ polymerization and melt processing. Melt processing is done simultaneously when the polymer is being processed through an extruder, injection molder, or other processing machine. The polymer pellets and clay are pressed together using shear forces to help with exfoliation and dispersion. With in-situ polymerization, clay is added directly to the liquid monomer during the polymerization stage. In the solution included intercalation method, clay is added to a polymer solution using solvents to integrate the polymer and clay molecules.

Conventional composites

"Tortuous path" in layered silicate nanocomposites



Formation of tortuous path in polymer clay nano composite

In addition to addressing spoilage and flavour issues, nanocomposites also offer other benefits like lighter weight and better recyclability, and suggest that producers may be able to significantly reduce transportation and production costs by reducing the amount of material used to package items. Nanocomposites, at the present time, are more expensive than most plastic resins but the price continues to drop and it is expected that nanocomposites materials will be very cost competitive in the near future. In Tamil Nadu Agricultural University, Coimbatore, nano-film developed with clay composite is known to extend the shelf life of vegetables up to 21 days without any sign of deterioration in quality.

Nano Biodegradable Packaging

The use of nanomaterials to strengthen bio plastics (plant-based plastics) may enable bio based nanofilms plastics to be used instead of fossil-fuel based plastics for food packaging and carry bags. Bio based nanocomposites are a new class of materials in food packaging industry with improved barrier and mechanical properties as compared to those of neat biopolymers. They are biodegradable and they are also produced from renewable resources and thus making them environment friendly. It should be noted that barrier properties and especially mechanical properties of bio based nano-films are stronger than edible films and synthetic polymeric films. Unlike edible films, they could not have been consumed as a part of food.

Bio based nanocomposites are produced from incorporation of nanoclay into biopolymers (or Edible films). Advantages of bio based nanocomposites are numerous and possibilities for application in the packaging industry are endless. Bio based nanocomposites can be used to extend the shelf-life of the fresh products such as fruits and vegetables by controlling respiratory exchange. Also it can improve the quality of fresh, frozen, and processed meat, poultry, and seafood products by retarding moisture loss, reducing lipid oxidation and discoloration, enhancing product appearance, and reducing oil uptake by battered and breaded products during frying.

Cellulose Based Films

Cellulose is the most abundantly occurring natural polymer on Earth and is a linear polymer of anhydroglucose. Though it is a cheap polymer, cellulose is difficult to use because of its hydrophilic nature, insolubility and crystalline structure. To make cellulose or cellophane film, cellulose is dissolved in a toxic mixture of sodium hydroxide and carbon disulphide and then recast into sulfuric acid. The cellophane produced is very hydrophilic and, therefore, moisture sensitive. It is often coated with nitrocellulose wax or poly-vinylidene chloride to improve barrier properties. However, there is considerable potential for the development of an improved cellulose film product or an improved production method as the existing product is problematic.

Fish Gelatin Based Nano-films

Fish gelatin has been identified as an alternative source for mammalian gelatin and many research programs are being carried out on the improvement of the properties of fish gelatin. One such identified applications is the use of fish gelatin for the development of biodegradable films. The films, which are formed from natural polymers, are not on par with the existing petrochemical-based films in their mechanical properties and hence there is a need to improve their mechanical properties. Nano-scale clay fillers are used in the films to improve their properties. In addition, the use of natural preservatives in food packaging materials has an additional advantage to improve the shelf life of foods. Hence, it is highly desirable to develop a practically applicable food packaging material, which is eco-friendly as well as protective to the food product by using the nanotechnology.

Starch Based Nano-composites

Starch is a better candidate for the preparation of thermoplastic plastic foam type packaging materials. Several studies have been carried to improve the mechanical and hydrophobic properties of the native starch based thermoplastic starch by adding natural fibers, plasticizers, synthetic degradable polymers and acetylated starches. The addition of proteins and cellulose in the preparation of bio composites will definitely improve the mechanical and water resistance of the thermo foam packaging material. In spite of the many advantageous properties, cassava starch presently not used in medical as well as agriculture fields. By exploiting the nano technological advances in the field of biocomposites, cassava starch can be better utilized.

Polymer Nanocomposites

Polymer nanocomposites consist of resins (either thermoset or thermoplastics) that have fillers added with at least one dimension measured in nanofilter. Because the nanoparticles are so small and their aspect ratios (largest dimension/smallest dimension) are very high, even at low loadings, certain polymer properties can be greatly improved without the detrimental impact on density, transparency, and processability associated with conventional reinforcements like talc or glass. New packaging materials created with this technology demonstrate an increased shelf life and are less likely to shatter.

Active Nanopackaging Materials

The incorporation of bioactive compounds such as antimicrobial compounds and antioxidants into food packaging materials has received considerable attention. Films with antimicrobial activity could help control the growth of pathogenic and spoilage microorganisms. An antimicrobial nanofilters or film is particularly desirable due to its acceptable structural integrity and barrier properties imparted by the Nanofilters matrix, and the antimicrobial properties contributed by the natural antimicrobial agents impregnated within. Materials in the nanoscale range have a higher surface-to-volume ratio when compared with their microscale counterparts. This allows nanomaterials to be able to attach more copies of biological molecules, which confers greater efficiency. Nanoscale materials have been investigated for antimicrobial activity so that they can be used as growth inhibitors, killing agents or antibiotic carriers.

Antimicrobial Nanopackaging Materials

The incorporation of antimicrobial compounds into food packaging materials has received considerable attention. Films with antimicrobial activity could help control the growth of pathogenic and spoilage microorganisms. An antimicrobial nano-film is particularly desirable due to its acceptable structural integrity and barrier properties imparted by the nano-film matrix, and the antimicrobial properties contributed by the natural antimicrobial agents impregnated within. Materials in the nanoscale range have a higher surface-to-volume ratio when compared with their microscale counterparts. This allows nanomaterials to be able to attach more copies of biological molecules, which confers greater efficiency. Nanoscale materials have been investigated for antimicrobial activity so that they can be used as growth inhibitors, killing agents or antibiotic carriers.

Intelligent Packaging Concepts Based on Nanosensors

Food safety also requires confirmation of the authenticity of products. This is where application of nano-barcodes incorporated into printing inks or coatings has shown the potential for use in tracing the authenticity of the packaged product. Food quality indicators have also been developed that provide visual indication to the consumer when a packaged foodstuff starts to deteriorate. An example of such food quality indicators is a label based on detection of hydrogen sulphide, which is designed for use on fresh poultry products. The indicator is based on a reaction between hydrogen sulphide and a nanolayer of silver . The nanosilver layer is opaque light brown, but when processed meat starts to deteriorate silver sulphide is formed and the layer becomes transparent, indicating that the food may be unsafe to consume. The accomplishments made by Indian Agricultural Scientists and published literatures collectively suggest that the nanotechnology has a big role to play in nano-packaging materials and nano-food systems which facilitate extension shelf life of perishables while preventing the post harvest and storage losses.

The food packaging materials should include:

- Antibodies attached to the fluorescent nano-particles to detect chemicals and food borne pathogens
- Biodegradable nano-sensors for temperature, moisture and time monitoring
- Nano-clays and nano-films as barrier materials to prevent spoilage and prevent oxygen absorption
- Electrochemical nano-sensors to detect ethylene
- Anti-microbial and anti-fungal surface coatings with nano-particles
- Heat resistant films
- Modified permeation behavior of foils

Food Supplements

A food supplement is typically, a nutrient, such as a vitamin, or mineral, which is taken as a pill or drink in addition to the normal diet, or added to a food, which would otherwise not contain that nutrient. Some have argued that since these vitamins or minerals are already found in the body that there should be little concern. However, some, like vitamin A, can be toxic in extremely large doses so increasing the bioavailability of such a vitamin might be harmful.

Nano food supplements include :

- Nano-sized powder to increase the absorption of nutrients
- Cellulose nano-crystals as drug carriers
- Nano-encapsulation for improved availability and targeted delivery
- Nano-chelates to deliver nutrients more efficiently to cells without affecting colour or flavour of foods
- Vitamin sprays dispersing active molecules into nano droplets for better absorption .

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Status and Scenario of Horticulture Growth and Development in India and in the World

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Introduction

Horticulture is the science of cultivation, management, postharvest handling, value addition and marketing of fruits, vegetables, ornamental, aromatic and medicinal plants, spices and plantation crops. Looking to its important role in nutritional security, poverty alleviation and employment generation, it has rightly been emerged in form of horticulture industry and as one of the most significant sectors in the world. The production of fruits, vegetables and flowers has acquired much importance in recent times due to their increasing demand. Changing lifestyles of people across the globe and attempts to overcome the stressful lifestyle, and inclination towards healthy and balanced eating habits has made people include fruits and vegetables in their daily diet. In the case of flowers, the demand for fresh flowers has steadily increased not only for decoration but also for many other purposes like essential oils, cosmetics, aroma therapy, dry flowers, pot-pourries, natural dyes, medicines, etc. Rising incomes and growing consumer interest in a variety of fresh fruits and vegetables year-round is stimulating international trade in horticulture.

Over the years, horticulture has emerged as one of the potential agricultural enterprise in accelerating the growth of economy in India. It offers not only a wide range of options to the farmers for crop diversification, but also provides ample scope for sustaining large number of Agro-industries which generate huge employment opportunities. Horticulture sector has received focused attention from 7th five year plan onwards in India, as a result, there has been not only sustained increase in production of horticulture crops but hi-tech horticulture also been recognized as a commercial proposition. India has several advantages in the sector that includes suitable climate and soil with a wide range to suit variety of horticultural products, man power and technology availability with the stabilizing economy. Despite these advantages, India's share in the global market is insignificant - it accounts for only 1.7 per cent of the global trade in vegetables and 0.5 per cent in fruits and less than 0.5 % in flowers. India is the second largest producer of fruits and vegetables contributing 12.6 per cent and 14 per cent respectively in the world fruit and vegetable production (NHB Database 2013). According to Euromonitor International's research, around 90% of Indian consumers' retail food expenditure is spent on fresh food categories, with major sales share taken up by fruit and vegetables. According to Euromonitor International's Countries and Consumers database, in future the Indian consumers will continue to spend more per capita on fresh food and it is estimated that there will be 130 million new consumers in India by 2015 (Sinha and Thomas 2012).

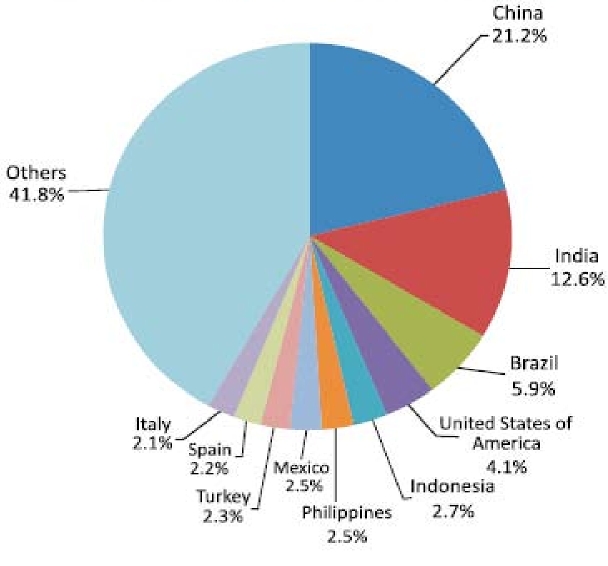
World Scenario

Several governments and private enterprises across the globe have initiated measures to support this industry, Looking to the rising demand for fruits, vegetables and flowers has been constantly on the rise - in some countries this industry already plays a very important role and contributes significantly to the economy. The initiatives have been in the form of both investments and policies for the development of the industry. Subsequently, not only have the primary producers, the farmers, been benefitted majorly, associated sectors like transportation, distribution, storage, processing and packaging have also received a huge fillip (Global Horticulture Market Outlook 2015). Numerous employment opportunities have been generated, benefiting large sections of people associated with it, both directly and indirectly.

Horticulture Status at Global level- Important Facts, Figures and Statistics

Global fruit production was reported at 64,67,57,638 MT from an area of 5,72,65,135 ha with average productivity of 11.3 MT/ha and vegetable production has been 1,15,91,79,443 MT, from an area of 5,89,71,121 ha with average productivity of 19.7 MT/ha in 2012-13. The size of the global floriculture industry stood at around 176 billion US$ during 2012 (APEDA 2014). There are several Indian companies as well as foreign companies who have been focusing all their energies to succeed in the organized retail sector of Indian horticulture commodities. The Indian retail industry is worth $470 million and organized retail stands at $26 million which is around 6% of the market (Sinha and Thomas 2012).

Fruits: China is the largest producer of fruits in the world accounting for about 21.2% of the global production. India is at the second position contributing 12.6% to the overall production and Brazil is the third largest producer (5.9%). Productivity of fruits in the world is highest in USA (23.3 MT/ha), followed by Indonesia (22.3 MT/ha) and Brazil (16.5 MT/ha) while India and China both rank eight in productivity (11.6 MT/ha). India ranks first in the production of banana, mango, guava and papaya and in the productivity of grapes (21.1 MT/ha). With regard to apple production, China ranks first, followed by USA and Turkey while India ranks fifth. In grapes, China leads, followed by USA and Italy while India falls on tenth. Brazil ranks first in orange production, Thailand in Pineapple production while India falls on fourth and sixth rank respectively. The leading fruit producing countries in 2012-13 are shown in Fig. 1.



With regard to productivity in Banana, Indonesia ranks first (58.9 MT/ha), followed by Guatemala (40.9 MT/ha) and India (34.2 MT/ha). In case of mango and guava productivity, Kenya ranks first (48.8 MT/ha), followed by Brazil (16 MT/ha), Pakistan (11.2) while India falls on eight rank (7.7 MT/ha). Dominican Republic has highest productivity of papaya (312.7 MT/ha), followed by Guatemala (89.8 MT/ha) and Indonesia (86.7 MT/ha) where India falls on seventh rank. Productivity of apple is highest in Chille (44.5 MT/ha), followed by Italy (36.4) and France (33.7 MT/ha) while India holds tenth position.

Vegetables: The same trend is reflected in vegetable production with China emerging as the world's largest producer (49.5%) followed by India (14%) and USA (3.1%) occupying a distant second and third position. China holds first rank in the production of major vegetables like Brinjal (58 %), Cabbage (46.8%), Cauliflower and broccoli (42.9%), onion (27.1%), tomato (30.8%) and potato (23.5%) while India holds second position. India leads the world in okra production contributing a whopping 72.9 % to the global basket followed by Nigeria (12.6 %). The leading vegetable producing countries in 2012-13 are shown in Fig. 2.

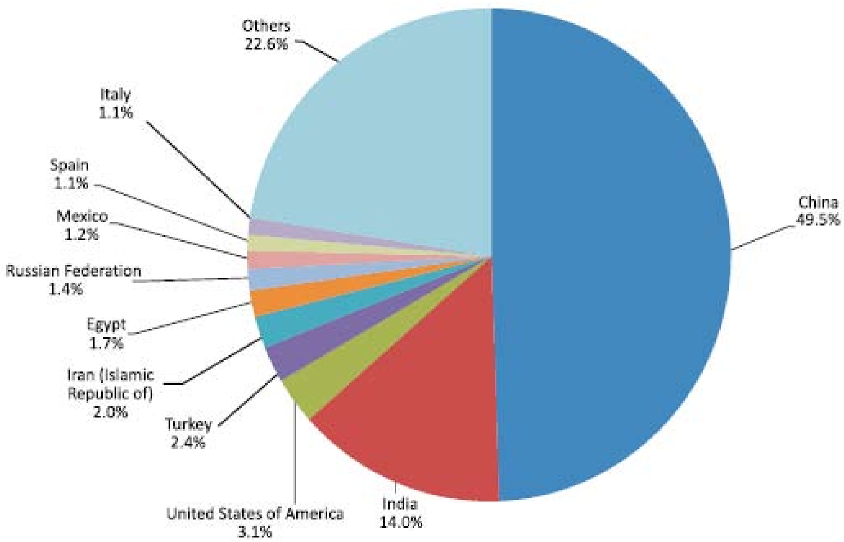


Fig. 2: The leading vegetable producing countries in 2012-13 (NHB Database 2013)

Productivity of Brinjal is highest in Spain (68.5 MT/ha), followed by China (36.0 MT/ha.). With regard to cauliflower and broccoli, Egypt has highest productivity (28.6 MT/ha) followed by Germany (26.7 MT/ha). Republic of Korea ranks first in cabbage productivity with an astounding 71.2 MT/ha, followed by Japan (67.6 MT/ha). Highest productivity of Okra is found in Ghana (20 MT/ha) followed by Egypt (14 MT/ha) and India (12 MT/ha). The productivity of USA (54.6 MT/ha) is 2.5 times more than that of the global average (19.4 MT/ha) in Onion. As far as productivity of tomato is concerned, USA is again leading with 88 MT/ha, followed by Spain (82.1 MT/ha). In case of potato productivity, Netherlands leads with 45.2 MT/ha followed by Germany (44.8 MT/ha)

Floriculture: At global level, flora business is around US$ 176 billion, which is expanding day by day and with an annual average growth rate of 10.3 per cent, is expected to reach US$ 250 billion by 2025. Flowers and foliage accounted for around 52.45 per cent, and live plants, bulbs and cuttings accounted for 47.55 per cent of total floriculture products at global trade (APEDA

2014). International trade in floriculture, to a large extent is organized along regional lines. Developed countries in Europe, America and Asia account for more than 90 per cent of the total world trade in floriculture products. Germany is the leading country in floriculture trade with 17.04% share, followed by USA (10.57%) and Netherlands (10%) while India falls on fifty second rank (0.08%). Roses contribute around 16.43% of the total floriculture trade. In recent years, a paradigm change in the flora industry has been observed and has lead to the development of new productions centers in Asia and Africa which were earlier concentrated in USA and Europe. In Asia, India, China and Thailand are moving progressively in this direction and emerging leading countries. Asia-Pacific countries are the main suppliers to Japan and Hong Kong. African and other European countries are the principal suppliers to Europe's main markets, and the supplies to the United States are mainly catered by Colombia and Ecuador.

Indian Scenario

India has a wide variety of climate and soil on which horticultural crops such as, fruits; vegetables, potato and other tropical tuber crops; ornamental, medicinal and aromatic plants; plantation crops; spices, cashew and cocoa are grown. Horticultural crops for which the Indian topography and agro climates are well suited is an ideal way of achieving sustainability of small holdings, increasing employment, improving environment, providing an enormous export potential and above all achieving nutritional security. Thus, India is rightly known as the fruit and vegetable basket of the world as being a home of wide variety of fruits and vegetables and holds a unique position in production figures among other countries. The corporate sector is also showing greater interest in horticulture. Further, a major shift in consumption pattern of fresh and processed fruits and vegetables is being foreseen with greater technology adoption both in traditional horticultural enterprise as well as in commercial horticulture sector. Horticulture accounts for about 13.08% of gross cropped area (192.79 million hectares) in the country and contributes around 30% to Indian Agricultural GDP. Its share is about 37% of the total exports of agricultural commodities (Gupta *et al.,* 2012).

The horticulture production has shown quantum jump in the recent plans over the preceding plans. The area and production in the year 2011-12 showed an increase of 20.8% and 36.5% respectively, over that in the previous plan period ending in the year 2005-06. This is suggestive of a productivity led growth than the area led one. The production of horticulture produce has been around 268.85 Million tons from 23.69 million ha, in the year 2012-13. During the last decade, horticulture sector as a whole has registered a compound growth of over 6 per cent as seen from the trend of horticulture growth in India (Gupta et al 2012) and also seen in figure 3. The increase in the production has been highly significant in fruits (80%), vegetable crops (91%) in last decade while in ornamentals has registered 99.19 % increase in case of loose flowers and 76% increase in cut flowers in last five years.

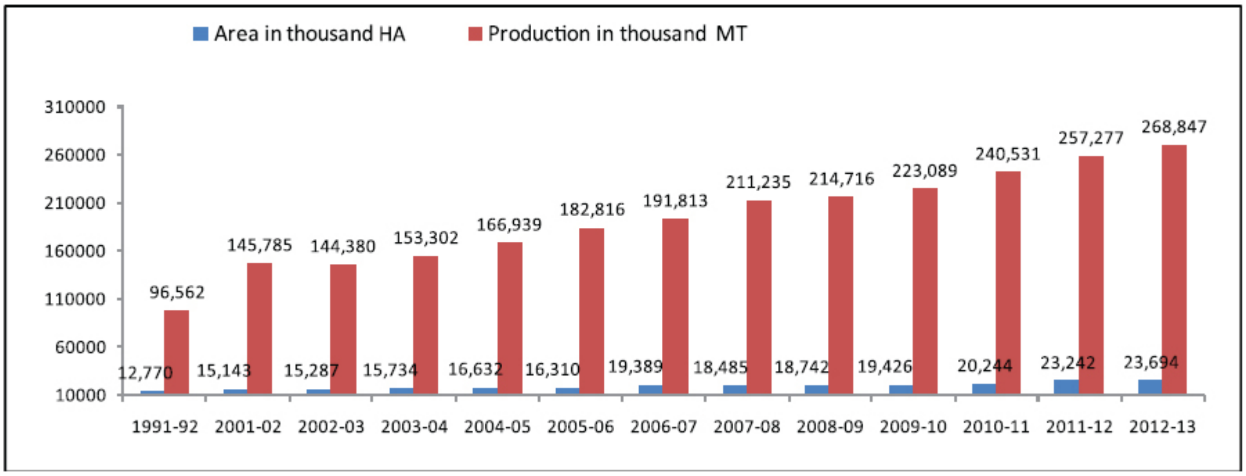


Fig. 3: Area and production trend of horticultural crops in India

The productivity of horticultural crops increased from 7.5 MT/ha in 1991-92 to 11.3 MT/ha in 2012-13. The increased production of horticulture crops is the resultant of increase in both area and productivity. The current level of 268.85 million tons during 2012-13, is 40% higher than production achieved during 2006-07 with 22% increase in area under horticulture. There has been a gradual increase in area and production of horticulture crops during the period 1991-92 to 2012-13, the significant increase in growth trend (in per cent) over the previous year in last three years is suggested below.

Crop	10-11 OVER 09-10		11-12 OVER 10-11		12-13 OVER 11-12	
	Area	Production	Area	Production	Area	Production
Horticulture	4.5	7.8	6.5	7.0	1.9	4.5
Fruit	0.8	4.7	5.0	2.1	4.1	6.4
Vegetable	6.4	9.6	5.8	6.7	2.4	3.7

Fruits-Present Status

The present estimated area under fruit cultivation in India is about 6.98 million ha with a production of 81.29 million tons and productivity of 11.6 MT/ha. The trend of fruit production in the country from the year 1991-92 to 2012-13 has shown almost three fold increase with two and half times increase in area as depicted in Fig. 4. Banana, Mango, Citrus are the major fruits having higher production share in the country, besides, papaya, guava, apple, grapes, pineapple and others as shown in the Fig. 5.

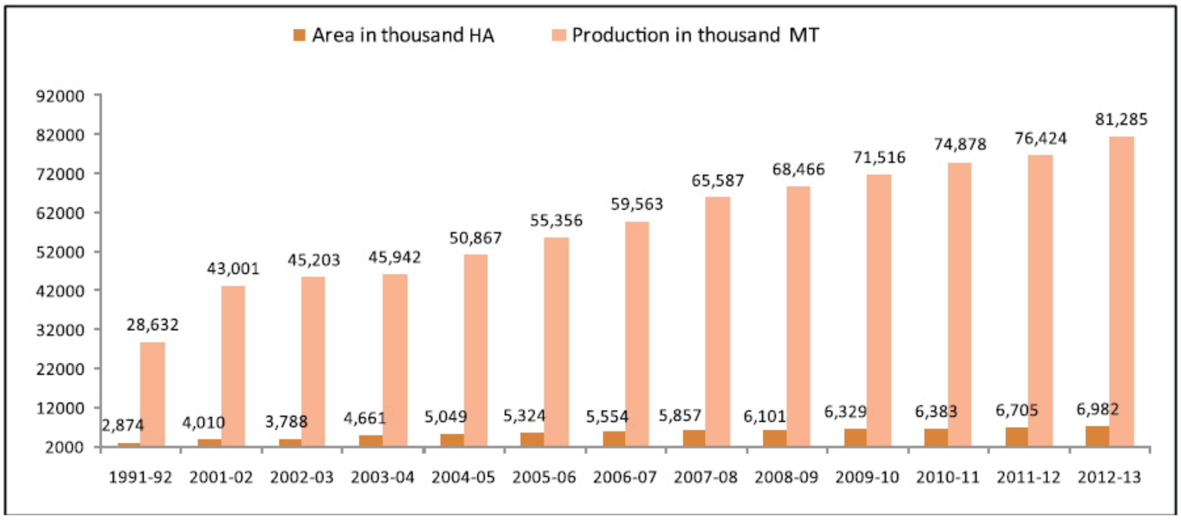


Fig. 4 : Area and production trend of fruits in India

The leading fruit producing states in the country in terms of area are Maharashtra (22.2%), Andhra Pradesh (13.2%), Karnataka (5.6%), Gujarat (5.5%), Kerala (4.7%) and others while in terms of production are AP(17.1%), Maharashtra (12.0%) and Gujarat (10.4%) as shown in the Fig. 6.

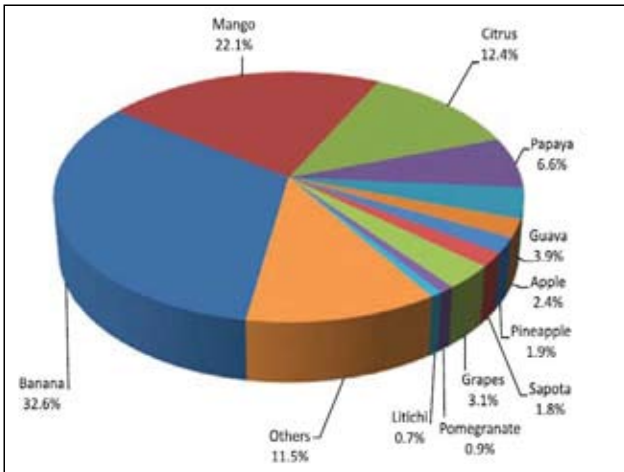


Fig. 5: Production share of major fruits in India

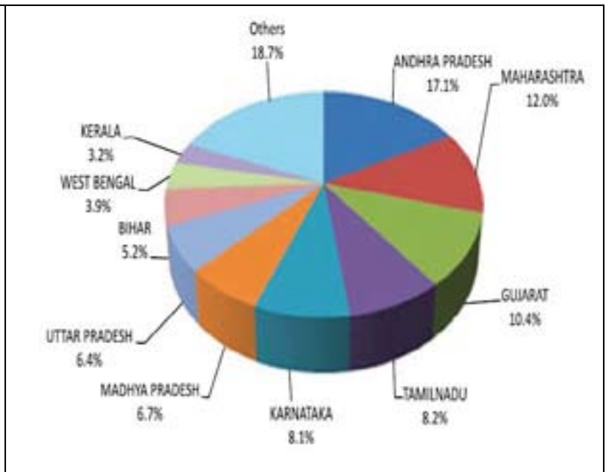


Fig. 6: The major fruit producing states in the country

Vegetables

Vegetables constitute more than 50 crops like cucurbits, leguminous, solanaceous, brassicas, root and leafy vegetables and are grown in tropical and temperate regions. Onion, tomato, brinjal, cabbage, cauliflower, okra, peas and cucurbits are widely grown and are in great demand in the country. The present estimated area under vegetable crops in India is about 9.21 million hectares with a production of 162.187 million tons and productivity of 17.6 MT/ha. The trend of vegetable production from the year 1991-92 to 2012-13 is depicted in Fig. 7. There is maximum production of potato (28%), followed by tomato (11.2%), onion (10.4%), brinjal (8.3%), cabbage (5.3%), cauliflower (4.9%), tapioca (4.5%) etc in the world as shown in Fig. 8.

The leading vegetable producing states in the country are West Bengal (15.7%), Uttar Pradesh (12.1%), Bihar (10.1%), as shown in the Fig. 9.

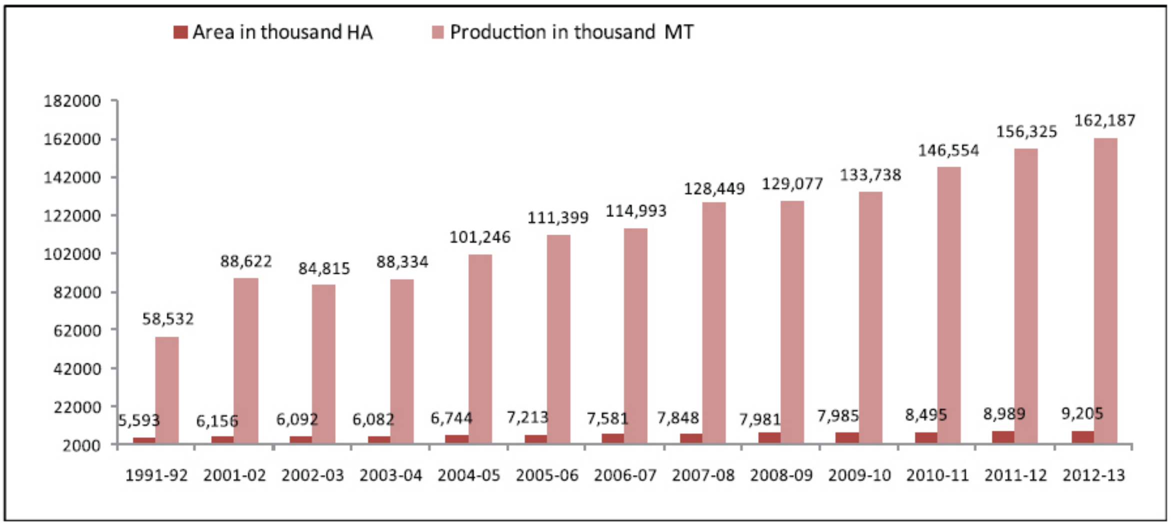


Fig. 7 Area and production trend of vegetable crops in India

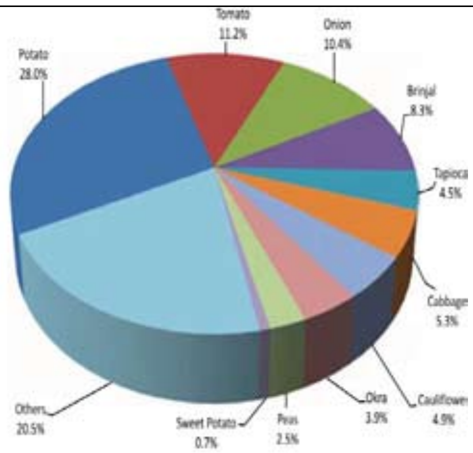


Fig. 8 Production share of vegetables in India

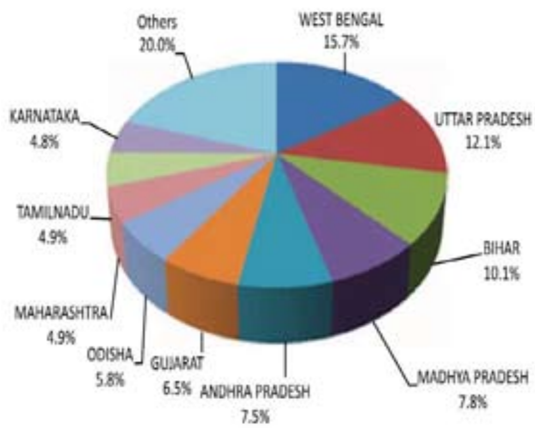


Fig. 9 Major vegetable producing states in India

Spices and Plantation

The present estimated area under spice cultivation in India is about 3.08 million ha with a production of 5.74 million tons and productivity of 1.9 MT/ha, year 2012-13. The trend of spice production in the country from the year 1991-92 to 2012-13 has shown almost three fold increase with one and half times increase in area. Chilli, garlic, turmeric, ginger, coriander are the major spices having higher production share up to 82.56% in the country, besides tamarind, fenugreek, fennel, peppers, cardamom, ajwain, nutmeg, etc are also cultivated on a small scale.

Plantation crops are cultivated in an estimated area around 3.64 million ha with a production of 16.99 million tons and productivity of 4.7 MT/ha. The trend of plantation production in the country from the year 1991-92 to 2012-13 has shown almost two fold increase with one and half times increase in area. Coconut (91.90%), cashewnut (4.44%), arecanut (3.58%) and cocoa (0.08%) are the plantation crops produced in the country.

Floriculture

In our country, flowers are grown in around 233,000 ha land, with the production of loose flowers around 1729,000 MT and that of cut flowers 76732 lac numbers (2012-13), as per NHB 2013 database. However, the contribution by numerous ornamental nurseries is excluded from these statistics due to unavailability of data although pot plant industry forms the major part of the world flower trade (>30%). The area under flower production has increased by 40%, loose flower production by 75% while cut flower production by 60% in last five years, as trend depicted from Table 1. Tradition of growing flowers is observed in the whole country. Loose flowers like marigold, china aster, jasmine, crossandra, barleria etc occupy major flower cultivated area of the country as the domestic consumption is very high. Tamil Nadu, Karnataka and Andhra Pradesh are the leading loose flower producing states. Cut flowers like rose, tuberose, gladiolus, chrysanthemum etc are highly popular and widely cultivated in the country. West Bengal, Karnataka, Maharashtra, Andhra Pradesh and Orissa are the leading cut flower producing states. Further, the trend of protected cultivation of cut flowers is also increasing in recent years in the country. Major flowers cultivated are rose, gerbera, carnation, etc. under polyhouse mainly in Maharashtra, Karnataka, Uttrakhand and Gujarat. Orchids like Dendrobiums, Vanda, Paphiopedilums, Oncidiums, Phalaenopsis and Cymbidiums and Anthuriums are grown under net house mainly at Sikkim, Arunachal Pradesh and Kerala. Liliums, Alstroemeria, tulips, etc are cultivated in Kashmir, HP and Uttarakhand.

Table 1 : Area and Production trend of flower cultivation in India

YEAR	AREA (IN '000 HA)	PRODUCTION LOOSE (IN '000MT)	PRODUCTION CUT (IN LAKH NOS.)
2006-07	144	880	37175
2007-08	166	868	43654
2008-09	167	987	47942
2009-10	183	1021	66671
2010-11	191	1031	69027
2011-12	254	1652	75066
2012-13	233	1729	76732

Horticultural Exports from India

Today horticultural crops cover about 25 per cent of total agricultural exports of the country. The vast production base offers India tremendous opportunities for export. During 2012-13, India exported fruits and vegetables worth Rs.5986.70 crores which comprised of fruits worth Rs. 2503.73 crores and vegetables worth Rs. 3482.97 crores. Export of Processed fruits and vegetables was worth Rs. 5121.16 crores. Mangoes, Walnuts, Grapes, Bananas, Pomegranates account for larger portion of fruits exported from the country while Onions, Okra, Bitter Gourd, Green Chilles, Mushrooms and Potatoes contribute largely to the vegetable export basket. Mango pulp, resins, preserved cucumbers and gherkins, dehydrated onions and garlic powder, frozen and dried vegetables, jam, jellies, cashewnuts etc. Fresh mango export comprised of 55584.98 MT of worth Rs 264.71 crores while 147815.71 MT of mango pulp worth Rs. 608.55 crores was exported in the year 2012-13 that was two point three times higher than fresh mangoes. 172744.42 MT of grapes worth of value Rs. 1259.42 crores while 30041.71 MT of resins worth of value Rs. 268.83 crores was exported in the year 2012-13.The major destinations for Indian fruits and vegetables are UAE, Bangladesh, Malaysia, UK, Netherland, Pakistan, Saudi Arabia, Sri Lanka and Nepal. Though India's share in the global market is still nearly 1% only, there is increasing acceptance of horticulture produce from the country. This has occurred due to concurrent developments in the areas of state-of-the-art cold chain infrastructure and quality assurance measures. Apart from large investment pumped in by the private sector, public sector has also taken initiatives and with APEDA's assistance several Centers for Perishable Cargoes and integrated post harvest handling facilities have been set up in the country wherein capacity building initiatives at the farmers, processors and exporters' levels has also contributed towards this effort. In view of floriculture exports, an exponential growth of floriculture products was being observed in 2006-07 when the exports reached to 649.6 crores. But since then, down fall to 340.14 crores (2007-8), 368.81 crore(2008-9), 294.46 crore (2009-10) and 296.04 (2010-11) has been witnessed owing to the downfall on the world economy. However, an overall rise with the establishment of a large number of export oriented cut flower units which has given a recognition to Indian flowers in the international market and the growing dry flower industry that contribute to 60-70% in the exports. With this, little rise in exports is witnessed, 365.32 (2011-12), 423.23 crore (2012-13) in the past two years (APEDA 2014). Important cut flowers exported from India include Roses, Lilies, Carnations, and Orchids. Major importers of flora products from our country are USA, Netherlands, Germany, United Kingdom, Japan, Canada and Japan. Thus, there exists the great potential and vast opportunities for export of cut flowers. Other associated activities of flower growing in India include the dry flower industry and the essential oil industry. India is the fifth largest exporter of dried flowers, and second largest exporter of dried foliage in the world accounting for around 7 per cent of world exports in dry flowers and foliage. The main export markets for India's dry flower industry are USA, Netherlands, UK and Germany. Despite of a decline in the total export in the Country, Indian spices exports have been able to record strident gains, registering a compound annual average growth rate of 23% in value and 11% in volume and India commands a formidable position in the World Spice Trade. During the 2012-13, a total of 7,26,613 tons of spices and spice products valued Rs.12112.76 crores has been exported from the country as against 5,75,270 tons valued Rs.9783.42 crores in 2011-12, registering an increase of 26% in volume and 24% in terms of value (Spices Board of India).

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Challenges and Opportunities for Augmentation of Agriculture Productivity through Interventions of Omics Technologies

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Introduction

We know that during the past two decades, there have been numerous developments in the genetic and genomic technologies enabling us to understand complex biological systems in an integrative manner through holistic approaches in research and development. Since the sequencing of the human genome, and later several plant genomes efforts are made to discover the number of the genes and their functions. The tools for determining the functionality of the genes are just beginning to appear. Initially the methodologies to understanding functionality of the genes were largely based on comparative studies between model organisms. The very high number of genes with unknown functions demanded the need to develop new methods and technologies that may be helpful in assigning functions to the identified genes. Advancements in computing techniques and software opened the door for new technologies to be able to take an applied approach by studying biomolecules of biological systems needed for proper functioning of the cell and take a holistic approach in agriculture research. Besides genomics, several other technologies are developed in the last decade that take an 'omics' approach, i.e., an integrated approach in the study of cell structure and function. It is hoped that the applied integrative omics approaches may be useful in establishing cause and effect relationships between genotype and phenotype. These 'omics' approaches include the integration of genomics, proteomics, transcriptomics, metabolomics and other omics technologies to do the non-targeted studies of biomolecules involved in the appropriate functioning of the cells and their responses to environmental changes. The applications of these technologies have also been utilized in the field of nutrition for studies on how nutrients and other metabolites effect the appropriate functioning of the cell. With these emerging techniques to understand the molecular functioning of the biological systems, it is envisaged that they might be helpful to provide personalized dietary advice to people based on their individual genotypes in the future. Whilst nutritional genomics is a fast growing field in the nutritional sciences focusing on the diet-gene relationships, there is an increasing understanding that other technologies will also be crucial in understanding the whole biological processes involved in metabolism of food. Advent of newer approaches of omics sciences and technologies will enable us to address several issues and challenges faced by modern agriculture and also to ensure food and nutritional security.

Challenges in Agriculture

Agriculture plays important role in the course of the human civilization development. As the world population continues to grow, more and more agricultural products are required to meet people's needs. Besides, the increased energy demand, water scarcity, climate changing and environment destruction by human activity that have been brought about by the increasing population would all pose tremendous challenge to future agricultural production.

Food Safety

Food safety is receiving heightened attention worldwide as the important links between food and health are increasingly recognized. Improving food safety is an essential element of improving food security, which exists when populations have access to sufficient and healthy food. At the same time, as food trade expands throughout the world, food safety has become a shared concern among both developed and developing countries. Agricultural production is far from satisfying people's needs for food under current conditions of agricultural production, and there is a huge challenge confronting agricultural production whether in quantity or quality.

Energy Demand

With the reduce of fossil energy and increase in energy price, more and more developed countries, based on energy security considerations, are beginning vigorously to research and develop bioenergy, the production of which would consume large amount of agricultural products. Energy demand is still on the rise now, which means more and more agricultural products will be used to produce more fuel.

Climate Change

Climate is one of the most important factors influencing agricultural production. Climate changing would exert harmful influence on the potential for agricultural production, which would decrease the yield per unit of main crops like corn. Influence of this kind is more conspicuous in low-latitude area like Africa, Asia and Latin America. Even more disappointingly, with climate becoming warmer, crop diseases and pests also show a tendency of increased variety, expanded area, increased hazard and difficult governance. In this way, the management of agricultural production would become more and more challenging.

Water Shortage

Fresh water is a backbone of agriculture. At present, agriculture water accounts for 69% of the world total water consumption and it surpasses 90% in some arid countries. As population growth and urbanization continue, the proportion of domestic water consumption is also on the rise. And improperly disposed waste water from cities and industries has aggravated the quality of water resources in some regions.

Soil Degradation and Loss of fertility

The severity and scope of soil degradation and loss of fertility have been growing in many places of the world. Land degradation, desertification and bad farming practices and so on, which are caused by unauthorized cultivation of marginal land, deforestation for farmland expansion and soil degradation, have all degraded soil to certain extent. Land degradation would produce harmful results, such as decreased agricultural productivity, population migration, food insecurity, destruction of basic resources and ecological system, and even the loss of biological diversity due to habitat changes in species and inheritance.

Human Action

Extensive use of agrochemicals like fungicides, pesticides, germicide etc. by growers is the major challenges to protect our ecosystem. In order to improve productivity and crops production so as to increase their income and agricultural sustainability together, special attention has to be given for newer and eco-friendly strategies for crop protection and maintaining the environment and eco-systems.

Intervention of Omics in Relation to Agriculture Production

Agriculture is one field which gives humans an identity of their own. In India, agriculture has always been considered as the back-bone of our economy. We have learnt ways and means to harvest resources for our food, clothing and shelter. Therefore, besides knowing about the basics of agriculture, one should also be aware of the modern agriculture practices, newer technologies and researches in the field of agriculture for better yield and sustainable development. The large scale genome sequencing projects have given agricultural scientists access to an exponentially growing lists of genomes, from organisms covering all three forms of life. This has brought about a paradigm shift in the way scientists address the problem of food and nutritional security. A boom in exciting molecular technologies has taken the investigation of gene structure and function to an unprecedented level and more comprehensive measurement of cellular metabolites. The process of scientific research has changed fundamentally with the advent of the science of 'OMICS'. Although a majority of the omics approaches are still in expansion phase, but the tremendous effect they have on world agriculture is already evident in the form of "GENE REVOLUTION". Omics technologies have substantially transformed both the throughput and the design of scientific experiments. The omics technologies allow the generation of plentiful amounts of data at multiple levels of experimentation from gene sequence and expression to protein and metabolite patterns underlying variability in cellular networks and function at whole plant level. This signals a new era or approaching scientific queries. That is, the arrival of 'big biology' and a systems approach to scientific practice with global measurements of metabolic pathways in agricultural sciences.

In view of the amplified throughput data availability, the process of research has fundamentally been altered in 'omics science'. Normally, a scientist addresses a scientific problem by postulating a hypothesis and working through the experimentation to prove or disprove the hypothesis. With the omics approach, asking an initial research question is not always necessary or a pre-requisite. Genome or proteome wide data can be collected in an omics experiment without an existing hypothesis, followed by generation and testing of biological hypotheses. This reversal from the 'first hypothesize-then-experiment' tradition to 'first experiment-then-hypothesize' mode of operation offers the promise to discover unprecedented patho-physiological mechanisms of stress tolerance and other complex traits in crop plants.

Unraveling the genome sequences is only the beginning of the era of genomics. Once this is done, the genomic sequences will be used to study the function of numerous genes (functional genomics), to compare the genes in one organism with another (comparative genomics), and to generate the holistic structures of proteins from several protein families, thus offering clues to their function analysis. In agriculture, the main purpose of the application of genomics is to gain a better understanding of the whole genome of plants so that agronomically important genes may be identified and targeted to produce more nutritious and safe food, while at the same protecting our fragile environment from non-sustainable agricultural practices.

Unlike the genomics, proteome is highly dynamic and it changes from time to time in response to different environmental stimuli. The goal of proteomics is to understand how the structure and function of proteins allow them to do what they do, what they interact with, and how they contribute to processes associated with crop productivity. Similarly metabolomics can be used to determine differences between the levels of thousands of molecules between a healthy and diseased plant. The technology can also be used to determine the nutritional difference between traditional and genetically modified crops, and in identifying plant defense metabolites. Contiguous to this is an important aspect of interpretation and integration of the experimental data within the context of the whole cell as well as cell physiology. We are still learning and developing the bio-informatics tools to store and integrate different types of datasets.

Opportunities in Omics Technologies

In order to make today's agriculture sustainable it is necessary that scientist adopt innovative technologies that can increase the crop productivity. Under such circumstances molecular approaches including modern genomics and genetic engineering technologies have emerged as powerful tools to assure rapid and precise selection for the trait(s) of interest.

Recent advances in omics technologies including that of next generation sequencing and high-throughput genotyping have helped immensely in understanding the functions and regulation of genes in crop plants. Plant genomics and bioinformatics is a rapidly developing field, which is radically improving our understanding of plant biology by making available novel tools for the improvement of plant properties relevant to sustainable agricultural production.

The ever-increasing availability of genome sequences in crop plants have facilitated greatly the development of genetic and genomic resources that will allow us to address biological functions and a number of basic processes relevant to crop production leading to sustainable agriculture. The following are the main key areaof omics and the associated technologies and applications.

- Proteomics and epigenomics
- Applications of plant metabolomics
- Nutrigenomics and its therapeutic applications
- Microalgal omics and omics approaches in biofuel production
- Next-generation sequencing and omics technology for transgenic plant analysis
- Omics approaches in crop improvement
- Engineering dark-operative chlorophyll synthesis
- Computational regulomics and network biology
- Omics techniques for the analysis of RNA splicing
- New fields, including metagenomics, glycomics, and miRNA

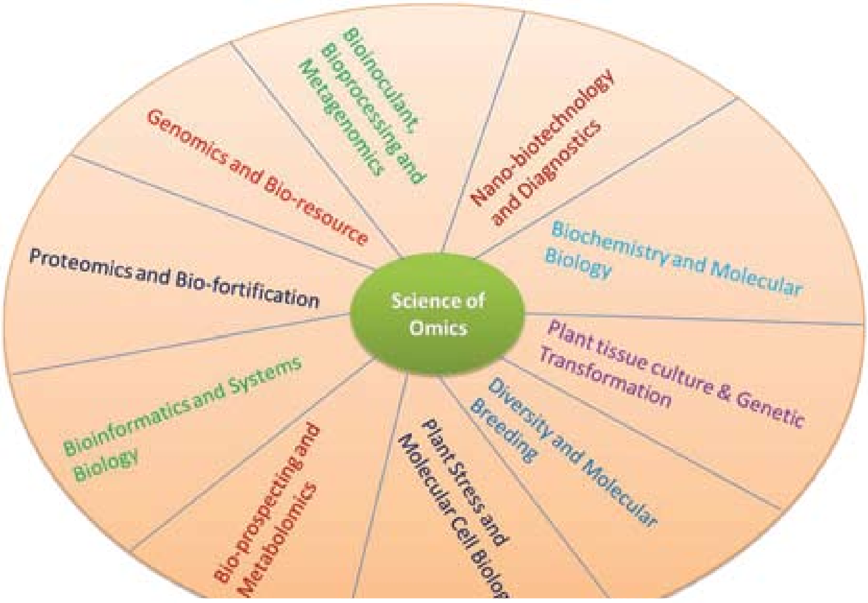

Fig. 1. of Omics: An Overview

This article provides a comprehensive overview of 'omics' technologies and application in area of agriculture to improve crop productivity. Some of the opportunities of omics technologies given in figure 1 and are also summarized below.

Genomics & Bio-resource

Bio-resource refers to the total biological variation manifested as individual plants, animals or their genes, which could be utilized as drugs, food or feed, etc., along with the development of improved crops and animals for higher yield and tolerance to biotic and abiotic stresses. Man depends on these bio-resources for his continued existence and, therefore, he must use and preserve them for future generations. India harbors two hot spots of biodiversity of the world. These are the Eastern Himalayas and the Western Ghats which are abode of numerous plant, animals and microbial species. Since utilization of the available bio-resources, to our advantage, is an inevitable part of existence, there has to be a balance between uses of resources and their conservation. In this way, we could preserve our ecosystem, which although altered would still be rich in bio-resources.

Computational advances and the development of high throughput sequencing methods have led to a virtual explosion of genomics, proteomics, and metabolomics data, providing new approaches to problems in biotechnology, especially agricultural biotechnology. The complete sequencing of the *Arabidopsis thaliana* genome has been regarded as a landmark in plant sciences and so far 10 plant genomes have been sequenced and sequencing of several other genomes is underway. Over the last two decades, comparative genomics has shown that the organization of genes within plant genomes has remained conserved over the evolutionary periods. Advances in the field of structural and functional genomics and equitational bio-resource utilization will encompasses a wider range of technologies and disciplines such as biocomputational engineering, bioenergy, and genome systems analysis *etc*, so as to achieve the goals of world food and nutritional security.

The Genomics option amalgamates the use of computational techniques to convert large amounts of information from DNA sequencing, DNA chips, and other high-throughput experimental methods into useful information that can be utilized for enhancing agricultural productivity. The emphasis is on DNA and protein sequence alignment, analysis and understanding the relationship between plant's genome and its phenotype. The promise of functional genomics is to expand and synthesize genomic and proteomic knowledge into an understanding of the dynamic properties of plant at cellular and/or organismal levels. This would provide a more complete picture of how biological function arises from the information encoded in an organism's genome. Besides, it will also provide opportunity to explore genomics for identification of novel genes from bioresources having hidden value for engineering superior traits.

As we enter 21st century, optimal utilization of available bio-resources in sync with the genomics approaches is poised to become a major platform for driving significant progress over the next 20-50 years. The knowledge and understanding of genome sequences, and their relation with metabolic control mechanisms will allow a sound scientific basis for a healthier and more reliable food supply.

Proteomics & Biofortification

One of the greatest problems for India is the undernourishment and malnutrition among the children and women. According to estimates of World Bank, India ranks second in the world, after Bangladesh, in terms of number of children suffering from malnutrition, where 47% of the children exhibit a degree of malnutrition. 50% of poor women of reproductive age are anaemic in India. Protein energy malnutrition and micronutrient deficiencies of Vitamin A, Iron and Zinc contribute to high mortality rate in children and women due to onset of various illnesses and diseases. Biofortification is seen as an effective strategy for coping with the problems of protein energy malnutrition and micronutrient deficiencies, prevalent among children and women in the developing world including India.

The objective of biofortification is to enrich the plant foods for essential micronutrients and proteins as plants grow naturally. It has been realized that biofortification of staple food crops such as rice and wheat would solve the malnutrition problem associated with rural poor as these staple foods predominate the diet of poor people. In this regard, Genetic engineering methods hold a great promise for development of biofortified foods. The genetic engineering based strategies include insertion of novel genes from heterologous system, over expression of already existing genes, disruption of pathways involved in synthesis of inhibitors of trace elements absorption and increased synthesis of enhancers of trace element absorption in order to increase the nutrient contents in staple food crops. Its application has already been seen in the form of golden rice developed to solve the problem of Vitamin A deficiency. However, implementation of such methods requires identification of nutritionally important genes and promoters which are associated with accumulation of high quality of proteins and micronutrients in seeds of staple crops.

Proteomics technologies aim at studying the global patterns of protein content, protein activities, modifications and localization, and interactions of proteins with other proteins or molecules of the cell. The proteomics techniques such as 2D gel electrophoresis, MALDI-TOF have potential for the detection and identification of proteins expressed in particular tissue, organ or organellae which in turn facilitate identification of relevant genes through reverse genetics approach. Such approaches, therefore, can be utilized to identify key candidate genes involved in uptake, transport, accumulation and availability of a potentially useful protein or micronutrient in the seeds. These studies also facilitate the understanding of molecular mechanism of remobilization of nutrient from leaves to grain seeds and it's subsequent compartmentalization within the seed. The unravelling such molecular mechanism involved in synthesis and accumulation of seed storage proteins and other nutritionally important nutrients would help in identification of key genes/transcription factors/ promoters which could subsequently be transferred in staple food crops for biofortification. Some examples of such biofortification strategies may include the manipulation of enzyme levels in biosynthesis pathways to increase levels of accumulated vitamins, higher expression of the molecular "pumps" that allow plants to take up more minerals from the soil or deposit a specific nutrient in seed grain and elevation of protein content by integration of genes from protein-rich crops into the staple food crops. Recent example of later is development of genetically engineered potato expressing the gene of an *Amaranthus* protein so as to enhance the protein content of potato. Another approach is to transfer the genes for the good quality proteins rich in essential amino acids in to staple crops. Ethnic cereal crops, which unfortunately neglected crops, are bestowed with good quality proteins and micronutrients like calcium, iron and zinc. In these crops, the seed storage protein genes are regulated by the concerted or combinatorial action of seed specific transcription factors which bind to their respective DNA binding sites on the promoter region. Advances in proteomics can be utilized to investigate the role of these components in accumulation of seed storage proteins in seeds by performing proteomics based co expression analysis and isolation and identification of genes for the same. The transporter proteins involved with accumulation of micronutrient in the seeds can be identified and their genes can subsequently be over expressed in staple crops so as to increase their bioavailability in the seeds. It will certainly help in opening new vistas for biofortification research programs.

Bioinformatics and Systems Biology

The biological sciences are now in the midst of a true fife sciences revolution akin to what physics experienced just after the turn of the last century. Now researchers are making constant effort to gain insight into living systems through their molecular function. Subsequent coordinated activities are now in a phase of unparalleled growth that is reflected by the amount of data generated from each experiment. This huge information from seemingly disparate datasets is converted into useful knowledge through bioinformatics. Bioinformatics is the application of information technology to help in collecting, linking, and manipulating different types of biological information to understand new biological insights. In other words, bioinformatics is an information management and manipulation system for molecular biology, biochemistry, health sector, environmental biology and agriculture by addressing biological data collection, data, mining, data analyses, interpretation and finding of genes and protein, modeling and product design especially' drug design, developing methods to predict the structure and/or function of newly discovered proteins and structural RNA, sequences, clustering protein sequences into families of related sequences, development of protein models, aligning similar proteins and generating phylogenetic trees to examine evolutionary relationships.

In an agriculture dependent country like India, bioinformatics has a very important role to play where it can be used for improving the nutritional content, increasing the yield of the agricultural produce and implanting resistance to several biotic and abiotic stresses. The sequencing of the genomes of microbes, plants and animals should have enormous benefits for the agricultural community. Bioinformatics facilitates both the analysis of genomic and postgenomic data, and the integration of data from the related fields of transcriptomics, proteomics and metabolomics. Computational analysis of these sequence data generated by genome sequencing, proteomics and analysis based technologies is critically important. Advances in genomics particularly in the area of genome projects have led to generation of huge amount of biological information which now can successfully be utilized for improvement of existing crop varieties. Bioinformatics which is a blend of biology and technology allows us to handle this biological data through retrieval, storage and analysis of biological information with the help of computers. Various bioinformatics tools, software programs and databases can now be utilized for DNA sequence analysis, gene discovery and identification of key candidate genes which hold great potential to redesign our crops for improved productivity.

There has been a paradigm shift from single gene approach (i.e. Gene by gene approach) in understanding the mechanism of biological phenomenon to working with several genes at a time. This shift has resulted from the observation that any biological response results from cross talk of many biomolecules which act in inter-dependent manner. As a result, many high throughput technologies have been evolved which provide a glimpse of all the molecules involved in a process. The process has been accelerated by research in the field of genomics. However, there exists a wide gap between genotype and phenotype in manifestation .of a trait. To fill this gap research is conducted at different levels- whole plant, cellular, biochemical, gene and protein levels. All these areas of unparalleled scientific efforts have led to the accumulation of large quantities of biological information. Bioinformatics which is culmination of biology and computational technology attempts to use these data to design novel strategies to get holistic view of biological system and to design novel strategies to address the problems of agricultural, medicinal and industrial importance. Systems biology is the understanding of biological systems at system level and works on system that is composed of molecules like DNA, RNA and protein. Bioinformatics tools including simulation, docking and protein -protein interaction tools can be used to search for the genes for specific function or manipulate the sequence for better fit and study the function of these genes or protein at system level. This specific genetic knowledge could then be used to produce stronger, more drought resistant, disease resistant, insect resistant, nutritionally improved and productive crops.

Bio- Prospecting and Metabolomics

Bioprospecting is the exploration, extraction and screening of biological diversity for genetic and biochemical resources. The indigenous knowledge is also applied to develop a commercially valuable product. In other words you can say that it is a scientific research that looks for a useful application, process, or product in nature. A common perception is that bioprospecting is a new science linked to modern biotechnology. However, the fact is that humankind has been studying, manipulating, and exploiting natural diversity ever since the emergence of *Homosapiens* over 150,000 years ago. Our early ancestors explored biodiversity and learned how to derive benefits from nature. Early bioprospecting led to the improvement of methods for growing food, building shelters, and maintaining health. In genomics era, scientists continue to find useful applications for compounds from nature. Bioprospecting is simply an extension of our long history of exploring nature to improve our quality of life. Bioprospecting should bolster economic and conservation goals underpinning medical and agricultural advances needed to combat disease and sustain a growing human population.

In the early stages, prospecting largely centered on the plants from the forest ecosystem. However, in recent times, various others form of biodiversity like insects, algae and microorganisms have been explored with considerable success. Bioprospecting of plants and microorganism for pharmaceuticals purposes is not only useful for pharmaceutical farms but also the host country and local people, who are benefited from the ownership of the biological resources. The term metabolomics is the newly emerging field of the omics research and an integral part of bioprospecting. It is a comprehensive and simultaneous systematic determination of metabolite levels in the metabolome and their changes over time as a consequence of stimuli. Metabolome is the qualitative & quantitative assessment of all low molecular weight compounds present in cells & required for maintenance, growth, and cellular normal function. Metabolomics facilitate the identification and quantification of economical valuable products from natural resources. Several techniques have been applied for metabolome analysis according to type of sample we are going to analyze such as NMR, HPLC, GC-MS and CE-MS etc. Bioprospecting has frequently been cited as a sustainable use of biodiversity. But there is a growing concern that many pharmaceutical farms and Biotechnology companies explore the natural resources to develop the profitable and patented product without given any recognitions and money to the people who maintained and improved the traditional plant varieties for medicines. It is termed as biopiracy and there are no effective guidelines and conditions to stop it. To overcome the problem of biopiracy it is necessary that terms and conditions apply for exploring biodiversity and the discoveries through it should be equally shared between pharmaceutical companies and local people. Besides, it will provide an opportunity to learn how to convert bioresource into wealth and also rejuvenate old principles of Ayurvedic biology into newer scientific perspectives for exploring optimum use of huge bioresouces for biomedical and agricultural applications.

Plant Stress & Molecular Cell Biology

The world today faces serious societal challenges in the areas of food, environment, energy and health. Although, the "green revolution" had an immense impact on Indian agriculture since the 1960's, its benefits were limited mainly to farming under non-stress or moderately stressed conditions. For the farmers in stress prone agriculture, the "green revolution" had made only a moderate impact. A major challenge in modern agriculture is to cope with biotic and abiotic stresses in an economical and environmentally sustainable way. Additionally, the global population is likely to cross 7 billion by 2025 and 10 billion by 2050, which will put extra burden on the already saturated crop yields.

Environmental stresses, including biotic as well as abiotic stresses, present some of the most enduring factors limiting agricultural productivity. Apart from biotic stresses caused by plant pathogens, there are a number of abiotic stresses such as extreme temperatures, drought, salinity and radiation which have detrimental effects on plant growth and productivity, especially when several of them occur simultaneously. In the world only 9% of the area is conducive for crop production, while 91% is under one of the other kind of environmental stress. Ironically, the area under stress is likely to increase further due to land degradation and urbanization. There is also impending concern about the impacts of climate change and its variability on agricultural production. Research confirms that while crops would respond positively to elevated CO_2 in the absence of climate change, the associated impacts of high temperatures, altered patterns of precipitation, and possibly increased frequency of extreme events such as drought and floods, will likely combine to decrease yields and increase production risks worldwide.

In recent years 'global warming' and its effect on crop production has become a very 'contentious' issue. Solving this problem at the plant science level is almost exclusively a question of coping with plant stress. It is to be noted that global environmental concerns are born out of the recognition that ecological processes do not always respect national boundaries and that environmental problems often have impacts beyond borders; sometimes globally. Biotic stresses such as viruses, fungi, bacteria, weeds, insects and other pests and pathogens are a major constraint to agricultural productivity from fields to markets, in the developing world. With few resources to combat or prevent infection and infestation, people farming small tracts of land are most vulnerable to these stresses and can experience devastating crop losses. Currently, most crop protection strategies involve genetic improvement of plants to resist pests and pathogens and/or the application of chemical deterrents. Soliciting transformative solutions to the pest and pathogen pressures faced by the farming community, is urgently required.

International agricultural and environmental research institutions are now re-discovering plant stress as a major component of the effect of global warming on local and global food production. The advances in plant stress tolerance and associated response are becoming increasingly important not only because agricultural production need to keep pace with increasing demand for agricultural produce, but also due to possible changes in climate that may make the environment much more hostile for agricultural production than what it is today.

Advances in plant molecular biology have provided new knowledge and technologies needed to address these challenges. A promising source of excitement are the powerful tools of modern plant molecular biology in functional genomics and gene expression profiling in stress response, that seems to provide a ray of new hope. These include the use of microarrays and genome mapping to detect and precisely manipulate stress-response genes in breeding programmes, and in the growing ability to engineer new or 'foreign' genes into plant genomes. Great advances have been made in recent years in understanding the molecular basis of plant response and plant tolerance to various biotic & abiotic stresses. Despite this, it will be prudent to admit that a huge gap persists between the findings at the molecular level and the application of this knowledge at the whole plant level for improved yield on-farm. Nevertheless, plant genomics remains a key component of global food security, and prosperity for the foreseeable future.

Diversity and Molecular Breeding

Diversity is one of today's buzz words and concept of diversity can be examined as a positive aspect of a global world and globalised society. Diversity is in many ways reflective of our present world order, but there are ways of taking this further without necessary endangering its alternatives. There is much scope to explore the full range of what diversity means and explore modes of diversity in real-life situations. Genetic diversity offers opportunities to utilize various genomic resources and technologies such as molecular marker technology and molecular breeding in an effort to breed new verities of desirable traits. Improved varieties, landraces and wild species can be explored for their desirable traits and this knoweldge can be further utilized to develop new varieties through marker assisted selection.

Molecular markers are DNA based markers which are either coding or noncoding sequence in nature and that assist in crop breeding programmes. The restriction fragment length polymorphism (RFLP) was the first DNA based marker to be used successfully in crop improvement followed by others like AFLP, SSR, DarT, and SNPs, for significant use in plant breeding programmes, molecular markers essentially need to be present in abundance in the genome and be polymorphic in nature, amongst the various other salient features required. These markers help in effective utilization of germplasm and improve the genetic gains more precisely and efficiently by using marker assisted selection (MAS). MAS application strategies in plant breeding includes development of suitable mapping population, linkage analysis and development of linkage map using suitable markers, QTL identification and QTL-marker association analysis, validation of marker-QTL association and then integration of MAS in plant breeding process. MAS aids plant breeding in numerous ways, namely by marker assisted backcrossing, marker ssisted background selection, linkage drag in gene introgression, marker assisted gene pyramiding, marker assisted recurrent parent selection and early generation marker assisted selection. MAS is more efficient over phenotypic selection alone, however, theoretical and analytical investigations reveal maximum selection efficiency for quantitative traits by use of a combination of molecular and phenotypic information.

In the present scenario it is clear that there are several opportunities for scientists in India to access large-scale marker services. Thus, there is less need now to consider major investments in in-house technology. The need is now to build the capacity of scientists/breeders in the country to better understand how best to apply genomics in their programs, including data interpretation and management. There is a head to the develop overall strategies and options for the application of molecular technologies in breeding and the opportunities for providing molecular technology to research and breeding programs via technology platforms and regional biotechnology laboratories will be discussed. The presentations will also focus on the potential impacts of molecular-based breeding and examples for capacity building and communities of practice toward the use of genomics in breeding. A 'tsunami' of genomic data and information is coming. Therefore, effective data management and analysis systems will be critical and could become a major impediment for scientists to optimally use genomics.

Plant Tissue Culture and Transformation

The practice of plant tissue culture has been change the way some nurserymen approach of plant propagation. Plant tissue culture comprises a set of*in vitro* techniques, methods and strategies that are part of plant biotechnology. Plant tissue-culture technology is playing an increasingly important role in basic and applied studies, including crop improvement. In modern agriculture, only about 150 plant species are extensively cultivated. Many of these are reaching the limits of their improvement by traditional methods. The application of tissue-culture technology, as a central tool or as an adjunct to other methods, including recombinant DNA techniques, is at the vanguard in plant modification and improvement for agriculture, horticulture and forestry. Tissue culture techniques, in combination with molecular techniques, have been successfully used to incorporate specific traits through gene transfer. Commercially glyphosate-tolerant soybeans, Lepidoptera-tolerant corn, glyphosate-tolerant cotton Bt cotton and Bt maize are commercially released varieties. Since their release, these technologies have been adopted at an impressive rate. The main reasons for the rapid adoption are that the new technologies were a very good deal for farmers. Current estimates place cost reductions in the case of soybeans at about US$20 per hectare in USA, mainly because of the reduction in energy costs (weed management cost).

In vitro techniques forthe culture ofprotoplasts, anthers, microspores, ovules and embryos have been used to create new genetic variation in the breeding lines, often via haploid production. Cell culture has also produced somaclonal and gametoclonal variants with crop-improvement potential. The culture of single cells and meristems can be effectively used to eradicate pathogens fromplanting material and thereby dramatically improve the yield ofestablished cultivars. Large-scale micropropagation laboratories are providing millions ofplants forthe commercial ornamental market and the agricultural, clonally-propagated crop market. In respect to medicinal plants, the production of useful metabolite by plant cell culture has been carried out on an increasing scale since the end of the 1950's. Their results stimulated more recent studies on the industrial application of this technology in many countries. However, there are still a few barriers that must be overcome before commercialization of many other products. To overcome barriers hindering industrial application of plant cell cultures, however, it is required to conduct more fundamental research, including elucidation of biosynthetic pathways of many useful principle compound and secondary metabolites in plants and mechanisms for their biosynthesis, collaboration with a number of researchers in other scientific fields is also very helpful.

Similarly, foreign proteins can be synthesized using plant tissue culture and transgenic plants. Choosing the method for commercial production requires case-by-case analysis. A wide range of factors must be considered, including cost of production, market volume, the efficacy, safety and stability of the product, and whether the foreign protein has different biochemical or pharmacological properties compared with material from existing sources. Plant cell and root cultures have been demonstrated to produce a wide range of recombinant proteins. The role of plant tissue culture as a means for commercial protein production is not clear at present, but is likely to depend on the ability to express high levels of proteins *in vitro* by manipulating culture conditions. Extracellular localisation and the stability of secreted proteins in the medium of plant cultures may be important keys to economic feasibility, allowing easier product recovery without destroying the biomass. Because the controlled environment in plant cultures offers advantages for GMP and regulatory compliance, a potential niche for reactor-scale plant tissue culture is the rapid production of low-to-medium volume therapeutic proteins. Technology for modifying the glycans of plant glycoproteins may be required before plant systems can be fully exploited for the manufacture of injectable drugs and vaccines.

Considering the recent trends in plant tissue culture and transformation "what is being done" and to explore "what can be done" with regard to the tissue culture of commercially valuable plants is the need of time.

Biochemistry and Molecular Biology

Molecular biology chiefly concerns itself with understanding the interactions between the various systems of a cell, including the interactions between DNA, RNA and protein biosynthesis as well as learning how these interactions are regulated. This discipline of science overlaps with Biochemistry which is the study of the chemical substances and vital processes occurring in living organisms. Biochemists focus heavily on the role, function, and structure of biomolecules. Rapid advances in the field of Molecular Biology and Biochemistry have enabled identification of molecular principles which underly plant behaviour. The identification of various factors and their cognate target sites involved in the regulation of plant development and adaption processes has led to distinct molecular models which explain how plants cope with different environmental stresses of light, water, nutrient conditions as and various biotic stresses. This in turn has facilitated formulation of effective strategies to develop stress tolerant crop varieties through molecular manipulation of key important genes or proteins. The recently developed ability to determine entire genomic sequences has provided the data needed to accomplish massive comparisons of derived protein sequences, the results of which may be used to formulate and test hypotheses about biochemical function of a specific plant protein. With the advent of omics technologies it has become possible to understand the behaviour of whole genome and gene networks involved in regulation of complex agronomic traits. This has been possible due to availability of molecular maps, quantitative trait loci (QTL's), genomic and expressed tag sequences from model plant *Arabidopsis thaliana* and various crop plants such as rice and sorghum. Comparative and functional genomics approaches are being utilized for understanding gene functions and for studying simulataneous interaction of various genes governing a complex agronomic trait. With the inception of genomic research, coordination of regulation of a set of genes is possible by transfer of key regulatory master switch gene.

Nanobiotechnology and Diagnostics

India is an agricultural economy. Indian Farm scientists foresee food scarcity in the impending years which could prove to be a serious threat to the India and the world economy. The scarcity of food would grow into a serious global issue that needs to be tackled head-on. Besides, crops are generally considered as soft targets during food production and distribution networks. Molecular diagnostics technologies will also play an important role in practice of agriculture, food and biological warfare in the 21st century. Nanobiotechnology extends the limits of molecular diagnostics to the nanoscale. In general it has been one of the most important innovations of recent years and has rapidly become the basis of many products that are now in use, especially in crops. The success of this novel technology has been in its potential to offer smarter solutions that have broad applications in agriculture. The potential of nanodiagnostics arises from the fact that most biological molecules and cell organelles fall within the nanometer scale. Conventional methods of pathogen identification have often depended on identification of disease symptoms, isolation and culturing of organisms, and identification by morphology and biochemical tests. The major limitations of these culture based morphological approaches, however, are the reliance on the ability of organism to be cultured, time-consuming nature and requirement of extensive taxonomic expertise. Laboratory diagnostics for plant pathogens have traditionally relied on methods of detecting the pathogen by culture or antibodies, using a variety of techniques such as neutralization, enzyme-linked immunosorbent assay, agar gel immunodiffusion and complement fixation. The field of nanobiotechnology and molecular diagnostics has to offer to improve diagnostics is mainly increased sensitivity and faster detection.

Biological tests measuring the presence or activity of selected substances become quicker, more sensitive and more flexible when certain nanoscale particles are put to work as tags or labels. Some of the nano particles that have entered into the arena of controlling plant diseases are nano forms of carbon, silver, silica and alumino-silicates. Multicolor optical coding for biological assays has been achieved by embedding different-sized quantum dots into polymeric microbeads. Nanopore technology for analysis of nucleic acids converts strings of nucleotides directly into electronic signatures. DNA nanomachines can function as biomolecular detectors for homogeneous assays. Nanobiotechnology can be exploited to develop biosensors and other efficient diagnostic tools for crop diagnostics. Nanobarcodes, submicrometer metallic barcodes with striping patterns prepared by sequential electrochemical depositon of metal, show differential reflectivity of adjacent stripes enabling identification of the striping patterns by conventional light microscopy. The processes and products that are precise and impossible to achieve through conventional systems can be achieved by atom by atom manipulation using nanobiotechnology. Nano-particles are able to controlling the crop diseases. Nutrient deficiency and food contaminants can also be detected using nanosensors. “Smart delivery systems” for agriculture can possess timely controlled, spatially targeted, self-regulated, remotely regulated, pre-programmed, or multi-functional characteristics to avoid biological barriers to successful targeting. It can monitor the effects of delivery of nutrients or bioactive molecules or any pesticide molecules. In the Smart delivery system, a small sealed package carries the drug which opens up only when the desirable location or infection site of the human or animal system is reached. The nano food packaging sector has experienced some of the most significant developments in terms of commercialization. Manufacturers are applying nano techniques with the aim of improving the quality, durability and shelf life of packaged foods. Nanobiotechnology can be employed to synthesize smart nano-devices that release active herbicide and insecticide molecules only when moisture is available in rain-fed system besides targeting both leaves and tubers. Nanoinsecticides are better than the conventional insecticides due to its small size, reduced run off, higher water suspension/solubility, less damage to the environment. Nanofertilizers may be used as a strategy to regulate the smart release of nutrients that commensurate with crop requirement.

Bio-Inoculant, Bioprocessing and Metagenomics

Bioprocessing is related to the use of biological sources like microorganisms, enzymes, plant and animal cells in converting raw materials or substrates into various new value-added food or non-food products. Bioprocessing research focuses on three main thrust areas namely fermentation and microbial technology, enzyme technology and cell culture and plant metabolites technology. There is need for extensive research which have the potential for helping the agri-food industry to improve process efficiency, enhance product quality and, extend shelf-life of fresh and processed agri-food products. In the genomic era, vast genome sequence information can be utilized to manipulate the metabolism of the organism resulting in more efficient strains for bioprocessing purposes. Science of omics can be used to produce more efficient enzymes, optimize fermentation conditions and identify new gene targets for enhancing the bioprocessing of crop produce. Functional genomics approaches provide insight in to cell's metabolism which can be exploited for metabolic engineering to develop value added products.

Bioinoculants have shown great potential as a supplementary, renewable and environmental-friendly source of plant nutrients, and are an important component of Integrated Nutrient Management (INM). Bioinoculants are the live microbial cells of single species or consortium of different microbial isolates that are applied to the soil or treated with plant/seed material to improve the plant health. Broadly bioinoculants include biofertilizers and biopesticides. Omics technologies can be utilized to authenticate different strains of bioinoculants to maintain quality standards and to identify different genes which could be used to develop improved strains of bioinoculants.

Metagenomics is the study of metagenomes, genetic material recovered directly from environmental samples. It holds immense potential to study useful microbial diversity present in the environment and which is non-culturable and cannot be studied by traditional microbiological methods. Science of "Omics" has revolutionized the study of microorganisms present in the environment and improved our understanding of the composition, phylogeny, and physiology of microbial communities. Currently, there is a major emphasis on the application of "omics" approaches such as genomics, proteomics, functional genomics, etc. to determine the identities and functions of microbes inhabiting different environments. Needless to say, such recent developments will be of significant value in discovering new microbes and microbial genes and to exploit them in solving the urgent challenges facing the environment, agriculture, and human health.

Challenges in Omics

With the beginning of new technologies and acquired knowledge, the number of fields in omics and their applications in diverse areas are rapidly increasing in the postgenomics era. Such emerging fields—including Next generation sequening, regulomics, spliceomics, metagenomics, and environomics—present budding solutions to combat global challenges in agriculture and the environment.

Genome

At the level of DNA, genomic data reveal the information that is stored in the genomes of organisms and passed across generations. These include sequences of genes coding for functional proteins, regulatory motifs that serve as markers for the regulation of the expression of specific genes, as well and individual differences in the genetic composition of populations, such as single nucleotide polymorphisms (SNPs—common individual differences at a single nucleotide base) and copy number variants (CNVs—multiplicity or lack of certain DNA segments in genomic sequences), inversions, or transpositions. Sequence data drives translational research through genome-wide association studies (GWAS), discovery of driver mutations and structural variants in progressive diseases of plants and transfer of biological knowledge across model organisms via comparative genomics. Genome sequencing is traditionally achieved by exploiting of the natural process of DNA replication. On the other hand, identification of SNPs and CNVs has been usually carried out using DNA microarrays, which exploit the natural process of hybridization. on the other hand, sequencing technology and associated computational techniques are now being transformed by the appearance of short read sequence data, also known as next-generation sequencing.

Transcriptome

DNA microarrays have been used generally to monitor the retrieval of genomic information under various conditions. More specifically, the relative quantity of mRNA molecules that are present in a sample can be measured simultaneously for thousands of mRNA sequences (transcriptome), enabling comparison of the expression of thousands of genes in a given sample or across samples. With the arrival of next-generation sequencing technologies, genome-wide assessment mRNA expression of is also becoming more reliable through whole transcriptome shotgun sequencing (RNAseq). Genome-wide assessment of mRNA expression enables identification of genes and groups of genes that are differentially expressed under various conditions, detection of coexpressed genes, and inference of the regulatory effect of genes among each other. Dysregulated genes identified via screening of the transcriptome serve as markers for diagnosis and prognosis of various diseases in plants, as well as targets for therapeutic intervention.

Proteome

Although the expression of a gene at the transcriptomic level serves as an approximation to the abundance of the corresponding protein in the sample, it does not necessarily capture the functional activity of the protein, since protein expression is also regulated after transcription,

through several mechanisms including mRNA degradation, alternative splicing, and posttranslational modification. Proteomic screening captures molecular abundance and activity at the functional level. A common method, 2-D polyacrylamide gel electrophoresis enables separation of proteins in a given sample based on their electrochemical properties (e.g., isoelectric point or mass). Separated proteins can then be identified using mass spectrometry (MS). Although proteomic screening techniques are useful in quantifying the expression, as well as modification of proteins at the functional level, established proteomic screening techniques can only monitor the expression of a limited subset of proteins in the cell at a time. Furthermore, techniques such as flow cytometry allow screening of protein activity at the resolution of thousands of individual cells; however, this comes at the price of a limited coverage of the proteome. Proteomic data enables detection of functional proteins and their modifications that have a role in the development and progression of disease and development of causal models for cellular signaling, driving translational science at the functional level in crop plants.

Interactome

In addition to abundance at the level of single molecules, present high-throughput screening techniques enable identification of physical interactions among proteins. A common method, yeast two-hybrid (Y2H) screening identifies interactions between pairs of proteins by exploiting the modularity of the activating and binding domains of eukaryotic transcription factors. Namely, in Y2H, the activating and binding domains of a specific transcription factor are separated, and each domain is fused to one of the two (prey and bait) proteins. Subsequently, the interaction between the two proteins is captured by the expression of a reporter gene that is the target of the transcription factor. Tandem affinity purification (TAP), on the other hand, identifies interactions between a single bait protein and multiple other proteins .This is achieved by tagging the protein of interest and introducing it to the host. Once the bait protein is retrieved along with other proteins attached to it, these interacting partners are identified using MS. Experimentally identified protein–protein interactions (PPIs) are organized into PPI networks, which provide a high-level and static description of cellular organization, commonly referred to as the interactome. Currently, established PPI network models assume binary interactions between pairs of proteins, which is naturally descriptive of the outcome of Y2H screening. On the other hand, multiple interactions identified by TAP are represented by either a star network around the bait protein (spoke model) or a clique of all proteins retrieved by the bait protein, including itself (matrix model). An important limitation of high-throughput PPIs, however, is their incomplete and noisy nature. Furthermore, these interactions only represent a snapshot of the dynamical organization of proteins in the cell. Currently available PPI data sets are also highly prone to ascertainment bias. Motivated by these considerations, PPI data are often integrated with other – omic datasets to assess the reliability of each interaction. In recent years, PPI networks have been extremely useful in understanding the systems biology of complex diseases, through identification of protein complexes, functional modules, and signaling pathways network-based functional annotation, network-based disease gene prioritization, and identification of dysregulated pathways in plant systems.

Metabolome

Metabolism, i.e., chains of chemical reactions that change various forms of matter and energy into one another, is one of the fundamental processes in living systems. The organization of metabolic reactions is generally abstracted using metabolic network models, which represent the complex web of relationships between metabolites (compounds consumed and/or produced by reactions) and enzymes (gene products that catalyze reactions). Today, several well-characterized metabolic pathways for diverse species, including humans and other model organisms, are available in public databases. However, large-scale analyses of the kinetics of metabolic networks are bound by data availability and computational complexity. Nevertheless, flux balance analyses that rely on steady-state assumption provide significant insights into the dynamics of metabolism. These analyses are enabled by monitoring of the abundance of metabolites via NMR and MS, as well as monitoring of the abundance and functional activity of enzymes through transcriptomic and proteomic screening for identification of complex agricultural traits.

Expression Data Analysis for Diagnosis and Prediction

Systems approaches have proven of great utility for the diagnosis of diseases in plants, with increasing power expected to continue to emerge in the future. Despite notable and significant challenges that remain, one area that has shown significant promise is the mining of global gene expression data sets to identify molecular signatures that can be used for diagnosis and treatment selection. These studies typically involve the collection of samples from two or more classes (e.g., diseased plant and normal plant) and the use of a set of data on which to train a molecular classifier and another set on which to test. the absence of a true test set, resampling methods such as cross validation are generally used to estimate likely performance of the classifier on future data. Challenges often arise in these studies when different measurement platforms are used in training and test sets. The ability to generate an accurate classifier is a function of factors such as: (i) the size of the training set relative to the number of features, (ii) the computational method used, and (iii) the inherent distinctness of the selected phenotypes. Typically, the number of samples is far less than the number of transcripts, leading to over-fitting being a significant problem. This leads to the need for computational methods that aid in avoiding over-fitting when selecting a classifier.

Network-based Disease Gene Prioritization

Characterization of disease-associated difference in plant genome is an important step toward enhancing our understanding of the cellular mechanisms that drive complex diseases, with profound applications in modeling, diagnosis and management intervention. Genomewide linkage and association studies in healthy and affected plants provide chromosomal regions containing hundreds of polymorphisms that are potentially associated with certain diseases. These polymorphisms often span up to 300 genes, only a few of which probably have a role in the manifestation of disease. Investigation of that many candidates *via* sequencing is clearly an expensive task, thus not always a feasible option. Consequently, computational methods are primarily used to integrate omics datasets to prioritize and identify the most likely disease-associated gene and proteins. Protein-protein interactions provide an invaluable resource in this regard, since they provide functional information in a network context and they can be obtained at a large scale via high-throughput screening. Network-based analyses of diverse phenotypes demonstrate that products of genes that are implicated in similar diseases are clustered together into “hot spots” in PPI networks.

Big Data in Genomics: Challenges and Solutions

These revolutionary modifications in Big Data generation and acquisition create profound challenges for storage, transfer and security of information. Indeed, it may now be less expensive to generate the data than it is to store it. One example of this issue is the NationalCenter for Biotechnology Information (NCBI). The NCBI has been leading Big Data efforts in plants and animal science since 1988, but neither the NCBI nor anyone in the private sector has a comprehensive, inexpensive,and secure solution to the problem of data storage. These capabilities are beyond the reach of small laboratories or institutions, posing several challenges for the future of agricultural research. Another challenge is to transfer data from one location to another; it is mainly done by shipping external hard disks through the mail.

Potential Challenges of Omics

Currently the potential challenges of omics are as follows:

1. Availability of computational resources. More and more data have been and are being generated. How to stored and analyse these data.
2. Lack of reference database, especially the reference phytochemicals for metabolomics, where some metabolites with unknown structure might be produces.
3. Reproducibility: why cannot one group's findings be reproduced in another person or in another group.
4. Noise: "omics" can generate so much data that noise overwhelms signal. Why is it that we find fewer gene as our instruments and methodologies advance.
5. Fishing: the search for novel genes in complex samples, i.e., discovery-mode "omics", has been frequently criticized as a "fishing expedition" in which one blindly hopes to find something interesting and yet often falls short.

Summary

This article highlighted new tools based on omics technology have a high impact on next-generation bio-products. They can improve the understanding of Genomics, Transcriptomics, Metagenomics, Proteomics, Metabolomics and other related areas of omics. New functions and interactions of plant-associated abiotic and biotic agent can be identified using omics techniques. The omics researches are also helpful for solving problem related to the agricultural challenges. A public dialogue is required in addition to research in order to promote the application of omics technology in the future for both agriculture and food.

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Invasive and Emerging Diseases- A Challenge for Smart Horticulture

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The horticulture production (263 million tonnes from 23.24 million ha) has overtaken grain production (259.32 million tonnes from 125 million ha) for the first time since independence. Now, all fruits and vegetables are available across the length and breadth of the country. Besides, investment in horticultural enterprise reaps benefits probably more than any sector in agriculture. Despite this, the threats of climate change coupled with declining land, water and agricultural labour force besides rising input costs necessitated the development of efficient horticultural production systems. A number of biotic factors, of late, pose a serious challenge in sustainable production of horticultural crops. Cost effective and sustainable integrated disease management and plant quarantine approaches are required to minimize crop losses and to produce quality and pesticide residue free spices, which facilitate international market access to boost exports. Accurate identification of the plant diseases affecting horticultural crops is a key factor for bio-security preparedness and adopting eco-friendly and effective control strategies. Pathogens that are responsible for plant diseases can be classified in four categories: i.Invasive pathogen or new- whose introduction causes or is likely to cause economic or environmental harm or harm to human health or pathogens detected within the last five years; ii. Emerging - pathogen incidence has increased within the last 20 years; iii. Re-emerging - pathogens associated with chemical resistance or changes in management or cultivars, previously controlled infections; and, iv. Threatening - pathogens not reported in India. This article describes invasive and emerging diseases in horticultural crops in India and their management strategies.

Fruit Crops

India is the second largest producer of fruits in the world after Brazil with a production of 74.87 million tones, accounting for 10 per cent of the world production.The Indian fruit industry is typically seasonal and depends on small and marginal farm holdings. Fruit production in India is mostly for domestic markets, but fruit industries also contribute significantly to exports. In 2010–11, fresh fruit exports were worth Rs 10,646million, wine exports were worth of Rs 250 million, and other processed fruit produce was worth Rs 21,303 million.

Tropical Fruit Crops

Banana : India is the world largest producer of banana, with a total production of 26.47 million tonnes from an area of 0.770 million hectares. Wilt (*Fusarium oxysporum* f.sp. *cuebense*), sigatoka leaf spot disease (*Mycosphaerella* spp), banana bunchy top disease (*Banana bunchy top virus*), bract mosaic disease (*Banana bract mosaic virus*), streak disease (*Banana streak virus*) and banana mosaic or infectious chlorosis (*Cucumber mosaic virus*) are nationally important as they have spread all over the banana growing regions of the country and cause significant reduction in the yield. The tropical race-4 of *Fusarium* wilt pathogen *Xanthomonas* sp. and *Pseudomonas* sp are not reported from India.

Citrus: Citrus is the third most important fruit crop in India, after banana and mango, with an estimated production of 9.63 million tonnes of fruits and area coverage of 9.87 lakh hectares. *Phytophthora* induced diseases are considered as one of the important factors of citrus decline. They may cause damping-off of seedlings in the seedbed, root and crown rot in nurseries, foot rot, gummosis, fibrous root rot and brown rot of fruits in orchards. *P. citrophthora*, *P. nicotianae*, and *P. palmivora* are the major and widely distributed species causing citrus diseases in India. The management of citrus diseases caused by *Phytophthora* is an integrated approach, which includes use of resistant/tolerant rootstocks, improved cultural practices and use of chemicals and bio-control agents. Some of the most serious diseases of citrus in the world are caused by bacteria. These include citrus canker, greening, blast or black pit and citrus variegated chlorosis. Among these canker and greening are the two most widespread and important bacterial diseases of citrus prevalent in India. There are three different forms of citrus canker disease caused by various pathovars and variants of the bacterium *Xanthomonas axonopodis*. The most effective management of canker is by supplementing the use of resistant cultivars with integrated systems of compatible cultural practices and phytosanitary measures, including quarantine and regulatory programmes. Citrus greening disease (CGD) is one of the most destructive maladies of citrus and known to be caused by a phloem limited, non cultured bacterium, *"Candidatus* Liberibacter spp.," belonging to the alpha-proteobacterial subdivision. The Indian citrus industry urgently needs to establish a functional citrus budwood certification programme before the industry is confronted with an epidemic of viral diseases. Since citrus is predominantly a vegetatively propagated crop, use of healthy, virus-free planting material is the needs of the hour for putting citrus industry on sound scientific footing.

Grapes: In India, grape is grown in about 1.0 lakh hectares with an annual production of eight to 9.0 lakh tones. Commercial grape varieties belonging to *Vitis vinifera* are highly susceptible to three important diseases *viz*. downy mildew (*Plasmopara viticola)*, powdery mildew (*Uncinula necator)* and anthracnose (*Colletotrichum* spp). However, during recent times rust (*Phakospora vitis*) infection is becoming serious in areas where black varieties like Sharad Seedless and its clones and Bangalore blue are dominantly cultivated. Similarly in hotter areas like Solapur, Osmanabad and Latur districts, bacterial (*Xanthomonas*) infection is seen during August to October period on leaves. Both rust and bacterial leaf spots causes premature leaf drop. In recent years, grapevine leafroll associated virus-3 has been observed in some vines. Besides these, postharvest decay is another problem reducing shelf life and the market value of grapes. Grape growers follow 'Good Agricultural Practices'. Only those fungicides which are registered with the Central Insecticide Board (CIB), Faridabad, India, against a specific grape disease are recommended for control of that disease. During monsoon season which corresponds to the vegetative growth period, non-systemic fungicides, especially copper based fungicides, which are broad spectrum and have good rain fastness can provide effective control of downy mildew. They will also help in controlling anthracnose and bacterial blight diseases, which occur during this wet period. Systemic fungicides are usually not recommended during this period. However, non-systemic fungicides are not preferred during active shoot growth period as they do not protect the new growth.

Pomegranate: The cultivation of pomegranate in India gained importance after 1986, thereafter, it steadily increased to occupy first rank in area (1.25 lakh ha) and production (8.20 lakh tonnes) at the global level. Among various fungal and bacterial diseases of pomegranate, bacterial blight/oily spot and wilt/decline are the two most important diseases that cause economic losses to the growers. Crop losses to the tune of Rs. 200 million in Karnataka during 2007-08 and Rs. 10 billion in Maharashtra during 2006-07 have been reported. The pomegranate bacterial blight was caused by *Xanthomonas campasteris* pv. *punicae.* Looking into the importance of pomegranate crop and heavy losses caused by bacterial blight, an 'Orchard Health Management Schedule' was finalized. The OHM schedule focuses on integrated approach through use of disease free planting material, orchard sanitation, proper plant nutrition and irrigation, cultural practices and chemical spray schedules. The wilt manifests itself as yellowing of leaves in some twigs or branches, followed by drooping and drying of leaves as the external signs. In addition to *Ceratocystis. fimbriata*, *Meloidogyne incognita* (root-knot nematode) and shot hole borer - *Xyleborus fornicates and X. perforans* - are also associated with wilt. Implementing wilt management early during disease development is important and prophylactic measures are better than cure, holds all the more true for the control of wilt diseases as no effective therapeutic treatment is known so far.

Guava: It is an important fruit of subtropical countries. Wilt is one of the most destructive diseases of guava in India and loss due to this disease is substantial. As the disease is of soil borne in nature, there are limitations for the control of this disease. Other important field diseases of guava are anthracnose, canker and algal leaf and fruit spot. The wilt plants show yellow colouration with slight leaf curling at the terminal branches, becoming reddish at the later stage and subsequently shedding of leaves take place. *T*he exact cause of the disease is still not fully understood. Various pathogens involved with the affected plants viz. *Fusarium oxysporum* f.sp. *psidii*, *F. solani*, *Macrophomina phaeseoli, Rhizoctonia bataticola, Cephlosporium* sp., *Gliocladium roseum* and *Verticillium albo-atrum* etc. have been reported by different workers. Considering the complexity of the problem integrated eco-friendly approach for the control of guava wilt was suggested by utilizing bioagent *Aspergillus niger* strain AN17 and resistant root stock (*P. molle x P. guajava*) and intercropping of guava with turmeric or marigold as well proper cultural practices and can be integrated to minimize losses due to the disease. Anthracnose is serious problem in Uttar Pradesh, Punjab and Karnataka. It causes die back, twig blight, wither tip and fruit spots. The disease is caused by *Colletotrichum psidii.* Effective control of anthracnose can be achieved by sprays of Bordeaux mixture (3:3:50) at 7 days interval. Copper oxychloride, cuprous oxide, zineb also significantly control the disease.

Temperate Fruit Crops

Apple: Apple is the most important fruit of temperate regions of the world. Apple scab is one of the most destructive diseases of the apple prevalent throughout the world. Scab symptoms can be observed predominantly on the leaves and fruits. The disease is caused by the fungus, *Venturia inaequalis* with its imperfect stage *Spilocaea pomi.* High rainfall and relative humidity are the most important factors for disease development and also known as wet weather disease. Collar rotis serious disease attacking apple trees at soil level and girdles the stem/crown completely leading to death of the plant. Collar rot of apple is mainly caused by *Phytophthoracactorum.* Waterlogged soil with temperature of 12 to 20°C and pH 5 to 6 has been found to be the best for disease spread. The Alternaria blight is caused by *Alternaria mali* Robt. and in India it was reported in Kashmir and Himachal Pradesh. The disease produces small, oval to irregular, dark brown lesions on leaves in late spring or early summer, which enlarge and coalesce to form irregular patches. Premature defoliation of apple caused by *Marssonina coronaria* is one of the major causes in declining apple production in apple growing states of India. The disease appeared in epiphytotic form first in Himachal Pradesh during 1996, 1997 and 1999. Again in 2005 and 2006 cropping season, it occurred in epiphytotic form. Cankers cause losses by girdling and eventually killing shoots, limbs and main trunk

Pears: Pears are one of the oldest and most patronized fruit of the world. Pear scab is a serious disease in almost all pear growing countries including India. The losses occurred due to mid season defoliation, failure of fruit bud formation, weakening of trees, reduction in fruit production and devaluation of fruit quality. Pear scab, incited by *Venturia pirina,* causes circular, rough and olive green coloured lesions on leaves and dark brown to black patches on fruits. This disease is responsible for crop losses up to 30%.The period of wetting and favourable temperature required for infection is quite similar to that of apple scab. Black rot is an important disease and has been reported from India, Australia, New Zealand, North and South America and Zimbabwe. In India, it appears in more or less severe form depending upon the environmental factors of the particular state. Black rot is caused by *Botryosphaeria obtuse.* Leaf spots, caused mainly by *Mycosphaerella* spp. and *Phyllosticta* spp. are also economically important.

Stone fruits: Stone fruits such as peach, plum, apricot and cherry are grown in considerable quantity mainly in the North-Western Indian States of Jammu and Kashmir, Himachal Pradesh and in Uttar Pradesh hills.Peach leaf curl is common disease of all the stone fruits, but peach is the main host for fungus.Curling and puckering of leaves due to hypertrophy and hyperplasia of the cells is the characteristic symptom.Leaf curl is damaging when the weather is cool and moist. Disease causes defoliation of peach trees, which may lead to small fruit or fruit drop. Different species of *Taphrina* cause leaf, flower and fruit deformation on stone fruits and forest trees. *Taphrina deformans* causes leaf curl on peach and nectarine, *T. communis* and *T. pruni* on plums, *T. cerasi* causes leaf curl and witches broom on cherries and *T. coerulescens* causes leaf blister of oak. The walnut is grown extensively in almost all the temperate countries where summers are not too cool. In India, it is mainly grown in Jammu and Kashmir, Himachal Pradesh and Uttar Pradesh hills. Walnut blight is responsible for damage of more than 50 per cent of the crop in USA in 1953. In India, it was first reported from UP hills infecting 16 to 47 per cent nuts of different exotic varieties. The disease is caused by a gram negative bacterium *Xanthomonas arboricola pv.juglandis.* The Leaf blotch, caused by *Marssonina juglandis,* is widespread in occurrence and destructive at young nut stage causing pre-mature nut drop and extensive yield loss and it is prevalent in almost all the walnut growing localities of Kashmir.*Agrobacterium tumefaciens incited crown galls are also emerging as a serious production constraints in many stone fruit crops.*

Vegetable Crops

Vegetables are important in human diet as they provide nutritional and health benefits. India is the second largest producer of vegetables in world with an annual production of 87.53 million tonnes from 5.86 million hectares, accounting 14.4% to the world production. In India, potato, tomato, chilli, cucurbits, brinjal and okra are economically important and occupy approximately 50 % of the total area under vegetable production. Potato, chilli, tomato, brinjal, okra and cucurbits are cultivated in an area of 1.23, 9.3, 0.35, 0.49, 3.38 and 4.29 million ha with a production of 2.25, 8.0, 5.3, 0.78,3.4 and 4.5 million metric tonnes respectively. Vegetable crops are largely cultivated by small and marginal farmers and diseases are the major limiting factors to sustainable vegetable production. Vegetable crops are threatened by a wide variety of plant diseases. Among these, fungal diseases are the most important ones and some diseases wipe out entire harvests.

Fungal Diseases: Among the fungal diseases, damping off seedlings, Alternaria leaf blights, anthracnose, *Phytophthora* blights, mildews, wilts, Rhizoctonia diseases, Sclerotina rots, Sclerotium diseases, Phoma leaf spot and stem canker, club root, white rust, Cercospora leaf spots, rusts, scabs, *Ramularia* leaf spot, grey mould, Septoria leaf spots, Ascochyta blight and gummy stem blights are the major diseases that cause serious economic losses in vegetable crops.

Diseases caused by *Phytophthora* spp are emerging as major concern in India due to emergence/migration of new clonal population with increased virulence and multiple fungicidal resistances. Although *Phytophthora* blight was a serious limiting factor in potato in India since 1952, these diseases never posed any threat to other vegetable crops. Since 2008, severe outbreaks of *Phytophthora* diseases such as late blight on tomato (*P.infestans*), fruit rot on brinjal and cucurbits (*P.nicotianae*), foliar blights and wilts in chili (*P.boehmeriae* and *P.capsici*) were noticed. The migration of 13_A2 genotype of *P. infestans* from Europe was the cause of outbreaks of destructive late blight in India and stresses the importance of bio-security in agricultural trade. The emergence of *P.boehmeriae* was responsible for severe leaf blight epidemics on hot pepper in South India although it is not serious pathogen on any crop in any part of the world. These invasive and emerging *Phytophthora* species have epidemiological and management implications for the production of vegetable crops in India.

Detection of seed borne fungal pathogens and accurate disease identification are the key components in planning an effective and efficient disease control program. The ready to usePCR based diagnostic assays for seed borne fungal pathogens like *Alternaria* spp and *Colletotrichum* spp and digitally assisted diagnosis (DAD) for field diagnosis are to be employed. Disease forecasting models such as FAST, EPIDEM simulation model, TOMCAST and BLITECAST and effecting modifications to suite local conditions have been successfully implemented for early forewarning blights in tomato and reduced 50 percent sprays in many growing tomato countries. The computer based *Alternaria, Cercospora* and *Phytophthora* infection prediction models for early prediction in vegetable crops have been developed at IIHR, Bangalore and these models are being evaluated at different locations across the country.

Many plant genetic engineering strategies to develop fungal resistance based on constitutive expression of pathogenesis-related (PR) protein genes such as chitinase (PR-3) and ß-1,3-glucanase (PR-2), which are efficient in the lysis of chitin and glucan polymers of the fungal cell wall, have been employed.Combined expression of both chitinase and ß-1,3-glucanase genes in tomato to *Fusarium oxysporum*, carrot to *Alternaria dauci, A. radicina, C. carotae* and *Erysiphe heraclei,Brassica napus* against *Leptosphaeria maculans* have been reported. The successful application of fungal bio-control agents like *Trichoderma* spp. and bacterial antagonists (*Pseudomonas fluorescens* and *Bacillus* sp) for the control of soil-borne diseases in several vegetable crops have been reported. However, biological control in the phyllosphere is not so successful due to restriction of microbial growth on leaves by harsh environmental conditions and low levels of nutrients on leaf surfaces and unfavourable microclimatic conditions.

Seed pro, an immobilized product of *Trichoderma harzianum* OTPB3 has been developed at Indian institute of Horticultural Research, Bangalore for production of quality and disease free vegetable seedlings and this technology has been transferred to M/s Multiplex Biotech Pvt Ltd, Bangalore, M/s Poabs Biotech Limited, Trivandrum and M/s Agrilife, Hyderabad for commercial production. The Seedpro is highly effective in promoting seedling growth, vigour and yield in cereal crops like rice and wheat, vegetable crops such as brinjal, beans, bitter gourd, bottle gourd, cabbage, chilli, carrot, cauliflower, pumpkin, ridge gourd, tomato, oil seed crop such as soya bean, fruit crop such as papaya, tuber crops such as potato and ginger and commercial crops like cotton. The results indicated that the Seedpro has effectively enhanced root length, shoot length, leaf area, seedling vigor and seedling biomass from 28.0 to 78.0 per cent over control depending upon the crop tested and it enhanced yield of 25-30% in potato and ginger treated with Seedpro compared to control. The levels of indole-3-acetic acid and gibberellic acid were increased significantly in roots of seedlings treated by Seedpro. Treatment with Seedpro also enhances the levels of defense–related enzymes including peroxidase, polyphenol oxidase and superoxide dismutase in range of plants in addition to plant growth and antibiosis. Integrated disease management strategies involving techniques such as management of seed borne infections, effective utilization of crop rotation technologies, achievement of clean soil by solarization or fumigation with bio-control agents and protection against air borne infections by changing planting dates, resistant varieties, fungicides and bio-fungicide formulations or combinations are critical inputs in managing the fungal diseases effectively in sustainable manner.

Bacterial Diseases: Pathogenic bacteria cause many serious diseases of vegetables.Among these, wilt (*Ralstonia solanacearum*) on brinjal, capsicum and tomato, black rot (*Xanthomonas campestris pv. campestris*) on broccoli, Brussels sprouts, cabbage, cauliflower, Chinese cabbage, kale, mustard, radish, rutabaga, and turnip, angular leaf spot (*Pseudomonas syringae pv. lachrymans*) on cucurbitaceae, bacterial caker (*Clavibacter michiganensis* subsp. *michiganensis*) on tomato and bacterial spot (*Xanthomonas vesicatoria*) on pepper and tomato are notable ones. Warm, wet weather favours the development of some bacterial diseases, while others are favoured by cool, wet conditions. Bacterial ooze can be used as diagnostic test for distinction from fungal wilts. Management strategies for bacterial diseases include good field sanitation, use of pathogen-free and certified disease-free transplants, crop rotation, avoidance of overhead irrigation,· use of resistant varieties where ever available and spray of copper compounds.

Viral diseases: Whiteflies transmitted Gemini viruses are emerged as a major threat to vegetable crops. The introduction and spread of a new biotype of *Bemisia tabaci* into new areas has been directly correlated with the increase in new and different Gemini virus diseases in tomato, cotton, melons, lettuce, beans, and other crops. Tospoviruses, the thrip-vectored, belong to the only plant infecting members of the Bunyaviridae family are gained importance as destructive diseases of vegetable crops in recent years. Among 20 tospoviruses reported world wide, five viruses such as groundnut bud necrosis virus(groundnut, important crops such as cowpea, mungbean, pea, potato, soybean, and tomato),watermelon bud necrosis virus (watermelon),peanut yellow spot virus (groundnut),capsicum chlorosis virus (tomato and chilli).andIris yellow spot virus (onion and garlic) are significant ones in India. Specialized techniques such as ELISA (enzyme-linked-immunosorbent-assay) and RT-PCR (reverse transcriptase polymerase chain reaction) are required to diagnosis the virus. Virus diseases are very difficult to control once they become established. It is highly recommended to use integrated management approach such as virus-free transplants, a combining of cultural practices, bio-security measures, field sanitation and disinfection practices, resistant cultivars, use of reflective mulches and insect-vector control strategies to reduce the impact of virus diseases on a vegetable crop.

Ornamental Crops

Floriculture is a fast emerging venture throughout the world. In India the area under traditional flowers during 2007 was 73,536 ha under open condition. At present more than 1000 ha is cultivated under protected condition with the production of 3,65,668 MT. The major states carrying out floriculture business in India are Karnataka (20,780 ha), Tamil Nadu (17,750 ha) and West Bengal (13,750 ha). National income generated from this industry is about Rs.500 crores per annum including traditional flowers (jasmine, crossandra, tuberose *etc.,)* and modern cut flowers (rose, chrysanthemum, carnation, gerbera, lillium, anthurium *etc.,*). Global trade in cut flowers is estimated as 40 billion US dollars. Indian floriculture industry is growing at a compounded annual growth rate (CGAR) of 25 per cent over the past decade. Indian flower export markets are estimated at 11 billion US dollars at present and expected to grow upto 20 billion US dollars by 2020. The major impediment in the cultivation of modern cut flowers iare soil borne and foliar pathogens causing substantial yield loss, leading to deterioration in quality and quantity of the marketable blooms.

Carnation: Carnation "Divine Flower" cut flower and native of Mediterranean region, is an introduced cut flower crop in India and adapts well to the regions having mild climatic conditions like Nilgiris, Kodaikanal, Bangalore, Pune and Shimla. Fusarium wilt emerged as a major production constraint in carnation.

Chrysanthemum: Chrysanthemum, the "Queen of East" is a leading commercial flower crop, grown for cut and loose flowers. In India, Chrysanthemum is commercially cultivated in Bangalore (Karnataka), Pune (Maharashtra), Kolkata (West Bengal), Tamil Nadu, Punjab, Rajasthan, Gujarat, Delhi, Shimla and Solan. The seedlings of cut chrysanthemum are imported from other countries and cultivated commercially. It has resulted in the outbreak of white rust (*Puccinia horiana),* wilt (*Fusarium oxysporum* f.sp. *chrysanthemi*) and crown gall (*Agrobacterium tumefaciens*) in India.

Rose: Black spot (*Diplocarpon rosae*), Botrytis blight (*Botrytis cinerea*),crown gall (*Agrobacterium tumefaciens*), downy Mildew (*Peronospora sparsa*) and powdery mildew (*Sphaerotheca pannosa* var. *rosae*) are the important disease that limit the rose production and quality in India.

Plantation Crops

Plantation crops, by nature, blend effectively with environment contributing to sustainability, conservation of bio-diversity and stable ecosystem. This sector constitute a wide range of crops include coconut, arecanut, oil palm, cashew, tea, coffee, rubber and cocoa. Although plantation crops occupy less than 2% of the total cultivated area, they are earning over Rs 3700 million annually through exports. They also play an important role in employment generation as well as poverty alleviation in rural India despite they confined to small and marginal holdings. India is the largest producer and consumer of arecanut, cashew nut, tea and spices, third largest producer of coconut, fourth largest producer and consumer of rubber and sixth largest producer of coffee in the world.

Coffee: Although coffee is susceptible to several fungal diseases, viral and bacterial diseases have not been reported. Among the two cultivated species, arabica coffee is more susceptible than robusta. Leaf rust, black rot, anthracnose, root diseases, coffee trunk canker, berry blotch, collar rot, brown-eye-spot and stem necrosis are the important diseases.Coffee berry disease, caused by *Colletotrichum kahawe*, is confined only to coffee growing countries of African continent and no reports of its occurrence in India. Among the disease reported in India, Coffee leaf rust, also known as orange rust, caused by *Hemileia vastatrix* is one of the seven most important diseases and pests of tropical plants. Coffee rust attacks mostly leaves and very rarely the young branches. Pale yellow circular spots initially appear on the lower surface of the leaves which later form orange yellow powdery mass. In advanced stages, defoliation and die-back of branches occur and berries on such branches fail to develop further. In nature, *H. vastatrix* produces uredinial, telial and basidial stages on coffee. Wet weather during May toNovember, intermittent rain and sun shine, mist or rain during dry weather from November to March, thin or no over head shade are the favourable factors for the disease development. Maintaining optimum shade, pruning coffee bushes after the harvest and before the blossom shower (January-February) and spraying of freshly prepared Bordeaux mixture (0.5%) with proper coverage on the under surface of foliage before the onset of southwest monsoon (May-June) are the recommended practices for disease management. Rust tolerant coffee cultivars such as Chandragiri, Sln. 5B, Sln.6 and Sln.9 can be grown. In case of severe disease epidemics, spot application of triademefon (0.8g/litre) can be recommended for highly susceptible arabica cultivars during August to avoid defoliation and die back. Second round prophylactic Bordeaux mixture (0.5%) during post monsoon period (September-October) is also required. Susceptible cultivars such as S.795 and Cauvery which showed higher incidence during September are to be sprayed with hexaconazole (2ml/liter) or triademefon (0.8g/litres) as Bordeaux mixture spray could not contain disease and defoliation at that stage.

Tea: Tea plants prefer warm humid climatic conditions, well – distributed rainfall, and long sunshine hours and these conditions are also favourable for diseases and pests and further, the monoculture habitat provides a stable microclimate for their easy transmission and establishment. Among the diseases, blister blight, grey blight, branch canker and red root diseases are the important ones. Of these, blister blight incited by the fungus, *Exobasidiumvexans* is the most important one, causing losses up to 50%. Blister blight attacks only the succulent leaves and stem of the harvestable shoots leading to heavy crop loss. The disease attains epidemic proportion during monsoon months (June-Dec). The disease symptom initially appears as a pale yellow translucent spot on young crop shoots (3 leaves and a bud). The spot gradually enlarges to a lesion with a bulge on the lower surface of the leaf, thus forming the characteristic blister. Blister blight pathogen is an obligate parasite with no known alternate or collateral host. Regulating shade by pollarding shade trees and annual lopping of side branches prior to monsoon reduce the incidence of blister blight. Triazole fungicides like cryproconazole, bitertanol, hexaconazole and propiconazole were found efficient in controlling blister blight. The usefulness of biocontrol agents like *Trichoderma harzianum*, *Gliocladium virens*, *Serratia marcescens, Pseudomonas fluorescens* and *Bacillus subtilis* have been explored.

Rubber: More than 90% of the rubber growing area in India is in the south western region of the peninsula comprising of areas in southern Tamil Nadu, Kerala and South Karnataka where heavy rainfall ranging from 2000 to 4000 mm is experienced annually. Though high rainfall pattern in this region favours good growth of rubber trees, it also leads to high humidity which favour growth of fungal pathogens in rubber plantations. In India, numerous diseases affect different parts of the rubber tree namely leaves, stem and root. Abnormal leaf fall, Powdery mildew, Corynespora leaf fall and Colletotrichum leaf disease are the most economically significant leaf diseases noticed in India. Abnormal leaf fall (ALF) disease caused by *Phytophthora* spp. is one of the most destructive diseases of rubber. In India, the disease occurs annually during southwest monsoon (June-September). Infection appear on pods, petiole, leaves and tender shoots, causing heavy defoliation. Six species of *Phytophthora*: *P. meadii*, *P. palmivora*, *P. botryosa*, *P. colocassiae*, *P. citrophthora* and *P. nicotianae* have been reported to cause abnormal leaf fall disease, however, the most common species encountered in the traditional rubber growing areas is *P. meadii.* Field sanitation and removal of all infected and dried up twigs, fruits and fruit stalks of the previous season from trees, to destroy the potential source of primary inoculum was reported to be essential for controlling the disease. All high yielding clones were found to be susceptible to ALF disease. However, clones RRII 105, PB 217 and GT 1 were observed to retain more leaves than the susceptible clones under similar prophylactic spraying. High volume spraying of Bordeaux mixture (1%) was more effective for control of the disease. For mature rubber trees the spray volume required is up to 3000 litres per hectare for effective control. Alternative to Bordeaux mixture, copper oxychloride (COC) dispersed in agricultural spray oil sprayed through low volume applicators proved effective for the control of this disease.

Powdery mildew disease caused by *Oidium heveae* primarily affects the immature leaflets of rubber trees during refoliation after the annual wintering causing secondary leaf fall. Infected leaves lose their shiny appearance and become dull with white powdery masses covering their entire surface or in patches. Prevalence of mist, dew and cloudy days with 75 to 80 per cent relative humidity are favourable for disease development. Manipulation of the time of refoliation to coincide with a period less favourable for disease development has been proposed to be an efficient means of indirect control of *Oidium*. Protective application with sulphur either as dust or wettable powder with portable or tractor-mounted machinery has been the standard method of control. The mixed use of systemic and non-systemic fungicides (tridemorph + sulphur), mixed use of a set of systemic (carbendazim + wettable sulphur) and a non-systemic fungicide (microsul); mixed application of tridemorph and sulphur in dust form or application of carbendazim at 0.2% a.i.) followed by thiophanatewere effective and economic.

Corynespora leaf fall disease caused by *Corynespora cassiicola* has currently been identified as an important constraint limitation to the production of natural rubber in South and South East Asian countries. The pathogen affects both young and mature leaves causing leaf blight and defoliation though immature leaves are more prone to infection than the mature leaves. Disease development is favoured by high humidity in the morning with moderately high (32-36°C) day temperature. **:** In nurseries, the disease intensity is reduced by providing light overhead shading. Vigorously growing seedlings are found less affected and hence balanced nutrition is recommended. Spraying of benomyl, mancozeb, captan or propineb, Bordeaux mixture or zineb and carbendazim have also been recommended. Colletotrichum leaf disease caused by *Colletotrichum acutatum* and *C. gloeosporioides* has become an increasingly important disease worldwide. Three different disease symptoms *viz*. raised spots, anthracnose and papery lesions are reported. An effective and economic method practiced in different countries is the avoidance of the disease by defoliating the trees during the dry periods which are non-conducive to disease development. Clones PB 217, PB 260 and RRRIM 600 are possessing better tolerance. The disease is controlled by fortnightly application of mancozeb (0.2%) , carbendazim (0.05 %) or Bordeaux mixture 1%.

Coconut: The coconut is mostly cultivated by small and marginal farmers for oil purpose even though every part of coconut is useful for mankind. Coconut is counteracted by many diseases, some of which are lethal and others are debilitating in nature. Bud rot, root (wilt) and basal stem rot are the important diseases that affect the coconut palm. The bud rot, caused by *Phytophthora palmivora,* has emerged as serious threat to coconut cultivation in Kerala, killing 2 lakh palms during 2010. The first visible symptom of bud rot is withering of the spindle marked by pale colour. The spear leaf or spindle turns brown and bends down. The affected spindle can easily be pulled out as the basal portion of the spindle is completely rotten emitting a foul smell. The disease is generally noticed during both southwest and northeast monsoon periods when wet weather conditions prevail. The temperature range of 20 - 24ºC and relative humidity of 98 - 100% were optimum for the development of the bud rot disease. Effective management of bud rot can be achieved only if the integrated plant protection measures are adopted at the right time. Removal of dead palms coupled with spray of Bordeaux mixture (1%) or pouring mancozeb (5g) dissolved in 300 ml of water or keeping 2 perforated mancozeb sachets as a prophylactic measure to prevent the disease. Root (wilt) disease is prevalent in a contiguous manner in all the 8 southern districts of Kerala starting from Trivandrum to Trichur and also prevalent in in the districts of Tamil Nadu and Karnataka adjoining to Kerala State. The most diagnostic symptom of the disease is abnormal inward bending or ribbing of the leaf lets in mid whorl termed as flaccidity. Concentrated and intensive research carried out at CPCRI has resulted in the identification of a phloem bound mollicute, *Phytoplasma* as the cause of the disease. Root wilt is not a lethal disease but a debilitating malady and responds to good management. Yield of the palms can be sustained or even improved through the adoption of integrated management practices consisting of balanced fertilizer application, addition of organic matter, raising and incorporation of green manure crops in basin, irrigation during summer months, leaf rot control and adopting inter and mixed cropping. The characteristic symptoms of the basal stem rot, caused by *Ganoderma applanatum* and *G. lucidum,* are outer whorl of the leaves turn yellow initially. Later, they exhibit light to moderate browning followed by drooping. In the crown, the leaflets wilt. Generally the disease is prevalent in sandy or sandy loam soils in coastal areas where coconut is grown under rainfed conditions and also in neglected plantations. Lack of soil moisture during summer months, water logging in rainy seasons.Irrigation along with FYM application and burying coconut husks in circular trench around the palm and Bordeaux mixture drenching was most effective in reducing the intensity.

Arecanut: Areca, commonly known as betel nut, is mainly grown as an important cash crop in Karnataka, Kerala, Assam, Meghalaya, Tamil Nadu and West Bengal. Fruit rot, yellow leaf disease and basal stem rot are major production constraints in arecanut production and productivity in India. Fruit rot has emerged as a major production constraint in 2013 and caused crop loss to the tune of Rs 790 crores. Fruit rot is characterized by rotting and heavy shedding of immature nuts. *Phytophthora meadii* is the cause of fruit rot. Southwest monsoon (June-September) plays a key role in the occurrence, persistence and spread of fruit rot. Continuous heavy rainfall with intermittent bright sunshine hours, optimum temperature (20-23°C) and high relative humidity (>90 %) are factors congenial for disease development. Covering of areca bunches with 'Kotta' or 'Karada' was in practice to control the fruit rot disease in Uttara Kannada areas of Karnataka in the early years of this century. In a mutlilocational trial on management of fruit rot using different fungicides revealed that Bordeaux mixture (1%) spray still holds good in controlling fruit rot compared to other systemic fungicides compared to systemic fungicides foestyl-Al (0.15%) and metalaxyl (0.5%). Covering the bunches with polythene covers before initiation of southwest monsoon are equally effective in managing fruit rot. Yellow leaf disease (YLD) is a slow decline disease affecting the productivity of the palm. The disease is known as 'kattuveecha in Malayalam and 'chandiroga or arasina roga' in Kannada. Symptoms of YLD are well pronounced immediately after the cessation of South West monsoon rains. Characteristic yellowing starts at the tip of the leaflets of two or three fronds of the outer most whorls. This yellowing gradually extends to the middle of the lamina showing a clear-cut demarcation of yellow and green parallel bands on both sides of the midrib of leaflets and this is the first visible symptom.*Phytoplasma* is a causal agent of YLD and it is transmitted by*Protista moesta.*The diseases caused by *Phytoplasma* are not curable by the application of conventional plant protection chemicals. It is recommend to adopt proper management practices to get additional income from affected gardens. The visual symptoms of the basal rot are yellowing of the outer whorl of the leaves, which gradually spreads to the inner whorl of leaves. Simultaneously, symptoms are also seen on the basal portion of the stem as small dull brown spots. These spots later coalesce to form bigger discolored patches. In the acute stage of the disease a brown gummy liquid oozes out through these patches. The bracket shaped fruiting bodies (basidiocarp) of the fungus are formed at the base of the trunk usually after the death of the palm or on the stump or rarely on the live palm.*Ganoderma lucidum*and *G. applanatum*were reported as causal agents of the disease. The root feeding of palms with 125 ml of tridemorph (1.5%) in the early stage of infection and soil drenching at quarterly intervalsis very effective in checking the disease. Besides chemical control, the diseased palms are to be isolated by taking trenches of 30 cm wide and 60 cm deep around the affected the palm to avoid root contact of healthy and diseased palms.

Cocoa: Cocoa is mainly cultivated as an intercrop in existing coconut, areca nut and oil palm plantations. Cocoa is grown in an area of 34,000 hectares (2008-09) mainly in Kerala, Karnataka, Tamil Nadu and Andhra Pradesh. Kerala is the leading cocoa producing State contributing to 78 per cent production in India. At present, India is producing only 15,600 tonnes against the demand of 45,000 tonnes, requiring large-scale imports. India imported cocoa worth Rs 804 crore during 2012-13. Black pod, stem canker and vascular streak dieback diseases are major production constraints in cocoa production in India. Since 1998, cocoa wilt has emerged as a major bottle neck in cocoa expansion in maidan parts of Karnataka. Black pod appears as one or more small, chocolate brown circular lesion(s) anywhere on the pod surface. The lesion increases rapidly and covers the whole pod surface. Then, the whole pod and beans are invaded by the fungus and the pod turns black in colour within 15 days of infection. *P.palmivora*, *P.capsici* and *P.citrophhtora* were reported as causal agents of the black pod. Black pod disease occurs during rainy season when humidity is high and the temperature is constantly optimum. In India, this disease is a serious problem during southwest monsoon period (June-September). . Periodic removal and destruction of infected pods alone will help to reduce the disease incidence to the extent of 50% and spraying of Bordeaux mixture (1%) at 15 days interval starting from the onset of southwest monsoon is effective in controlling the disease in severely affected gardens. Stem canker appears as greyish brown water soaked lesion with a broad dark brown to black margin. A reddish brown liquid oozing out from such lesions dries up and forms a rusty deposit. When the surface of the bark is scraped off, the affected tissues exhibit dull brownish grey or reddish brown colour. When the canker enlarges, it may encircle the trunk, causing 'sudden death' of the tree. *P. palmivora* has been reported as the only species causing stem canker of cocoa in India. Stem canker can be controlled in the initial stages by the excision of diseased bark followed by wound dressing with Bordeaux paste (10%).

Vascular-streak dieback (VSD) is a devastating disease confined to only Kerala state. The most diagnostic initial symptom of VSD is the yellowing of a single leaf, usually on the second or third flush behind the shoot apex, with typical scattered green islets. When stems are split, infected xylem is visible as dark streaks within the vascular tissue. The disease is caused by basidiomycete fungus Oncobasidium *theobromae.* Management strategies should include quarantine measures, the production of disease free seedlings/grafts, regular pruning of infected branches, and use of moderately resistant genotypes such as GVI 54, GVI 55, GIV 18.5 and M13-12. Systemic ergosterol biosynthesis inhibiting fungicides, including flutriafol, hexaconazole, propiconazole, tebuconazole,and triadimenol, have been successfully used to control VSD.Wilt is first reported from Hunsur in 1996 Mysore district of Karnataka. Then, disease caused severe epidemics in all the cocoa growing regions of Mysore, Mandya, Chamarajanagar and Bangalore rural districts of Karnataka, limiting cocoa expansion program. The disease appears in September, after southwest monsson ceases, reaches the peak during October-March and declines thereafter. Cocoa plants of 2-5 years-old are more susceptible to infection under field conditions. The first visible symptom of the diseased plant is yellowing or browning of the leaves on any branch of the plant.Then, branch wilts and finally death of the whole plantoccurs. The symptoms are associated with shot hole in the branches that are inhibited by *Xyleborus* beetles. When branch is split longitudinally, brown streaks are visible. Integrated practices for containing looses include removal and burning infected branches, disinfection of pruning tools and spray of propiconazole.

Spice Crops

India is considered as the home of spices. Spices are cultivated in an area of 5.98 million ha globally with a total production of 7.31 million tons. The major export oriented spice crops that are cultivated in our country are black pepper, cardamom, ginger, turmeric (*Curcuma longa* L.) and vanilla.

Black pepper: Black pepper is susceptible to a number of diseases of which foot rot or quick wilt, slow decline disease, anthracnose, phyllody and spike shedding are the major ones. Foot rot is the most dreaded disease of black pepper. The symptom appears on the leaves as black spots with fimbriate margins which enlarge and the leaves fall off. Infection from contaminated soil leads to collar infection as blackening which extend both upwards and downwards. The root infection also culminates in collar infection leading to death of the plants. Removal and destruction of partially or fully dead vines along with root system from the garden is necessary to reduce the buildup of pathogen inoculum. Use of pathogen free material is the foremost requirement for the production of disease free planting material. Being a wet weather pathogen, a compact fungicide schedule was recommended against both aerial and collar infections. This includes spraying of 1%Bordeaux mixture(BM), pasting collar with 10% BM (10%) and drenching the basin with either BM or copperoxychloride. In place of copper fungicides, the use of systemic fungicide metalaxyl-mancozeb (0.125% @ 5-10 l/vine) both as spray and drench after the receipt of a few monsoon showers are recommended. Application of the metalaxyl six months prior to harvest should be avoided to prevent traces of metalaxyl residues in the final produce. The antagonistic fungus *Trichoderma harzianum* is recommended to applyaround the base of the vine @ 50g/vine along with organic manure such as neem cake, farmyard manure, decomposed coffee pulp or coir pith before the onset of monsoon (May-June).

Mild to moderate foliar yellowing at different regions of the affected vine is the initial aerial symptom of slow decline disease caused by *Radopholus similis.* Uprooting and destruction of diseased vines along with root mass and replanting after a period of 9-12 months have to be undertaken in all nematode damaged plantations. Application of neem cake @ 2 kg/vine was highly effective against *M. incognita* than *R. similis.* Antagonistic fungi like *Paecilomyces lilacinus* and *Pasteuria penetrans* suppressed nematode infestation in black pepper and increased the production of root mass. Various nematicides like phenamiphos, aldicarb sulphone, phorate, carbofuran and aldicarb are also effective in controlling nematodes infecting black pepper. Anthracnose caused by *Colletotrichum gloeosporioides* is more prevalent under higher elevations and appears at the end of south west Monsoon. Brown sunken patches followed by characteristic cross splitting on the berries and angular to irregular brown lesions with a chlorotic halo on the leaves are characteristic symptoms of anthracnose. Spraying 1% Bordeaux mixture or a combination of fungicide containing carbendazim and mancozeb (0.2%) or mancozeb (0.1%) are recommended in addition to cultural practices.

Stunted disease is one of the most important viral diseases affecting black pepper in the country and the severity of the disease is high at higher altitudes. The disease is manifested as distortion, reduction in size and mottling and mosaic on the leaves along with stunting of the whole plant, reduction in spike length and poor filling of spikes. In severe cases leaves become abnormally narrow and give a sickle shaped appearance. The internodes of the vine become short leading to stunting of plants. Association of two viruses namely cucumber mosaic virus (CMV). The phyllody disease is characterized by deformed structure look like a tuft of leaves giving a witches broom appearance. The disease is caused by Phytoplasma belonging to aster yellow group. Aphids are known to transmit CMV whereas mealy bugs like citrus mealy bug, *Planococcus citri* (Risso) and striped mealy bug (*Ferrisia virgata*) are known to transmit the Badna virus associated with stunted disease. The major means of spread is through infected vines. Roguing the infected plants as and when noticed and destroying them by burning is a prerequisite in the management of these diseases. The planting material should not be collected from diseased gardens.

Cardamom: Mosaic or 'katte' disease, anthracnose and *Phytophthora* rot are serious problems and are major constraints in the successful cultivation and production of crop in India. Visible symptoms of capsule rot or azhukal disease appear simultaneously on capsules and leaves or first on capsules followed by lesions on leaves. The disease is caused by *Phytophthora meadii*. Presence of soil inoculum, thick shade in plantation, close spacing, high soil moisture and water logging together with favorable climatic conditions such as low temperature, high relative humidity and continuing rainfall predisposes the plant to infection. Removal of infected plant parts, shade regulation and proper drainage channels can reduce the intensity of disease incidence. Two to three rounds of sprays including one round of prophylactic spray with Bordeaux mixture (1%) or fosetyl –Al (0.3%) or spraying alternate rounds of Bordeaux mixture and metalaxyl- mancozeb (0.2%) after proper phytosanitation are effective in disease control.. Soil application of *T. viride*, *T.harzianum* and *Bacillus subtilis* are promising in the biological control of the disease. Integrated disease management is possible by one initial round foliar application of potassium phosphonate (0.3%) with two subsequent rounds soil application of

Trichoderma ($2x10^9$). Two cultivars each of Mysore and Malabar types' viz. MCC 60, 61, 12 and 40 (ICRI selections) were found moderately tolerant to azhukal disease. Leaf blight ('Chenthal' Disease) is characterized by the appearance of elongated water soaked lesions of varying sizes on the abaxial surface of young leaves which later turn to dark colour with a yellowish halo around. The disease is caused by *Colletotrichum gloeosporioides*. Providing adequate shades in the plantation and mulching the plants to conserve soil moisture ensure disease control to a greater extent. Three sprays at monthly intervals with carbendazim (0.1%) or mancozeb (0.3%) or copper oxychloride (0.25%) or Bordeaux mixture (1%) help to limit the spread of the disease.

Cardamom is found susceptible to three important viral diseases viz. mosaic (Katte), 'Kokke kandu' (cardamom vein clearing virus) and Nilgiri necrosis (cardamom necrosis virus disease). The symptoms of katte appears on the youngest leaf as slender chlorotic fleks measuring 2-3 mm in length which later develop into pale green discontinuous stripes running parallel are clearer on the emerging leaves. The disease is caused by the Maclura virus belonging to the Poty viride. The disease is transmitted through banana aphid *Pentalonia nigronervosa* (Coq.) and also through the infected rhizomes. Cardamom vein clearing or 'Kokke kandu' disease was reported in cardamom during 1993 and disease incidence of 0.1 -80% was observed in plantations and nurseries in Karnataka. The leaves show characteristic continuous or discontinuous intraveinal clearing, stunting, resetting, loosening of leaf sheath and shredding of leaves. The virus is not sap transmissible. The disease is transmitted through banana aphid *Pentalonia nigronervosa* f. *caladii.* Cardamom necrosis or Nilgiri necrosis disease was first observed in severe form in Nilgiris in Tamil Nadu and hence the name. Further the disease was observed in certain pockets in Kerala, Tamil Nadu and Karnataka. Young leaves show white, yellowish, continuous or broken streaks, proceeding from mid rib to leaf margin. Flexuous particles of 570-700nm long and 10-12nm broad belonging Carla to virus group was found associated with the disease. No insect transmission of the disease was recorded so far. Use of virus-free planting material is the primary requirement to check the spread of the virus. Removal of infected volunteers in replanted area and total avoidance of volunteers for nursery activity in hotspots are most important for producing virus free planting material.

Ginger: Ginger is an economically important rhizomatous spice crop susceptible to a number of diseases caused by fungi, bacteria and virus. Soft rot/rhizome rotreduces the potential yield to a greater extent in the field and storage and market and may cause losses up to 50%. The disease is predisposed by heavy and continuous rain followed by water logging conditions existing in the ginger fields during the monsoon or post- monsoon season. The disease is characterized by the appearance of water-soaked patches at the collar region of the pseudostem which extends to both sides and the collar becomes soft and watery leading to rotting of the pseudostem which fall off with a slight disturbance. The disease is mainly caused by *Pythium* species of which *P. myriotylum* Drechsler is the predominant species. High soil water, high relative humidity and relatively low temperature favor the disease development and spread. Since infected rhizomes serve as the primary source of inoculum, selection of disease free healthy seed rhizomes collected from disease free ginger tracts is a prerequisite in the management of the disease. Soil amendments using seed oil cakes of *Azadirachta indica*, *Calophyllum inophyllum* or *Pongamia glabra* are reported effective in reducing the rot incidence. As the disease is both seed-borne and soilborne in nature, the use of disinfested rhizomes followed by drenching the soil with a chemical is effective. Soil drenching with metalaxyl+ captafol three month after planting and seed treatment and soil drenching with metalaxyl formulations are effective for the control of the disease. Bio-agents viz. *T. harzianum*, *T. hamatum*, *T. virens* and bacterial isolates such as *Bacillus lentus*and *P.fluorescens* along with VAM fungi *Glomus* species have been found effective against the soft rot of ginger caused by *P.myriotylum.*

Bacterial wiltis one of the most destructive diseases of ginger leading to heavy crop loss in all the ginger growing countries. Under conducive conditions a crop loss up to 100 per cent was reported in many ginger growing states in India. Wilting and yellowing of the lower leaves which extends upward until all the leaves appear golden yellow is the first visible symptom of bacterial wilt. When diseased rhizomes are cut, white milky exudates flows freely from the cut end indicating the presence of bacteria inside the vascular tissues. Bacterial wilt of ginger is caused by the bacteria *Ralstonia solanacearum* biovar III. Selection of healthy rhizomes material from disease free areas, selection of field with no previous history of bacterial wilt, soil solarization, soil amendments with *Trichoderma harzianum*, treatment of rhizomes with streptomycin or oxytetracycline, crop rotation with non-host plants like cereals, paddy, maize are the recommended practices.

Turmeric: Turmeric , a zingiberacious member, is one of the most important commercial crop known for its aromatic and medicinal properties. The crop is susceptible to a number of fungal diseases. Bacterial and viral diseases are not so common and are of minor importance. The important fungal diseases affecting the crop are Rhizome rot, leaf blotch and leaf spots. Rhizome rot is most destructive disease. The leaf blotch disease is characterized by the appearance of water soaked lesions at the base of the pseudo stem and yellowing of the lower leaves.Different species of *Pythium* viz.,*P. myriotylum, P. graminicolum, P. aphanidermatum* etc. of which *P. aphanidermatum* are found as the predominant pathogen. Rhizome treatment with a combination of macozeb (0.25%) and quinalphos 0.075% for 15 minutes is the recommended practice. Soil drenching with metalaxyl-mancozeb (0.2%) or macozeb (0.25%) at 15-20 day interval twice with the first appearance of the symptom is effective in managing the disease. Crop rotation is also recommended to reduce the incidence of rhizome rot. PCT-13 and PCT-14 from Andhra Pradesh and Ca 69 and Shillong from Assam were found to be tolerant to rhizome rot.The disease is characterized by the appearance of small scattered oily looking translucent spots on the lower leaves when the plants are in 3-4 leaf stage. The disease is caused by *Taphrina maculans*. Moist cloudy weather with temperature of 25-30°C during August-September months predisposes the plant to infection.Cutting and burning of diseased leaves would greatly help in preventing the spread of the disease. Foliar spray using fungicides such as zineb (0. 2%), mancozeb (0.3), copper oxychloride (0.2%), carbendazim (0.1%) and cuman L (3%) etc. are effective in controlling the disease. The varieties such as CLL 324, Amalapuram, Mydukur, Karhadi local, CLL 326, Ochira 24 and Alleppey among *C. longa* group and ca 68, ca 67, Dahgi and Kasthuri among *C. aromatica* types were resistant to infection.

Vanilla: It is a native to the humid tropical rain forests, is now widely cultivated in India for its aromatic vanillin. It is grown as an intercrop along with arecanut, coconut, coffee and black pepper, in homestead gardens and as a pure crop in standards such as *Glyricidia*, *Plumeria*, *Dadaps* and concrete or stone poles. The diseases affect almost all the plant parts like roots, stem, leaves and beans and inflorescence. Species of *Phytophthora, Fusarium, Sclerotium, Calospora* and *Colletotrichum* are the wide spread pathogens. No bacterial disease has so far been reported. Viral diseases are also common. Stem rot caused by *F. oxysporum* f.sp. *vanilla* is destructive disease and the disease appears in the form of water soaked lesions extending to both sides of the stem giving a brown coloured appearance. The disease can be controlled by spraying

0.2%mancozeb together with carbendazim.A combination of *T.harzianum* (2 g/pl) + carbendazim (0.1%), *T.harzianum* + cymoxanil and mancozeb (0.2%) and *T. harzianum* + hexaconazole (0.2%) showed 100 per cent survival of plants up to 120 days after treatment imposition. The stem blight appears as brown coloured blighted portions. The affected portion gradually shrinks, the leaves become yellowish and the vines dry off. The disease is caused by P. *meadii*. The spread of the disease can be controlled by spraying with Bordeaux mixture (1%) or potassium phosphonate (0.4%). Combined application of potassium phosphonate with biocontrol agents such as *Trichoderma* spp. and *Pseudomonas* spp.was found effectivefor the management of *Phytophthora* rot of vanilla.

Bio-security Preparedness

Invasive species are one of the most serious environmental threats of the 21st century. Once an invasive species becomes established at a new location, it may spread. The pace of establishment and spread depends on numerous factors, including the invasive species' reproduction mechanisms, ability to acclimatize or adapt, whether it has competitors, and what pathways are available for further movement. Prior to 2008, late blight was not considered a major problem on potato or tomato production in South India. Since the 2008 growing season, severe late blight epidemics have occurred on both tomato and potato crops in Karnataka, Tamil Nadu and Andhra Pradesh and have often caused 100% crop loss. The disease incidence was very severe even on Kufri Jyoti, a highly popular cultivar known to be partially resistant to late blight. Evidence has been provided to show that 13_A2, migrated from Europe, was responsible for such severe epidemics both on potato and tomato in South India and breakdown of resistance in Kufri Jyothi, a popular tolerant potato variety grown in these areas. As a result of severe outbreaks of late blight, the area under potato cultivation has drastically reduced from 51,475 to 17,000 ha during 2007 and 2008 in Hassan district, a major potato producing area of Karnataka state , affecting the livelihood of farmers in this region. Taking clue from the experiences of late blight, there is need to strengthen the bio-security measures in India.

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Soil-Borne Diseases: A Challenge for Climate Smart Horticulture

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Introduction

Climate change has become a major concern in agriculture world over, posing a serious threat to food security. Farmers have to struggle to cope with changing temperatures and rainfall patterns and increased flood and drought risks. The concept of climate-smart agriculture emerged in this context to sustainably increase agricultural productivity and incomes, adapting and building resilience to climate change and to reduce or remove greenhouse gas emissions (http://www.fao.org/climatechange/climatesmart). The temperature has increased globally by 0.74ºCin hundred years and CO_2 level in the atmosphere has increased from 280ppm in 1750 to 400ppm in 2013. The change in climate is manifested in the form of increased frequency of drought, higher temperature, erratic wet and dry cycle, salinity and inundation. Climate change has its effect on plant diseases.Soil health is the pre-determining factor in sustainable agricultural production. It can defined as ''the continued capacity of soil to function as a vital living system, within ecosystem and land-use boundaries, to sustain biological productivity, maintain the quality of air and water environments, and promote plant, animal, and human health'' (Doran *et al.,* 1996). Soil represents the greatest reservoir of biological diversity (Gams, 2007). Several of the soil processes such as decomposition of organic matter, nitrogen mineralisation, etc. that operates to benefit crop production are carried out by these organisms and thereby plays an important role in stabilisation of soil structure (Ritz and Young, 2004). Soil is also inhabited by a large class of soil-borne pathogens which are important determinants in the dynamics of plant populations in natural environments and in epidemics in agricultural environments.

Soil-borne Pathogens

Soil borne pathogens cause seed rot, pre and post emergence damping off, crown rot, blight and wilts in field and horticultural crops. The symptoms due to damage on below ground plant parts are similar to the ones caused by abiotic factors such as drought, stress and nutrient deficiencies. Hence, proper diagnosis is essential to manage the diseases. Soil borne plant pathogens are difficult to control compared to aerial pathogens (Bruehl, 1987).These pathogens can cause complete destruction of plants and occasionally, total loss of yield. Fungi and oomyetes are the major groups of soil-borne pathogens. For instance, *Phytophthora,* a major oomycete pathogen attack various plant parts and are responsible for the severe economic losses of various agricultural and horticultural crops. The genus comprises over one hundred species and is evolving day-by-day by breaching all barricades put up as host resistance and other management strategies (Kamoun, 2001). Among the soil borne pathogens plant parasitic nematodes constitute major group. They cause damage themselves and also favour entry of other pathogens like *Fusarium* and soil borne bacteria *Ralstonia solanacearum*.*Fusarium,* an important soil-borne pathogen causes the greatest number of fungal wilt diseases in higher plants (Naik *et al.,* 2008). Most of the species of this genus are non host-specific and are widely responsible for root rotting, decline in vigour, wilt and mortality in taxonomically diverse groups of plants. The highly resistant chlamydospores produced by *Fusarium* makes it very difficult to control. A few groups of non-spore forming bacteria cannot survive well in soil for long periods (Raaijmakers *et al.*, 2009). *Ralstonia solanacearum* is a major member of this group which causes bacterial wilt of over 450 species belonging to 54 families. An estimate from US showed that soil borne pathogens cause 50% of the crop loss (Lewis and Papavizas, 1991).*R. Solanacearum* causes bacterial wilt in ginger is both seed and soil borne.

Despite low initial densities of inoculum in soil, these pathogens can cause complete destruction of plants and occasionally, total loss of yield (Otten and Gilligan, 2006). The survival and spread of the pathogen is determined by the interaction taking place in the pathozone, the region surrounding susceptible hosts from which a pathogen can infect (Gilligan, 1990). A lot of biological, physical and chemical interactions take place in this region. A change in the soil physical condition affects the spatial (spread of fungal colonies leading to infection of a single host) and invasive (spread through a population of hosts) of the pathogen (Otten and Gilligan, 2006). Unlike air borne pathogen soil borne pathogens spread slowly is in space and time limited by several abiotic factors.

Influence of Climate on Soil Borne Diseases

Climatic change causes changes in soil-pathogen-plant interaction, thereby altering disease susceptibility of the plant. An increase in the concentration of CO_2 can increase the biomass production which promotes the development of biotrophic fungi (Chakraborty *et al.,* 2002). This can also accelerate pathogen evolution leading to emergence of more virulent ones (Gautam *et al.,* 2013). Changes in temperature and rainfall may alter the growth stage, development rate in the life cycle and pathogenicity of pathogens, and the physiology and resistance of the host plant (Chakraborty *et al.,* 1998). Climate change is also reported to cause a shift in the geographical distribution of host pathogens (Mina *et al.,* 2008). The pace of this migration may depend on the ability of the pathogen to survive between seasons and with changes in physiology and ecology in the new environment. Brasier and Scott (1994) predicted that global warming will make the oak decline pathogen, *Phytophthora cinnamomi,* more severe in regions of Europe where it is currently present and spread it northward and eastward. A change in temperature could induce an epidemic (Gautam *et al.,* 2013). In India, the last decade victimised the emergence of dry root rot (*Rhizoctonia bataticola*) of chickpea and *Phytophthora* blight (*Phytophthora drechsleri* f. sp. *cajani*) of pigeon pea as a potential threat to the production of these pulses (Pande and Shanna, 2010).

The severity and spread of soil-borne diseases due to temperature increase is further determined by the quantity of precipitation (Woods *et al.,* 2005). Some pathogens especially, *Phytophthora* are more likely to infect plants with increased moisture content. More frequent and extreme precipitation events result in longer periods with favourable pathogen environments. In perennial crops like black pepper, the growth depends up on weather conditions so also its pathogens (Anandaraj, 2000). It is thus clear that, soil-borne diseases are really a challenge in climate-smart horticulture. To cope up with this problem thorough understanding of the effects of climate change is essential.

Management of Soil-borne Diseases for Climate Smart-Horticulture

A thorough knowledge on the epidemiology and the pathosystem is essential to forewarn and manage soil borne diseases with application of decision support system.

Suppressive soil: Suppressive soils are the ones in which disease severity or incidence remains low, in spite of the presence of a pathogen, a susceptible host plant, and climatic conditions favourable for disease development (Baker and Cook, 1974). Soil-borne diseases are results of reduction of biodiversity of soil organisms. Restoring beneficial microorganism that attack, repel, or antagonise pathogens will render soil disease suppressive. Plants growing in disease suppressive soils resist diseases much better than in soils with low biodiversity. There are two types of disease suppression- specific and general. Specific suppression corresponds to one organism directly suppressing a known pathogen. Addition of biocontrol agents is an example of this. General suppression is the result of a high biodiversity in the soil which makes it an unfavourable condition for disease development. Plants have evolved a mechanism to recruit beneficial microorganisms by modulating the root exudates and rhizodeposition.

Biocontrol Agents for Suppression of Soil Borne Pathogens: Rhizosphere of plants is the region immediate surroundings of plant roots and is the zone where intense microbial activity occurs. Plant roots are the source of food hence the microbial population is denser than the bulk soil. Plant pathogens are also present in the bulk soil and have to encounter several obstacles before reaching the root surface. The microbial flora of the rhizosphere consists of neutral, beneficial and harmful organisms. The beneficial organisms bring about suppression of pathogens both by direct and indirect methods. Direct method is by direct pathogenesis as mycoparasitism of *Trichoderma* species or indirectly by enhancing the heath of the plants and also by triggering induced systemic resistance (ISR) by inducing genes responsible for salicylic acid or jasmonic acid pathway. Most endophytes and rhizobacteria belonging to *Pseudomonas fluorescens* induce ISR by producing lipopolysaccharides. Biocontrol is brought out by production of siderophore pyoverdine that chelates iron and starve the pathogens of iron nutrition. Production of 2, 4-diacetylphloroglucinol (DAPG) or cyclic lipopeptide surfactants are other mechanisms of bacterial biocontrol agents. Rhizobacteria also trigger ISR by volatile metabolites such as 2, 3 butanediol (Ryu *et al*., 2004). Species of *Trichoderma* are unique as they act in various ways; as endophyte, rhizosphere colonizer and free living antagonist.

Rhizosphere colonizing bacteria are known to have several beneficial effects on the host plants like nutrient solubilisation, nitrogen fixing production of antibiotics and enzymes that take part in biological control. Often, a consortia of bacteria are introduced in the rhizosphere to prevent soil borne pathogens (Kamlesh and Dubey, 2012; Raupach and Kloepper, 1998). In one such study, a consortium of bacteria was compared with a single application of *Trichoderma harzianum.* It was found that the beneficial effects such as growth promotion and disease suppression by *T. harzianum* were on par with a consortium of bacteria (Sibi, 2014). This indicates that the roots colonized by *Trichoderma* promotes the native microflora for nutrient mobilization and disease suppression.In several crops *Trichoderma* application enhances growth imparts health to the plant besides pathogen suppression and induction of ISR. It was also found that efficient strain works across several crops and geographical locations. While applying biocontrol agents like *Trichoderma* one has to bear in mind that spore forms are better than mycelial form as there is a spurt of activity mycophagous mites and other microfauna when mycelia are present affecting the population of introduced organism (Sibi *et al*., 2008).

Cultural Practices: Cultural practices are known to have great role in maintaining soil biological attributes, thereby protecting soil health resulting in disease suppressiveness (Janveir *et al.,* 2007). This has been well studied by many workers world over (Abawi and Widmer, 2000; Krupinsky *et al*., 2002; Bailey and Lazarovits, 2003; Peters *et al*., 2003). Water stagnation in perennial crops such as, apples citrus, black pepper predisposes plants to root infection by *Phytophthora.* Regulating the soil moisture by deep drains is a pre-requisite for disease management in orchards. The tuber rot of cassava caused by *Phytophthora* can be managed by breaking the hard pan caused by surface cultivation practices and providing proper drainage.

Crop Rotation: Crop rotation, which has been practiced since long time, helps in maintaining the structure and composition of soil. Continuous cropping with the same susceptible host plant will lead to the accumulation of specific plant pathogenic populations (Janveir *et al.,* 2007). Rotating crops with non-host or less susceptible plants may cause a decline in the specific pathogenic populations due to their natural mortality and the antagonistic activities of other microorganisms (Kurle *et al.,* 2001). This method is most applicable in the case of biotrophic pathogens that can survive only in the presence of their host (Bailey and Duczek, 1996). But in the case of pathogens with a wide/ non-specific host range such as *Rhizoctonia solani, Sclerotinia sclerotinium* etc. crop rotation is not a success (Umaerus *et al.,* 1989) and sometimes it may result in disease aggressiveness (Collange *et al.,* 2014).Soil borne pathogens survive in soil by producing several survival structures of both sexual and asexual origin. The oospores of *Phytophthora* and *Pythium*are typical sexual structures capable of surviving for long years. Asexual structures include chlamydopores of*Fusarium,* sclerotia of *Sclerotium, Rhizoctonia* etc. Crop rotation with non hosts prevents these survival structures to germinate. Continuous cultivation of same crop leads to pathogen build up.

In potato where about 40 soil borne diseases are reported, crop rotation of more than four years is recommended. In case of spices such as ginger and turmeric a three year rotation is the practice. In Himalayan Jhum or shifting cultivation more than ten year rotation is followed and if the period is reduced it leads to increased disease incidence and other ecology related issues. In perennial cropping system all the component crops have to be managed. In areca nut based cropping system with black pepper the cultural practices followed for areca nut are not conducive to black pepper and hence a balance has to be maintained to protect foot rot in black pepper by avoiding damage to the feeder root system.

Organic Compost: Composting is a natural way of dealing with waste, transforming it into soil improvement and plant nutrients. It helps in improving the quality and biodiversity of the soil. They are rich in labile carbon fractions which are a source of energy for microorganisms. Thus they are themselves a suitable medium for the growth of beneficial microbes especially, antagonistic microorganisms. *Phytophthora cinnamomi*, *Pythium irregulare*, *Rhizoctonia solani*, *Botrytis cinerea* and *Erwinia carotovora* var. *chrysantemi* in infested plant tissues have been found to be eradicated when buried and composted in hardwood bark (Hoitink *et al*., 1976). The nature of the organic material, which composting process used, and maturity of the compost affect any compost amendment regarding disease control (Hoitink and Fahy, 1986). Erhart *et al*. (1999) found that a bio-waste compost was suppressive towards *Pythium ultimum* when it was aged 4 months or more, but not when it was less than 4 months old. For most plantation crops in India, the recommendation is to deliver the bioagents along with composts. *In situ* composting of crop residues also add to enhanced microbial activity and organic matter content of soil.

Biofumigation: It is a regular agronomic practice to incorporate crop residues in to the soil to enhance organic matter content of the soil and thereby to activate microbial activity. Crop residues of cruciferous crops like cabbage and mustard contain glucosinolates which are released after cellular degradation and further enzymatic action by myrosinases release isothiocyanates that have fumigant action with is comparable to the chemical fumigants such as methyl bromide.

Crop residues of garlic, onion and leek release sulphurous volatiles like thiosulfinates that convert to disulfides. Biofumigation is a very important non chemical method of diseases management. Biofumigation with cabbage and mustard residues was successfully demonstrated to suppress soft rot in ginger across the country through All India Coordinated Research Project on Spices. This could be easily followed by farmers for managing soft rot in ginger by growing the crop during the monsoon season and cultivating cruciferous vegetables during winter in the same field.

Abiotic Parameters: Climatic changes can immensely alter the physical parameters of soil. A positive relation was found between soil suppressiveness and the most important soil parameters such as pH and nitrogen content. Hoper et al. (1995) found a positive correlation between pH and soil suppressiveness, soils with higher pH being more suppressive towards *Fusarium* wilts. Positive association was found between the N content of soil and the suppressiveness towards ectoparasitic nematodes (Rime *et al*., 2003), *Pseudomonas syringae* on bean and cucumber (Rotenberg *et al*., 2005), *Gaeumanomyces graminis* var *tritici* (Ggt) and *R. solani* on wheat (Pankhurst et al., 2002), and *Fusarium* spp. on asparagus (Hamel et al., 2005).On the contrary, comparing a suppressive and a conducive soil to ectoparasitic nematodes, Rime et al. (2003) found that the most acidic soil was the most suppressive one.The N content of soil was significantly negatively correlated with increased suppressiveness to *Fusarium solani* f.sp. *pisi* on pea (Oyarzun *et al*., 1998). In a recent study of the soils of Kerala where there is setback for re-establishing black pepper, it was seen that the pH has drastically changed to 4.0 to 4.5 and in most soils the phosphorus level has accumulated to toxic levels (Dinesh *et al*., 2014).The symptoms of black pepper such as yellowing and stunted growth is non availability of several nutrients leading to yellowing and growth reduction. In such cases the soil factors need to be addressed first for making it suitable for crop establishment than addressing the disease problem alone.

Summary

Climate change is a reality as we find the increased temperature and carbon dioxide level of the atmosphere and erratic rainfall. Such changes affect the crops and it is reported that increased temperature alters the resistance of plants making them more susceptible. This warrants caution and preparedness to face the challenges in the face of imminent climate change. The quality and nature of the products also depends up on the environmental factors as is reported for turmeric recently after an elaborate experiment across India (Anandaraj et al., 2014). Each plant recruits its own micro biomes which in turn affects the health of the host plant and encounter the pathogens infecting it. It is reported that the soil borne pathogens of potato have the same physical and environmental requirements as that of the host. In the natural habitat of black pepper both pathogen and the host lives in equilibrium and no disease symptoms are seen as the soil microflora keepthe pathogen population under check.Soil-borne diseases result from multiple and complex interactions they have with host plants and both biotic and abiotic soil compartments. It is well understood that these interactions are primarily based on the diverse microorganisms present in the soil. In the actual concern for sustainable agricultural production in this changing world, the possibility of controlling soil-borne diseases by adapting agricultural practices is to be assessed. A positive effect of such practices will enrich the biodiversity of soil which will modify a wide range of soil characteristics, thereby imparting disease suppression. There is a need to understand the interaction of the host with the beneficial microbes in the rhizosphere. The modern tools such as metagenomics and proteomics need to be applied to understand the tripartite interactions among the crop, the micro biome and the pathogen to develop and deploy appropriate management strategies to circumvent the damages caused by soil borne plant pathogens.

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Arbuscular Mycorrhizal Fungi : Significance of the Diversity and its Importance in Plant Growth Promotion

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An ecosystem processes are the combined activities of varieties of organisms and main component of the soil microbiota in most ecosystems are Arbuscular mycorrhizal fungi (AMF), an obligately symbiotic fungi colonizes the roots of the majority of plants including crop plants. It forms an effective link between the plants and ecosystems through symbiotic interaction. All mycorrhiza (ecto, endo and ect-endoycorrhiza) have in common a fungal connection between the soil and roots. Some host species may have more than one kind of mycorrhiza, but most form only one. Amongst all binds, AMF are the most widespread type of mycorrhiza. These fungi form branched hyphal structure, termed arbuscules which are formed inside the cortical cells of plant roots. Arbuscules are the main characteristic feature of all AM fungi, however, vesicles are produced by only *Glomus, Entrophospora, Acaulospora* and *Sclerocystis* which are terminal, globose and lipid rich structure in intracellular areas of root cortex (Strullu *et al.,* 1983). Hence in this article we will be using the term AMF to cover all kinds of fungi having endomycorrhizal association.

The AM symbiosis is typically mutulistic. As obligate symbionts, AMF are believed to be dependent upon the host plant for fixed carbon and in return plant receives a variety of benefits such as nutrient uptake, stress tolerance and resistance from pathogens, etc. The most important of these benefits is increased nutrient uptake notably of immobile nutrients such as P and Zn (Bolan, 1991).

Though there is no as such host specificityx in AMF but still the responses vary from genus, species and strain level. Hence, it is important to know the diversity of this unique fungi under different ecosystems. This article is framed to understand this issue and also to understand the significance of AMF in plant sustenance.

Arbuscular Mycorrhiza in Natural Ecosystem

Natural ecosystems are undisturbed habitats. Mycorrhizal fungi can regulate the communities in which they occur and protect the environment quality by enhancing beneficial biological interactions. The different population of AMF fungi buildup in soil around the root system because of different host plant in the Savannah ecosystem (Dodd *et al*., 1990). Coastal fore-dunes are natural defence structures, against shore erosion, protecting the coast by absorbing energy from the wind, tide and wave action(McHarg, 1972). Sylvia (1986), while studying the spatial and temporal distribution of AMF fungi associated with *Uninola paniculata* and Florida fore dunes, found the spores of AMF fungi are abundant, though not randomly distributed in primary sand dunes. Amongst others *Glomus destricola* was most abundant species, while *Glomus aggregatum* was rarely found in the dunes.

There is a great variability in the incidence of mycorrhization of plants under natural ecosystem. The soil poor in available nutrients such as P, provides conditions conducive for the heavily dependence of plants on mycorrhiza to cator to their nutrients needs through the mycobiont, where mycorrhiza serves an additional absorption organ and make available nutrients from their non-available form (Azcon and Ocampo, 1981). There is involvement of different types of mycorrhizal association with various host i.e., inter or intracellular mycorrhizal fungi or association of more than one mycorrhiza with single tree species.

In the sub - tropical Meghalaya, spore of four dominant AMF genera (*Glomus* sp., *Gigaspora* sp., *Sclerocystis* sp. and *Acaulospora* sp.) isolated from rhizosphere soils, *Glomus* spores were found dominant in all the soils. It indicates its adaptability to varied soil conditions (Sharma *et al.*, 1986).

AMF in Disturbed Ecosystem

The system which is affected by mining activities, forest fires, poor physico-bio-chemical conditions of the soil, low nutrient level of the soil, high level of thecheay, termed as disturbed ecosystem. The severity and duration of the disturbance also affects the potential long term dominance of non-mycorrhizal or facultative mycorrhizal plants. These plants are well known as early colonizers of disturbed facultative ecosystems (Trappe, 1987). In disturbed grassland and

AMF in natural ecosystem (Bhatia *et al.*,1996)

S. No.	Type of ecosystem	Mycorrhizal species
1	Natural forest	*Glomus mosseae, G. caledonium, G. albidum, G. fasciculatum, G. reticulatus, G. macrosporum; Gigaspora nigra, Gi. gigantea, Gi. auriglоba; Sclerocystis coremioides, S. sinuosa; Acaulospora sp.*
2	Deciduous and mixed deciduous forest	*Glomus aggregatum, G. albidum, G. deserticola, G. fasciculatum, Gigaspora margarita, Gi. gigantia, Gi. auriglоba; Sclerocystis coremioides, S. rubiformis; Acaulospora elegans*
3	Tropical forest	*Glomus tenue; Acaulospora murrowae; Scutellospora sp.*
4	Grassland, prairies, savannahs	*Glomus fasciculatum, G. macrocarpum, G. mosseae, G. albidum, G. clarum, G. calospora, G. caledonium; Gigaspora margarita, Gi. heterogama, Gi. calospora ,Gi. gigantea; Sclerocystis coremioides, S. rubiformis, S.sinuosa ; Acaulospora laevis; Entrophospora infrequens*
5	Evergreen forest	*Glomus fasciculatum, G. macrocarpum, G. albidum; Gigaspora sp.; Sclerocystis coremioides, S. rubiformis S. sinuosa; Acaulospora bireticulata*
6	Desert lands, sand dunes scurb jungle, arid semi-arid	*Glomus mosseae, G. fasciculatum, G. feugianum, G. geosporum, G. reticulatum, G. albidum, G.microcarpum; Gigaspora candida, Gi. gigantia; Sclerocystis*

		coremioides S. rubiformis, S. sinuosa ; Acaulospora sp. ; Entrophospora infrequens ; Scutellospora persica, S. calospora, S. Pellucida
7	Coastal mangroove vegetation, salt marshy vegetation, coastal tropical forests	*Glomus fasciculatum, G. albidum, G. macrocarpum, G. clarus, G. fulvus, G. intraradices, G. monosporous, G. occultum G. pubescens G. trimurum, G, aggregatum, G. citricola, G. etunicatum G. caledonium, G. reticulatus ; Gigaspora nigra, Gi. roseae ,Gi. gigantia ; Sclerocystis sinuosa, S. clavispora, S. coremioides ; Acaulospora bireticulata, A. scrobiculata ; Entrophospora schenkii ; Scutellospora persica, S. calospora, S. pellucida, S. fulgida*
8	Low land rainforest	*Glomus mosseae; Gigaspora sp. ; Sclerocystis rubiformis*
9	Alpine	*Glomus microcarpum, G. fasciculatum, G. albidum, G. macrocarpum ; Gigaspora sp.*

forested range lands, facultative mycorrhizal annual grass can replace perennial and obligate AMF shrubs. When soils are disturbed by the mining activity, AMF fungal biomass is mechanically disarticulated into various propagules which may serve as source of inoculum. There is small amount of active inoculum found in the top soil material of Wyoming Uranium mine (Christensen and Allen, 1980) for upto 12 years.

According to Birch(1986) and Read *et al*. (1976) the colonization of new roots by AMF occurs rapidly in undisturbed soil. Jasper (1989) explains the reason for this being due to contact with a preexisting network of infective hyphae. There is a strong correlation between the incidence of active mycorrhizal propagules and the incidence of mycorrhizal plants (Reeves *et al*., 1979). The low population of mycorrhizal fungi found in the disturbed land may not allow the plant hosts to become sufficiently infected to receive the growth stimulation that often accompanies normal infection levels.

Urban and industrial disposal on land has been a major concern among environmentalists because of their potential to harm the ecosystem. The irrigated field soil with waste water, favoured *G. mosseae* over *G. fasciculatum* (Safir *et al*., 1990). There is failure of the native AM fungi to proliferate with expanding root system after severe soil disturbance. Another form of soil disturbance could be erosion due to air and water which is accompanied not only by losses of AM fungal propagules but also by losses of organic matter and soil nutrients which result in degradation of physical and chemical properties of soil (Daniels,1984; El-Swaify *et al.*,1982; Lal, 1984).

Forest fire also affects the bacteria and fungi and results in lower level of AMF colonization. Rhizosphere spore numbers vary seasonally on burned and unburned sites. After the fire, the spore numbers on burned sites are lesser than on unburned sites but soon spore count increases on burned site to even more than the unburned site (Dhillion *etal*., 1988) because of root growth is more rapid on burned sites than on unburned sites and this root growth may provide the surface for fungal colonization on sites subjected to fire than those on sites not subjected to it.

AMF in disturbed site (Bhatia *et al*.,1996)

S.No.	Type of spoil	Mycorrhizal species
1	Coal mine spoil	*Glomus diaphanum*
2	Bauxite mineral sand	*Glomus sp ; Gigaspora sp.; Acaulospora sp.*
3	Granite substratum	*Glomus tenue*
4	Land disturbed from ranching and military activities	*Glomus aggregatum, G. etunicatum, G. intraradices, G. monosporum, ; Scutellospora calospora*
5	Gypsum marl with eroded alluvial soils and limestone	*Glomus mosseae, G. constrictum, G. fasciculatum; Acaulospora sp. ; Sclerocystis rubiformis ; Scutellospora dipurpurascens; Entrophospora infrequens*
6	Through emissions	*Gigaspora sp.*
7	Site adjacent to spoil	*Glomus fasciculatum, G. macrocarpum, G. microcarpum Glomus mosseae*
8	Soil enriched with zinc	*Glomus aggregatum, G. albidum, G. deserticola; Gigaspora gigantia ; Acaulospora bireticulata, A. Delicata ; Sclerocystis rubiformis ; Scutellospora dipurpurascens, S. heterogama*

Mycorrhizal Fungal Diversity Determines Plant Biodiversity

Almost all natural plant communities contain arbuscular mycorrhizal fungi. The functioning and stability of terrestrial ecosystem are determined by plant biodiversity and species composition (Schulze and Mooney, 1993; Hooper and Vitiousek, 1997). The below ground diversity of AMF is a major factor contributing to the maintenance of plant biodiversity and to ecosystem functioning. The ability of many plant species to co-exist and thus to determine plant biodiversity, can be explained by competitive interactions (Aarssen, 1983, Grace and Tilman, 1990), by spatial and temporal resource portioning (Ricklefs, 1977; Tilman, 1982), by disturbance creating new patches for colonization (Grubb,1977; Huston, 1979) and by interaction among different functional groups of organisms that constitute the ecosystems (Bever *et al*., 1997). The presence of AMF in ecosystem increases plant biodiversity (Grime *et al*., 1987). The communities of AMF also vary with species composition and species number. Different AMF species induce differential growth responses, in term of biomass production.

AMF colonization has been shown to increase reproduction and offspring survival, and thus it can increase population size. The positive response in growth and reproduction to AMF colonization may be inversely related to plant population density. AM fungi increase inequality in size and reproduction among plants within a population. AM fungi may thus exaggerates the genetic overrepresentation in the next generation of the most robust individuals in the current generation. AMF plants serve as important source of inoculum for initially non-mycorrhizal seedlings (Koide and Dickie, 2002).

Grime *et al*.(1987) suggested that the mechanism by which the presence of AMF affects the floristic diversity of plant communities, is interplant transport of assimilates from the dominant species in the canopy via a common mycorrhizal hyphal network to subordinate plant species. Another mechanism by which AMF may affect plant community structure by the differential growth response of plant species to colonization by AMF, their so called mycorrhizal dependency(Gerdemann,1975; Plenchette *et al.*,1983, Habte andManjunath 1991). Different plant species may respond differently to specific AMF species. The effect of each AMF species is not same in all the plant species and it gives different colonization rates. The plant species varies in its response to different AMF is a potentially important factor which determines the coexistence of plant species with AMF. Plants have variable responses to different mycorrhizal types and species and have different growth rates and physiological characteristics. This association of mycorrhiza and plant also influenced by the different conditions. With elevated CO_2, Rillig *et al*., (1999) found that AMF shifted from *Glomus* spp. to the *G. tenue*. Many plants can form multiple types of mycorrhizae. Allen *et al*.(1984) found that *Glomus fasciculatum* was found in rhizosphere of interspersed *Agropyron smithii* (C_3 grass) and *Bouteloua gracilis* (C_4 grass). The common mycelial network of AMF interconnects multiple plant species. Plants with high photosynthetic rates and allocation of C to mycorrhizae can preferentially support of the formation and maintenance of the common mycelial network which support to additional plants.

Mycorrhizal Interaction between Established Plants and Seedlings

The previously established plants may influence seedling, by providing mycorrhizal inoculum i.e., mycorrhizal hyphae, which is preexisting linkages between the plants. The network of hyphae provides the nutrient and help in establishment of new seedling. In many plant populations, seedlings grow near established plants and may thus become colonized by a preexisting mycorrhizal mycelium (Newman, 1988). Where AMF plants are absent, as in primary succession, lack of AMF inoculum may limit succession (Allen, 1987). Low levels of mycorrhizal colonization also may reduce yields of agronomic crops (Boswell *et al.,*1998 Kabir and Koide, 2000). Thus well established colonized plant is very important to newly established seedlings. The established plant not only influence the seedling colonization but also influence the species of fungi that colonize the seedling (Last *et al*., 1992).

Diversity on Molecular Basis

The AM symbiosis represent an ancient symbiosis hyphae and arbuscules have been reported in fossils of *Aglaophyton*, isolated from the Rhynie chert and this evidence has established the existence of AM symbiosis in the Devonian (Remy *et al.,* 1994; Taylor *et al.,*1995). Molecular based technologies have been particularly successful for studying ribosomal DNA seqences from AM fungi. Bianciotto and Bonfante (1992) suggested that AMF fungal genome has been modest with the estimated DNA contents of nuclei from the spores of different glomalean fungi indicating large genome as compared to other Zygomycetes, ranging from 0.13

to more than 1.00 pg DNA per nucleus. Ribosomal based DNA sequence analysis has revealed genetic variation both within and between AM fungal species (Sanders *et al*., 1995; Bago *et al.,* 1998; Clapp *et al*., 1999).

The arbuscle is thought to be the major site for nutrient exchange between the two symbiotic partners. Therefore mechanism should be present to facilitate the transport of these compounds. Membrane H^+ -ATPases are considered the major transport proteins controlling ionic and molecular transport processes at the cellular level in plants and fungi. Studies have revealed changes in distribution and activation of particular H+ -ATPases in the peri pheral, peri-arbuscular membranes of functional AM interfaces (Marx et al.,1982; Gianinazzi-Pearsson *et al.,*1991; Bago *et al*.,1997).Alternative PCR strategies employed to study AM fungi include random amplified polymorphic DNA (RAPD) (Wyss and Bonfante, 1993; Gadker *et al.,* 1997) and amplification of satellite regions (Longato and Bonfante,1997; Zeze *et al*.,1997). Utilizing a PCR cloning approach based on the use of highly degenerate primers, five partial genomic clones encoding P-type ATPases (GmHA1-5), were isolated from the AM fungus, *G.mosseae*. These clones represent putative isoforms, whose function remains to be analyzed but expression analysis of GmHA1 and GmHA2 demonstrated that the former was expressed in the intraradical hyphae and the later in the extraradical hyphae (Ferrol *et al.,* 2000). The nitrate reductase (NR), a nutritionally important fungal gene was identified in DNA from spores of *Glomus* using a PCR based strategy (Kaldorf *et al*., 1994). Moreover, *in situ* hybridization located the fungal NR in arbuscules but not in vesicles, suggesting differential fungal gene expression in the symbiotic state (Kaldorf *et al.,* 1998). During asymbiotic and symbiotic development of AM fungi they undergo extensive morphogenesis. Chitin synthases (*chs*) play key role in fungal morphogenetic processes. Targated approaches have been undertaken to amplify *chs* genes from AM fungi by utilizing degenerate primers designed on highly conserved chs domains. Two *chs* genes from class I and class IV have been isolated from *Glomus versiforme* (Lanfranko *et al.,*1999), while one class II (Gim*chs* 1) and two class IV (Gim*chs*2 and Gim*chs*3) *chs* genes have been isolated from *Gigaspora margarita* (Lanfranko *et al*.,1999b).

Evolution of Arbuscular Mycorrhiza

There are several types of mycorrhizae demonstrating multiple evolutionary events. Vesicles, arbuscles and hyphal structures found in fossils from the Devonian epoch. Fossil records and molecular clock dating suggest that all extant land plants have arisen from an ancestral AM condition. AM evolved cocurrently with the first colonization of land by plants some 450-500 million years ago and persist in most extant plant taxa. This myco-associations appear to be the result of relatively diffuse coevolutionary processes. AM found in most early land plants which include some non vascular plants like mosses and primitive vascular plants like fern. Many recently evolved plant groups like grasses, also form arbuscular mycorrhizae. There is almost no terrestrial habitat which is not colonized by AMF. In contrast to diverse array of plants that form AM, only ca. 150 Glomales species have so far been described (Cairney, 2000). AM associations are most prevalent in plants that inhabit mid-latitudes of the globe, where mean annul temperatures and rates of evapotranspiration are reasonably high (Read, 1991). Fossil evidence indicates that *Glomus* like fungi were present in roots of land plants during the early Devonian, some 400mya (Remy *et al*., 1994; Taylor *et al.,*1995) and that spores and hyphae of *Glomus*-like fungi existed from ca. 460 mya (Redecker *et al.,*2000a). using molecular clock analysis of rDNA sequence data from present day Glomales, Simon *et al*.,(1993) estimated that AM symbiosis has a single phylogenetic origin and that AM fungi arose 353-462 mya. Moreover, rDNA sequence data also imply that *Geosiphon pyriforme* a fungus that forms an endosymbiotic association with a cyanobacterium, may belong in the order Glomales and provides tantlising indirect evidence for the putative Glomales-algal partnership that may have preceded the colonization of land by AM plants (Gehrig *et al*.,1996). These molecular and fossils evidences have great significance which suggest that the ancestors of all current land plants probably formed AM.

AMF Diversity in Different Plant Species

The plant species may have various degrees of selectivity for AMF species that range from selective specialists to non-selective generalist. The local availability of fungi, rather than a species-specific interaction, is primary determinant of AMF community composition for these species. There is difference in AMF community between legumes and non-legumes and between legume root and root nodules. Different plant species contained different AMF community with different AMF diversity. The AMF communities in legumes differ from those in non-legumes, and one AMF sequence type, Glo8, is significantly more frequent in legumes than in non-legumes. Root nodules contained characteristic AMF community that were different from those in legume root, even through communities were similar in nodules from different legume species (Scheublin *et al*., 2004). This AMF sequence type is specialized in plants with high nitrogen concentration. There is change in AMF community composition occurred after nitrogen fertilization (Eom *et al*.,1999) and that *Glomus intraradices*, which correspond to the Glo8 sequence type, was the only the AMF species whose level increased after fertilization with nitrogen plus phosphorus (Johnson, 1993). The AMF associated with legumes more efficient than other AMF in supplying phosphorus and other micronutrients. The importance of tripartite of legumes-AMF-*Rhizobium* symbiosis for agriculture and ecology has been recognized and several attempts have been made to find the most effective combinations of AMF and *Rhizobium* species(Requena *et al*.,2001; Valdenegro *et al.,*2001; Xavier and Germida, 2002).

AM fungal growth rates are highly host specific. For example, *Acaulospora colossica* was dominant in association with *Allium vineale*, field garlic, but this fungus was a minor component of the community associated with *Plantago lanceolata* while *Scutellosporacalospora* sporulated profusely with *Plantago*, but was a minor component in association with *Allium* (Bever *et al*., 2001).

List of Efficient AM Fungi

In Agricultural Crops (Singh, 2001)

Agriculture crops	AMF species	Agriculture crops	AMF species
Allium cepa	*Gigaspora margarita* *G. calospora*	*Cucumis sativus*	*Glomus caledonium*
Arachis hypogea	*Glomus deserticola* *Glomus fasciculatum*	*Glycine max*	*Acaulospora scrobiculata*
Sorghum	*Glomus claedonium*	*Lycopersicum esculentum*	*Glomus etunicatum*
Acer sacchrum	*Glomus macrocarpum*	*Manihot esculenta*	*Glomus fasciculatum*
Cajanus cajan	*Glomus clarum*	*Oryza sativa* *cv.*Prakash	*Glomus intraradices*
Capsicum	*Glomus intraradices*	*Oryza sativa* (upland rice)	*Acaulospora spinosa*

Carica papaya	*Glomus fasciculatum*	*Phaseolus mungo*	*Glomus intraradices*
Trifolium	*Acaulospora trappei*	*Vigna radiata*	*Glomus epigaeum*
Triticum estivum	*Glomus intraradices*	*Vigna unguiculata*	*Glomus etunicatum*
Vigna mungo	*Glomus epigaeum*	*Zea mays*	*Glomus etunicatum*

In Tree Species

Tree species	AMF species	Tree Species	AMF species
Azadirachta indica	*Glomus mosseae*	*Medicago sativa*	*Glomus intraradices*
Apple	*Glomus mosseae*	*Tectona grandis*	*Glomus leptotichus*
Hevea brasiliensis	*Glomus clarum*	*Zizyphus mauritiana*	*Glomus fasciculatum*
Acacia nilotica	*Glomus mosseae* *Gigaspora gilmorei*	*Citrus jambhiri*	*Glomus fasciculatum*

In Desert Plants (Bhatia *et al*., 1996)

Desert plants	AMF species	Desert plants	AMF species
Opuntia	*Glomus fuegianum*	*Cactus*	*Glomus geosporum, G. mosseae, G. reticulate*

In Aquatic Plants (Bhatia *et al*., 1996)

Aquatic Plants	AMF species	Aquatic Plants	AMF species
Salvinia	*Glomus fasciculatum*	*Azolla*	*Glomus intraradices*
Chara	*Glomus multicaulis*	*Nymphea*	*Glomus multicaulis*

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Technological Challenges for Efficient Use of Water in Smart Horticulture

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With the advent of the 21st century, there has been a considerable increase in the area under horticulture crops specially under fruits and vegetables in our country. The simultaneous development in the area of information technology has lead the way for Smart Horticulture. Smart horticulture means the adoption of Precision Horticulture which by and large focuses on the proper use of the available resources in the right way at the right time with right quantity and right method of application. Use of information technology plays a significant role in carrying the technological knowledge to different stake holders with special reference to the end user i.e. farmers.

Efficient utilization of available water resources is crucial for a country like India, which shares 17 % of the global population with only 2.4 % of land and 4 % of the water resources. The per capita water availability, in terms of average utilizable water resources in the country, which was 6008 m^3 in 1947, is presently at 1250 $m^{3,}$ and is expected to dwindle down to 760 m^3 by 2050. All these emphasize the need for water conservation and improvement in water-use efficiency in agriculture, which consumes around 80 per cent of the available water resources. Thus one of the major challenges for Smart horticulture in the country as on today is the need for improvement in water use efficiency.

There are many technologies available for water savings through gravity fed surface irrigation. But, there are field level adoption problems. Large scale adoption of micro irrigation in Indian agriculture is one of the answers to save water a at fie ld level. Further, adoption of mulching technology alone, in the rainfed/residual moisture conditions, or coupled with drip under irrigated conditions, can improve the moisture / water use efficiencies to a considerable extent.

Micro Irrigation Technology

Micro Irrigation Potentiality in the Country

In the TASK FORCE report (2004), the total potentiality of micro irrigation in the country has been cited as 66 million hectares. This estimate takes into account both canal (surface water) and lift irrigation (ground water) sources. Since in the near future the adoption of micro irrigation through surface water is a distant possibility, subsequently Raman estimated the potentiality through ground water and lift irrigation The potentiality assessment for micro irrigation in each state was made (Raman, 2010)considering the source wise cropwise irrigated area in different states and the suitability of different crops for micro irrigation (Table 1). It has been assessed that there is potentiality of bringing around 45 million hectares under micro irrigation in the country. Out of this 45 million about 30 million hectares are suitable for sprinkler irrigation.

Table 1: Statewise Estimated MIS Potential in India ('000ha)

State	Sprinkler	Drip	Mini Sprinkler	Total MIS
Andhra Pradesh	387	730	264	1381
Assam	6	28	0	34
Bihar	1708	142	73	1923
Chhattishgarh	39	22	9	69
Goa	1	10	6	17
Gujarat	1679	1599	302	3580
Haryana	1992	398	17	2408
Himachal Pradesh	101	14	7	122
Jammu & Kashmir	11	5	1	18
Jharkhand	114	43	25	179
Karnataka	697	745	183	1625
Kerala	0	179	39	218
Madhya Pradesh	5015	1376	163	6553
Maharashtra	1598	1116	316	3030
Nagaland	42	11	1	54
Orissa	62	157	112	331
Punjab	2819	559	49	3427
Rajasthan	4931	727	243	5901
Tamil Nadu	158	710	168	1037
Tripura	0	1	1	2
Uttar Pradesh	8582	2207	377	11166
Uttarakhand	171	94	5	271
West Bengal	280	952	451	1683
Delhi	15	0	0	15
India	**30455**	**11823**	**2813**	**45091**

Source: Raman, 2010

for crops like cereals, pulses and oilseeds in addition to fodder. This is followed by drip with a potentiality of around 12 million hectares and the major crops suitable for this system are cotton, sugarcane, fruits and vegetables, spices and condiments . and some pulse crop like red gram etc.. In addition to the above two, there is potentiality for bringing an area of about 2.8 million hectares under mini sprinkler for crops like potato, onion, garlic, groundnut, short stature vegetable crops like cabbage, cauliflower etc.

Considering that atleast in 30 percent of the cases, the system purchased for a crop can be used in a cropping sequence, the potentiality of micro irrigation business can be estimated as 30 million hectares.

Micro Irrigation Adoption

Till March 2013, about 6.6 million hectares have come under micro irrigation in India (Table 2). This works out to 12 percent of the potential. Out of 6.6 million hectares, sprinkler's contribution is 3.8 million and that of drip's is 2.8 million hectares. Though Rajasthan leads with 1.25 million, it is predominated by sprinkler with coverage of 1.16 million hectare leaving only 80000 hectares under drip. Among the other leading micro irrigation adopting countries , the drip adoption predominates in states like Maharashtra and Andhra Pradesh while in Gujarat the adoption of both the systems are almost equal. In Karnataka and Madhya Pradesh, sprinkler adoption exceeds that of drip.

Challenges in Water Use through Micro Irrigation

The state and central governments are providing financial help to the farmers with the expectation that, with the use of micro irrigation the farmers will save considerable quantity of water. With the saved amount of water the farmers can extend the area under irrigation. Further, the drip adoption in a large scale by the farmers and using the system properly to achieve the w potential savings of water will help the government to save the exchequer with the principle of water saved is as good as water resource generated.

Table 2: Statewise Micro Irrigation Adoption ('000ha)

State	Drip	Sprinkler	Total
Rajasthan	84.1	1168.1	1252.2
Maharashtra	835.5	364.8	1200.4
Andhra Pradesh	736.5	323.7	1060.2
Karnataka	339.4	414.3	753.7
Haryana	20.1	545.7	565.8
Gujarat	350.3	318.8	669.1
Madhya Pradesh	130.9	179.7	310.5
Tamil Nadu	231.1	28.5	259.7
West Bengal	0.6	50.6	51.2
Chattishgarh	13.2	148.0	161.2
Orissa	13.4	59.3	72.7
Sikkim	4.8	2.6	7.4
Punjab	28.9	11.6	40.5
UP	14.5	18.2	32.7
Kerala	19.4	5.5	24.8
Bihar	1.5	67.4	68.9
Nagaland	0.2	5.0	5.2
Jharkhand	4.6	9.9	14.5
Goa	0.9	0.8	1.7
HP	0.1	0.6	0.7
Arunachal Pradesh	0.6	0.0	0.6
Assam	0.1	0.1	0.2
Mizoram	0.4	0.2	0.6
Uttranchal	0.0	0.0	0.0
Manipur	0.0	0.0	0.1
Tripura	0.1	0.4	0.5
Others	15.5	31.0	46.5
Total	2847.0	3754.6	6601.6

Source : NCPAH,2013

But it is a well known fact that the farmers in any part of the country are not utilizing the system to its fullest potential and there is lot of scope to improve their usage with special reference to water savings. The major reason for improper use of micro irrigation at farmers' level is the lack of knowledge on the water requirement of the crops at different stages and the operating time of the concerned system as per the system designs.

Mulching Technology

Mulching has lot of scope in improving the water /moisture use efficiencies especially in fruits and vegetable crops. Of all the mulch materials the organic and plastic mulches are more viable. Of the two the organic mulches have an edge over plastics for long term/perennial crops and vice versa.

Mulching Potentiality in the Country

Though mulching technology is applicable in irrigated and rainfed/residual moisture conditions, its practical adaptability in conventional gravity fed surface irrigated conditions has limitations. While most of the horticultural crops which are comparatively wide spaced are suitable for mulch technology, among the agricultural crops only the wide spaced ones like cotton, castor etc. are suitable for being brought under mulch technology.

Considering the above irrigated and crop suitability conditions, an estimation of the mulching potentiality in the country has been made by Raman (2013). It has been estimated that there is a potentiality of bringing about 26 million hectares, of which the estimated potentiality of horticultural crops is about 16 million hectares (Fig. 1)

The estimated mulching potential in horticultural crops (fruits, vegetables, spices and condiments and flowers) includes about 8.3 million alongwith drip and 7.9 million hectares under rainfed/residual moisture conditions (Table 3).Among the different states, the maximum potentiality has been estimated to be in Maharashtra with a figure of about 2 million hectares.

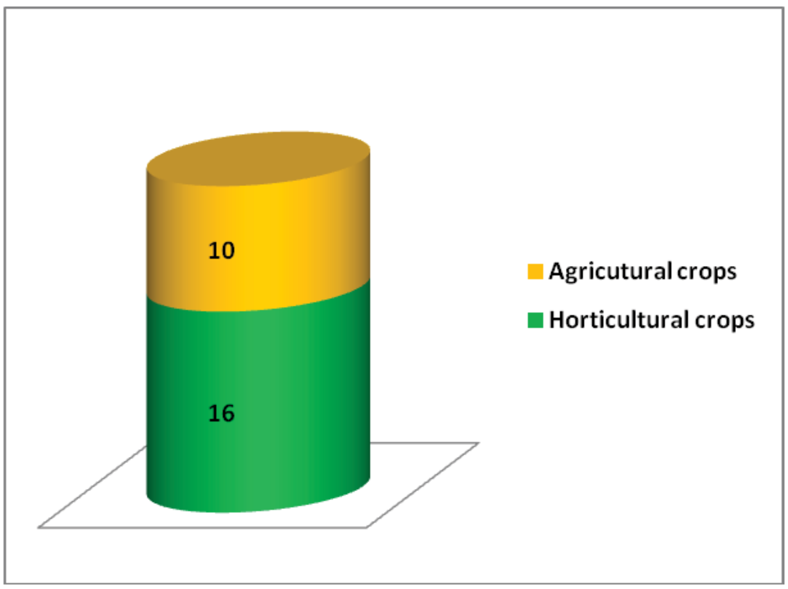

Fig. 1 : Estimated Mulching Potentiality (Million hectares)

Table 3: Statewise estimated mulch potential in horticultural crops

State	Mulch under Drip	Mulch alone	Total
Andhra Pradesh	494	709	1203
Arunachal Pradesh	32	45	77
Assam	55	216	271
Bihar	546	344	890
Chhattisgarh	87	232	318
Goa	14	64	78
Gujarat	679	493	1171
Haryana	130	165	295
Himachal Pradesh	165	83	248
Jammu & Kashmir	16	74	90
Jharkhand	153	83	235
Karnataka	769	649	1418
Kerala	516	827	1343
Madhya Pradesh	458	130	587
Maharashtra	1015	1046	2061
Manipur	49	34	83
Meghalaya	0	50	50
Mizoram	0	44	44
Nagaland	13	25	38
Orissa	141	632	772
Punjab	130	97	226
Rajasthan	522	172	694
Sikkim	20	40	60
Tamil Nadu	458	540	998
Tripura	33	39	72
Uttarakhand	125	120	245
Uttar Pradesh	894	321	1215
West Bengal	792	559	1351
Others	1	37	38
TOTAL	8305	7867	16194

Source Raman, 2013

Challenges in Water Use through Mulching Technology

The technologies developed at the different agricultural universities in the country has shown that, on an average, the irrigation requirement is 50 per cent less under plastic mulch and about 25 to 30 per cent less under organic mulch. Adoption of mulch with normal irrigation practices, many times, reduces the yield and sometimes increases the pest incidence. Hence the first challenge is to educate the farmers about the irrigation management aspects under different types of mulches. Secondly, recently, some agro textile materials are available which need be evaluated vis a vis plastics with special reference to water savings, techno economic viability and management and disposal problems.

Information Technology and Smart Horticulture

Information technology is an integral part of Smart horticulture. Though recently, Patel *et.al* (2014) developed an android application for providing informations regarding horticulture to the farmers of Gujarat, very little works have been reported on use of information technology for advising the farmers on irrigation management. The university of Georgia developed a sensor based irrigation controller and tested it under pot culture conditions The sensors in the system are placed in a few pots of each crop. There they feed real-time moisture information to the irrigation controller. The grower programs a different moisture threshold for each crop. When the soil moisture dips below that point, the irrigation system delivers water to the crop until optimal soil moisture is reached, shutting off automatically (Anon. http://www.smart-farms.net). Similarly, there have been many sensor based technologies under development for irrigating crops grown under green house conditions.

Climatic Data Based Irrigation Software for Crops Grown under Field Conditions

To advise the farmers and other stake holders on the water requirement of different crops at different stages of crop growth and the needed time of operation of the system depending upon the system design under different soil textural conditions and under different types of mulches an online software has been developed (Raman,2011).This software has been tested by some of the agricultural universities in the country. Further under International Water management Institute- TATA programme at the Water Technology Centerr, TNAU, Coimbatore the software was tested in the farmers' fields. In addition, this was used by an NGO for advising cotton farmers in Aurangabad, Maharashtra. The salient features of the software is as below:

Shakthi Irrigation Water Application Software (Siwaas)

Outline of the Software

This software works on the climatological approach of estimating the water requirement of the crops at different stages of the crop growth. Subsequently, it suggests the needed time of operation of the micro irrigation system depending upon the design of the system, soil type and mulch conditions.

The major features of the software are:

- It works on the climatological approach.
- Based on the district level meteorological data, estimates the water requirement of different crops, in different locations
- Presently it can suggest the water requirement of 65 to 70 agricultural and horticultural field crops and orchard crops.
- Estimates the water requirement as per the crop geometry
- Estimates the water requirement for different stages of crop growth
- Estimates the micro irrigation system operating time, depending on the lateral spacing, dripper/nozzle spacing and dripper/nozzle discharge rates.
- It can suggest the operating time in different soil types viz. heavy, medium and light.

- There is provision for considering the mulching aspects including the type of mulches while working out the operating time.
- Takes into account the micro irrigation system efficiency.
- Has the provision for editing the value of local pan evaporation so that the assessment becomes more accurate.
- Has the provision for entering the effective rainfall value so that the water requirement for the particular day is assessed moreprecisely.
- It can be used in Auto Irrigation systems
- It is amenable for periodical upgradations/modifications

The anticipated advantages of using the instrument:

- Help the farmer to adopt more scientific way of irrigation management under micro irrigation with mulch in different textured soils
- Additional water savings over the existing usage with drip/sprinkler/minisprinkler.
- More energy saving
- The government can divert the additional saved energy to other sectors like industries and generate more revenue.
- Farmer will be able to irrigate more area with the same system in unit time.
- More area can be brought under irrigation than with the present achievement through drip
- Possibilities of less pests and diseases including weeds
- Improvement in the water use efficiency resulting in more net returns per unit quantity of water used

Availability of the Software for different Stake holders

- The software is available as an android application.
- It can be accessed “online”
- The registered farmers will be advised twice in a week, through sms ,the water requirement of their crops, based on the date of sowing and crop geometry and mulch condition alongwith the needed time of operation based on the design of the micro irrigation system adopted by the farmer, be it drip or mini/micro sprinkler or conventional sprinkler.

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Technological Challenges in Adoption of GAPs in Litchi (*Litchi chinensis* Sonn.)

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Litchi (*Litchi chinensis* Sonn.) is an important commercial fruit crop of India, consumed both fresh and in processed form. It has an ever increasing demand in the domestic as well as international market, specially due to promotion of business enterprise and accessibility in national and international trade. The potential of export can be exploited by aggressive marketing and supplying better and safe quality fruits having minimum pesticide residues etc. Productivity of litchi has been recorded to be inconsistent in recent decade period. There exist a wide gap between actual and potential production, mainly due to narrow genetic base, non availability of superior quality cultivars, following the traditional production system and that too with poor technological support. Now the time has come to pay proper attention for this crop i.e. R & D level, as it is a major source of livelihood security, whereever grown successfully in its growing areas. This perennial evergreen subtropical fruit crop urgently requires high level adoption of Good Agricultural Practices (GAPs) to enhance quantum of quality production and exploit better marketing and export potential for economic viability and profitability.

Background Information

In recent years, there has been a steady increase in the national and international trade of agricultural commodities. Equally awareness and concern about safety issues related to fruits/fruit products. The occurrence of agri-horti produce / food related health hazards due to infective agents which include virus, bacteria, parasites and toxic agents including pesticides have raised the doubts about the safety and reliability of fruit production system. Thereby a new paradigm shift in agri-horti production system is ushered recently, where there is more concern about safety and quality of the production for increasingly discriminating and social conscious consumers. The export and import of highly perishable and important perennial fruit crops (production and consumption) has become imperative and critical. Simultaneously, the concern about the safety and quality issues of the production system and products also gained momentum at the international level. In this regard many countries in Europe and North America preferred such technical regulations to ensure safety of agri-food products but there were appreciable differences in the technical regulation prepared among the countries. This has led to the complications and now problems like shipment from developing countries being held up due to presence of pesticides residues and harmful elements beyond the permissible limits in the consignments. In case of litchi too, this is the major hindrance in increasing the ethnic marketing and export potential. This highly perishable fruit crop litchi has not been properly attended till date on these aspects. The export consignment of litchi usually donot carry the traceability certificate. Therefore, if a particular consignment was found any pesticide residues / contaminants or pathogens, future shipment from the particular exporting country should be held back until the problem is resolved. This has remained the major reason till date for the negligible quantum of litchi export from our country. The exporting country requires tracing the produce to the primary point of problem and hence traceability becomes vital in the international trade. Traceability can alleviate the problems of litchi fruit production related to safety produce in all stage of production from farm/orchard to consumers. In International trade w.r.t., litchi our country has to gain confidence on the safety of the produce and here lies the chief responsibility of the producers / growers is produce and supply safer and healthier produce. To achieve this, the producers / growers / farmers / entrepreneurs should properly communicate that they grow or go for production under safe production practices. At this juncture a strategies formulation / planning for this important fruit crop litchi has become very crucial and important. There is an urgent need to implement/ follow good agricultural practices (GAP) under litchi production system and as per modalities, it is required to ensure safer produce to the consumers, worldwide and to improve the potential export promotion and international trade.

Secondly in the era of climate change, there is an urgent need to relook into the production system and its management practices to mitigate its ill effect, which is also a great concern. In this context GAP plays the vital role as it applies recommendations and available knowledge to address environmental, economic and social sustainability for on farm production and post production processes resulting in safe and healthy (quality) production pertaining to the international regulatory framework for reducing risks associated with the use of pesticides, taking into account environmental and safety considerations. The adoption of GAP in litchi has been least attended, which ensures a clean safe working environment for growers, eliminating the potential contaminations and toxic residues of the fruit production.

In case of perennial fruit crop, more particularly for litchi, GAPs consist of guidelines addressing of site selection, adjacent land use, fertilizer use, water sourcing and use pest control and pesticide monitoring, harvesting practices including growers / workers hygiene, packaging, storage, field sanitation and produce transportation. It may include the post harvest operations too, because it involves steps of processing and preservation for making many value added food products.

Present Scenario

India is later starter in this area and litchi growers are not very active until recently but time and opportunities are wide open to learn from experiences of some other important commercial fruit crops, where much care and attention have been paid. There is need for an exhaustive study to understand the ground situation for the proper technological interventions. India's situation is typical like developing country environment. Poor level of infrastructure development and its facilities rendered to growers like common pack-houses and facilities of sorting, grading, packing and cold storage for litchi. Fragmented production leading to fragmented and inconsistent variable marketing / supply chain. There exist no transparency in pricing at farmer's end and high amount at consumer's level, as the produce reaches on the table are lacking traceability and even confident acceptability. Indian condition is different from other countries where there is lack of awareness, attention and concerted efforts for fruit production and post harvest handling till it reaches to consumer. The quantum of export is negligible for litchi, due to lack of adoption and certification by IndiaGAP / EureGAP, apart from unattended post harvest issues like proper / scientific / specific technology, common grade, infrastructure and skilled manpower to ensure quality and quantity of supply and storage.

Some of the important production practices for cultivation of litchi are being followed by farmers like use of air layered plants of orchard establishment, high density planting and canopy management to harness maximum solar energy, rejuvenation of to make old senile unproductive orchard productive, conservation of soil moisture with mulching, integrated plant nutrient management, maintenance of irrigation frequency, integrated pest management against major insect-pests (fruit borer, trunk borer and mite) and post harvest management through better packing methods along with valued added products. Many improved technologies at post harvest level like technology for Controlled Atmosphere and Modified Atmosphere (MA) are yet to be standardized at research centre/institutes. Residue analysis facilities are yet to be come at common and accessible front. There is formidable loss of fruits due to faulty method of harvesting and at post harvest level are still to be checked / controlled.

There is an urgent need to create an awareness of different aspects to be considered when implanting GAPs. Adoption of GAPs will help to promote sustainable production and contribute to meeting national and international environment and social development objectives. The objective of this paper is to create awareness of GAPs, initiative towards development of IndiaGAP Standards for the benefit of farming community and better adoption level by the proper technological intervention enhance quantum of safe and quality litchi production for bringing prosperity.

Challenges Related to GAPs

Awareness is needed (both by producers and consumers) for improved and required practices to be followed, technologies to be adopted that will lead not only to improvements in term of fruit yield and productivity but also for the environment, health and safety of producers/growers and consumers.

Though the production status envisages that India is second largest producer of litchi (only after China) in the world but until recently the production system is lacking consistency and criteria to ensure production of fruits according to specified quality and safety standards. There is high risk that small scale litchi growers will not be able to access super or export market opportunities unless they are adequately attended, informed, technically prepared and organized to meet this new challenge with Government and public agencies playing a facilitating role.

In some cases, GAPs implementation is not properly understood and practices, especially record keeping and certification, will increase the production cost and pose hindrances in marketing / export due to the lack of traceability. Due to lack of knowledge, adoption and harmonization of existing GAPs and in its related aspects, and availability of affordable certification systems are major hindrances in adoption of GAPs in litchi production system. It needs a proper policy, awareness through training / extension and adequate resources to facilitate improvement in adoption level of GAPs in litchi. To respond to these challenges and opportunities, various technical, economical, social, infrastructural and institutional challenges need to be overcome/attended in order to ensure fruit quality, safety to protect people's (consumers) health and bringing prosperity with economic viability. Furthermore, there is a need to increase awareness, ensure participation of growers (even small scale producers), processors, scientists, extension staff and market functionaries. Empowerment of these stakeholders within framework of GAPs can enhance quantum of quality production and its standards that foster the health of growers and consumers.

GAPs guidelines provides the opportunity to access and decide on the type of farming practices to be followed at each step in the production process. For each agricultural production system it aims to allow comprehensive management strategies and provide the capacity for tactical adjustment in response to changes. The implementation of GAP requires knowing, understanding, planning, measuring, monitoring and record keeping at each step of the production processes. Earlier, the agricultural sector in Europe and later in other countries too, faced increased concern from consumers, growers and governments about safety and environmental issues related to production. Recently of litchi production system in the growing areas has been associated with unhygienic condition and genesis of one/two deadly diseases (in Muzaffarpur, Bihar). There was great hue and cry and even litchi production system and its orchard floor management have been challenged. Till date, no concerted efforts and research pertaining to bring standard to safe production system and environment issues related to fruit production have been made. This has motivated to attend on these issues in the present context with well defined frame work.

Site History and Soil

Like other perennial fruit crops, litchi production too, should have proper site history and soil health information to have appropriate soil management activities to maintain and improve soil fertility by improving the availability of nutrients and uptake of water and nutrients through enhanced soil biological activities, replenishing soil organic matter and moisture and minimizing losses of soil and nutrients to erosion, runoff and leaching into surface or ground water. Though, soil management is generally undertaken at farm level, it effect the surrounding area due to off-site impacts on nutrients movements and mobility of livestock. The good practices for litchi related to soil must include maintaining and improving soil organic matter through raising green manures along with proper application at the initial stage or orchard and leaving the leaf fall/litter and mixing in soil in young and commercial bearing orchard as a measure to provide a conducive base for soil biota. Conjoint use of organic manure, biofertilizers and chemical fertilizers in reduced dose have given very encouraging results at the initial stage of experimentation. The growing of proper wind breaks to avoid damage during initial establishment phase of new plantation due to cyclones, speedy winds, it also reduces wind erosion. Reduced soil compaction issues for this orchard floor management practices are to be followed carefully.

Irrigation Water

The moisture content is the highest and major ingredient in the arillate juicy litchi fruit deciding the quality of the fruits. Even though water is an important and renewable source in all agri-horti production, its quality and quantity will directly effect the produce. Careful management of resources and efficient use of water for fruit production mainly through irrigation and livestock management are important criteria for GAPs. Efficient irrigation technology and management will minimize water and will avoid excessive leaching and Salinization. There is need to follow various practices that can monitor the plant / tree growth, fruit development and quality production, proper maintenance of soil water status. It is required to accurately schedule irrigation with technologies like drip irrigation, sprinklers and rain-guns. Flooding and channel application should be avoided. It is very essential to manage water table to prevent excessive extraction or accumulation and to provide adequate, safe and clean watering points for livestock and also to prevent salinization in this region. Apart from this, one important aspect that ensuring theavailability of potable water for field workers will minimize the risk of their developingdiseases and consequently contaminating fresh produce.

Crop Production

Litchi is a perennial fruit crop and hence its production involves, selection of cultivars/varieties to meet local consumer and market needs according to their suitability to site and their role with proper management of soil fertility, canopy, pest and disease. Perennial fruit crops are used to provide long term production options and opportunities for inter-cropping. Suitable annual crop can be grown in sequence including those with pasture, to maximize the biological benefits of interactions between nature of intercrop and productivity maintenance. Harvesting of fruits removes their nutrient contents from the site soil, which must be replenished to maintain long term productivity in sustainable manner (it can be thus GAPs related with litchi production), apart from the aspects of variety selection, nutrient management in litchi production system. GAPs relate to understanding of the litchi crop characteristic responses with input application, extent of quality production, market and consumer acceptability, less occurrence of physiological disorder, diseases and damage from insect pests, stress tolerance/ resistance nature. Litchi production system is very much dependent on edaphic and climatic adaptability, hence proper monitoring for beneficial response to fertilizers, irrigation and agro-chemicals are required to ensure through GAPs. Devising intercrops and its sequence to optimize use of labour, equipments and maximize biological benefits of weed control, provision of non-host crops to minimize insect (fruit borer, leaf roller and mite) attack / infestation of diseases. There should be provision to include legumes to provide a biological source of nitrogen. Soil testing and leaf nutrients analysis to monitor the dose of organic and inorganic fertilizers in balanced fashion in appropriate (ring method) way for proper nutrient replenishment each year after the fruit harvest is over.

Crop Protection

Litchi is an ever green perennial fast growing fruit crop, hence maintenance of plant/ tree health is essential for successful quality production in sustainable manner. This require long term strategies to manage risk by the use of safe measures to control insect-pest (including disease and weeds), clean cultivation of intercrops and the judicious use of agrochemicals to control these by following the principles of integrated pest management (IPM). Recently IPM module has been developed for safe litchi production. In case of litchi the use of GAPs relate to crop protection is very vital. In litchi production system, it has always been encouraged (government/scientist), the adoption of organic control practices to control the various pest and diseases, affecting quality fruit production. The application of pest-disease forecasting technique for litchi is yet to be encouraged properly after determination / intervention. It requires integration of all the possible methods and their short and long term effect on quality fruit production and environmental implications in order to minimize the use of inorganic insecticides or agro-chemicals and to promote IPM. There is need of proper awareness programme / training for storage and use of agro-chemicals according to legal requirements as per registration for perennial fruit crop production w.r.t., rates, timings and pre- and post harvest interval, even the application aspects also be ensured that operation is being performed by the skill/trained and knowledgeable person for traceability and safe quality fruit production, it is must to ensure that the equipment used for handling and application of agro-chemical complies with established safety and maintenance standard. Banned chemicals are never been used in any case. The growers should maintain accurate record for agro-chemicals used and timeliness practices performed. Maximum residue level (MRL) is intended primarily as a check that the pesticide is being used correctly (i.e.that the GAP for pesticide usage is being observed) and to assist international trade (export).

Harvest and On-farm Processing and Storage

Adoption of GAPs ensure the higher fruit yield and its quality, which depend upon implementation of acceptable protocols for harvesting, handling and off farm disposal (transportation, sorting, grading and packaging). Harvesting must conform regulations relating to pre-harvest operations. Harvesting of fruits should be taken up by the trend personnel with proper care (handling) to reduce the orchard damage and fruit wastage. The highly perishable litchi fruits also require clean and careful handling of the harvested produce and required processing steps to reach the consumer's table with its natural retained quality (fresh condition). For washing fruit recommended way and clean water should be used under hygienic and appropriate environmental conditions. Even for further packaging, transportation and storage, it is always encouraged to have the operations and handling under proper supervision, trained / skilled staff and use of proper equipments and machines.

Summary

Application of GAPs is bounded with certain principles and accordingly standards developed to ensure the production of quality fresh produce from growers, who use GAPs, that operate in an environmental responsible way and with proper regard for the health and well being of the consumer. Standard protocol of GAPs separately for litchi is required to be framed properly with the combined recommendations of team of scientists, litchi fruit growers and technical experts and officers from approved national/international certification bodies. The standard should be consistent and convincing for growers in Indian conditions. Growers should be properly trained and encouraged to improve and develop adoption levels with economic viability to growers. Good co-operative system / distribution and other related marketing functionaries properly linked with growers fostering safe, quick and economically viable produce sales. The litchi growers need to be encouraged to implement environment friendly and more towards organic farming practices, and they should be ensured to have better / premium prices and market stability of the highly perishable produce of litchi fruits. Technology for enhancing the water and nutrient efficiency through micro-irrigation and fertigation has to be properly integrated in the litchi production system. Improved techniques for production of disease free quality planting material have been developed for mango and some other perennial fruit crops have to be standardized and adopted for litchi too. To harness the solar energy, canopy management practices in litchi have been standardized, required to be looked into for safe and quality production. The technology for rejuvenation of old and senile orchards of litchi has been developed. The technology is gaining popularity because of high productivity, quality produce and its economic viability. Farm mechanization to increase harvesting and processing efficiency and to reduce crop loss has been implemented by developing fruit harvester, motor operated conveyer belt for sorting, grading and packaging. Low cost environment friendly cool chamber may prove worth for litchi also, should be tried. The safety related to pesticide to pesticide residues in case of litchi too is a constant concern of consumers, producers/ growers, wholesalers, retailers and governmental agencies responsible for consumer's health. It also affects the status good marketing and export. IndiaGAP currently operates as inspection and certification program to verify the safe use of pesticides in accordance to the recommended good agricultural practices (GAP), and to validate concerned fruit are free from pesticide residues or their existing pesticide residues or their existing pesticide residues are below the maximum residue levels. At present, the conformance rate of the producers who have engaged in the GAP process for litchi is at insignificant level. Small, medium and large scale farmers will achieve added value for their produce through judicious use of agricultural inputs are to be encouraged. As GAP ensures approved and appropriate methods of farming for production and also ensures better access to market for the produce. Consumers of domestic and foreign countries will be assured of better quality and safer fruits or processed products. GAP ensures sustainable production and business and industry will gain profit from better products. GAP ensures responsibilities to stakeholders of food supply chain. Altogether farmers, consumers and industry will enjoy a better environment with the increased level of adoption of GAPs.

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Potato an Option for Food and Nutritional Security

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Potato is consumed by one and all due to its versatility in way of cooking viz. boiling, baking, deep frying etc. Potato is popularly known as the "Vegetable King". It may be consumed in the form of snacks (chips, fries and dehydrated products) by the rich, though most of the undernourished households consume potato as primary or secondary source of food and nutrition. Potato is a flexible crop compared to other vegetables and can be grown under conditions where other crops may fail to grow. Moreover its short and flexible life cycle brings the yield within 100 to 120 days and is hence also suitable for double cropping and intercropping systems. Potato is a good option for food and is capable of producing nutritious food more quickly on lesser land compared to any other major food crop.

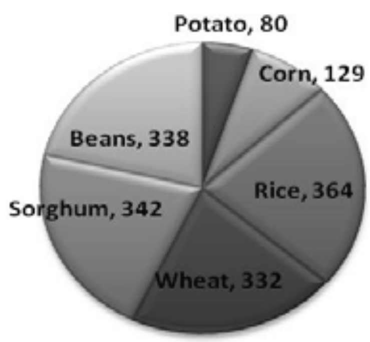
Potato is considered as the most productive vegetable and provides a major source of nutrition and income to many population and communities. Its content of dry matter, edible energy and edible protein makes it a good choice for nutrients availability. Potato is known to everyone as a supplier of energy but its ability to supply vital nutrients is vastly underestimated.Potato is anexcellent source of complex carbohydrates, dietary fibres and vitamin C. Potatoes also contain a variety of health-promoting compounds, such as, phytonutrients that have antioxidant activity. Among these, important health-promoting compounds are carotenoids, flavonoids, and caffeic acid, as well as unique tuber storage proteins, such as patatin, which exhibit activity against free radicals. Potato is a substantial source of ascorbic acid, thiamine, niacin, pantothenic acid and riboflavin. Potato is highly desirable in human diet as many of the compounds present in potato are important because of their beneficial effects on human health. The nutritive value of a potato containing food depends on other components served with it and on the method of preparation. By itself, potato is not fattening (and the feeling of satiety that comes from eating potato can actually help people to control their weight). However, preparing and serving potatoes with high-fat ingredients raises the caloric value of the dish. Since the starch in raw potato cannot be digested by humans, they are prepared for consumption by boiling (with or without the skin), baking or frying. Each preparation method affects potato composition in a different way, but all reduce fiber and protein content, due to leaching into cooking water and oil, destruction by heat treatment or chemical changes such as oxidation.

***'If one had to live on one food alone, the POTATO would be better by far than any other major food crop available today''* By:** *Dr RL Sawyer, Former DG, CIP, Lima, Peru.'*

Potato as a Low Energy Diet

Raw potato dry matter (100g) provides about 310 kcal and a boiled potato provides about 69 kcal per 100 g weight. The energy value of potato is less than major food crops like rice, wheat, maize and sorghum. Potatoes are an excellent source of complex carbohydrates. These carbohydrates take longer time to break down into glucose and results in energy that lasts longer. Complex carbohydrates are longer chains of sugars, such as starches and fiber. In potato, starch is the major carbohydrate and sucrose, fructose and glucose are the main sugars.

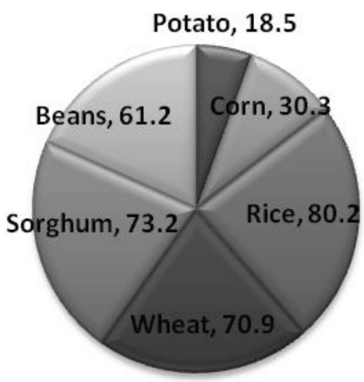
Carbohydrates are the body's primary source of fuel for energy. The energy produced through potato gets stored as glycogen in muscle and liver and functions as a readily available energy during prolonged, strenuous exercise. That's why; it is an important part of players' diet.



Comparison of energy provided by raw potato and other plant foods
(kcal per 100g edible portion)

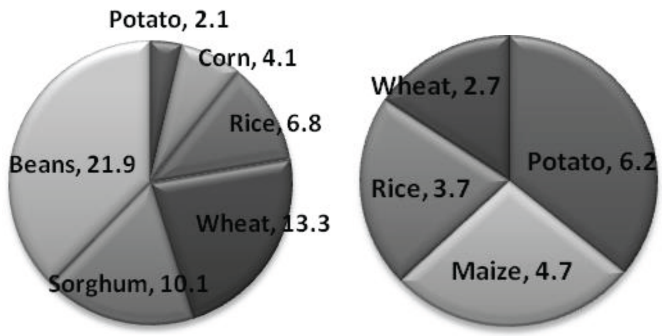
Potato: A Good Source of Carbohydrates

The major role of carbohydrates in nutrition is to provide energy. The complex carbohydrates present in potato are important to a healthy diet. Carbohydrates in potato are mostly found in the form of starch. On an average, potato contains 14% of starch on fresh weight basis. It provides most of the energy supplied by the potato. Sugars are the most basic carbohydrates, the building blocks of complex carbohydrates. Starch furnishes most of the energy supplied by the potato. Digestibility of this starch influences the energy value of the potato and hence also the bulk of potato which must be eaten to supply a given amount of energy. The digestibility of potato starch is low in raw state but improves considerably after cooking or processing. Sucrose, fructose and glucose are the main sugars in potato. Sugar quantity in potato influences the quality of processed potato products such as chips and French fries.



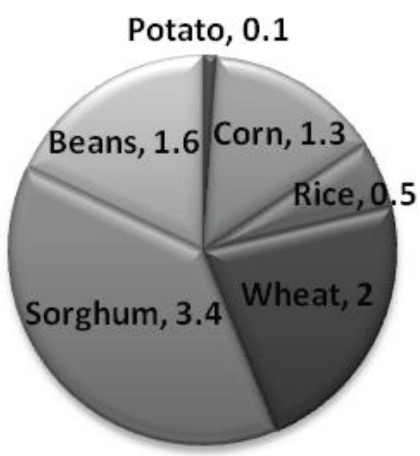
Carbohydrate content of raw potato vis-a-vis other plant foods (g per 100g edible portion) and a potato starch granule

Potato is a very good source of high quality protein. Average protein content of potato is 2% on fresh weight basis and about 10% on a dry weight basis. The total nitrogen of potato tubers can be divided into soluble protein, insoluble protein and soluble non-protein nitrogen. The insoluble protein fraction is mainly present in the peel. Soluble potato protein contains substantial levels of the essential amino acids. Free amino acids present in potatoes are totally available for absorption. Potato protein has an adequate ratio of total essential amino acids to total amino acids and a balance among individual essential amino acid concentrations to meet the needs of infants and small children. However, the digestibility of potato protein is relatively low in infants. The crude protein content in potato is higher than other major root and tuber crops like sweet potato, yam and cassava. Potato protein has a very high biological value because all essential amino acids are present in good proportion in it. It is much higher than major cereals and higher than even proteins of animal origin like milk and beef. With its high lysine content, potato can supplement diets which are limiting in lysine. Potato has a clear advantage over cereals in India because of its ability to provide high quality protein.



Protein content of raw potato and other plant foods (g/ 100g edible portion) left; Lysine content (g/ 100g Protein) of potato is higher than major cereal crops (right)

There is a common misconception that eating potato may cause obesity which is not at all a true statement, since potatoes contain very little quantity of fat. The average fat content of potato is 0.1% on fresh weight basis which is too low to have any negative nutritional significance. Fat content in potato is lower than major cereals like rice, wheat, maize and sorghum. The little fat present in potato contributes towards potato palatability. Nearly, 60-80% of the fatty acid content in potato is composed of unsaturated fatty acids and linoleic acid is the predominant one. The high content of unsaturated fatty acids increases the nutritive value of the fat present in potato. When eaten without added fat, potato is good for weight conscious people because of its low energy density. However, when fat is added to the fried or processed potato products, it becomes rich in energy and may certainly cause obesity.



Fat content of raw potato is negligible compared to other plant foods (g/ 100g edible portion); French fries of CPRI

Potatoes: Good Source of Vitamins

Potato is one of the rich natural source of vitamin C or ascorbic acid as it contains 30 mg or more of ascorbic acid per 100 g tuber. Potatoes have high quantities of vitamin C than other vegetables like carrots, onion and pumpkin. When consumed in sufficient quantity, potatoes itself can meet all the vitamin C requirements of an individual. Potato is an important source of thiamine, niacin and pyridoxine and its derivatives (vitamin B6 group). It also contains pantothenic acid (vitamin B5), riboflavin and folic acid. B-vitamins are essential for general health and growth, since they are water soluble. However it is recommended that potatoes should not be washed after peeling to prevent loss of vitamins.

Vitamin C: Potatoes are rich in vitamin C. Potato contains 20mg/100g Vitamin C that is far high compared to corn, wheat, rice, sorghum and beans. This water-soluble vitamin acts as an antioxidant and stabilizes or eliminates free radicals, thus helping to prevent cellular damage. Potato as major source of Vitamin C provides protection against scurvy. Vitamin C assists with the absorption of iron and may help support the body's immune system. The ascorbic acid content of potato declines when potatoes are stored, cooked or processed. Though potato loses some of its vitamin C during storage, substantial amounts are retained until it sprouts.

Vitamin B Complex: Potato is an important source of vitamin B complex. 100g of potato boiled in its skin can make substantial contribution to the daily requirement of thiamine, niacin, folic acid and pantothenic acid. All B vitamins help the body to convert food (carbohydrates) into fuel (glucose), which is used to produce energy. These B vitamins, often referred to as B complex vitamins, also help the body use fats and protein. B complex vitamins are needed for healthy skin, hair, eyes and liver. They are also required for proper functioning of nervous system.
Vitamin B1: Potatoes are important source of thiamin, niacin and pyridoxine. Potatoes provide 0.10 mg vitamin B1 (thiamine) per 100 g of freshly harvested potatoes. Thiamine is needed to release energy from carbohydrates. Insufficient intake of thiamine results in a disease called beriberi affecting the peripheral nervous system (polyneuritis) and/or the cardiovascular system.

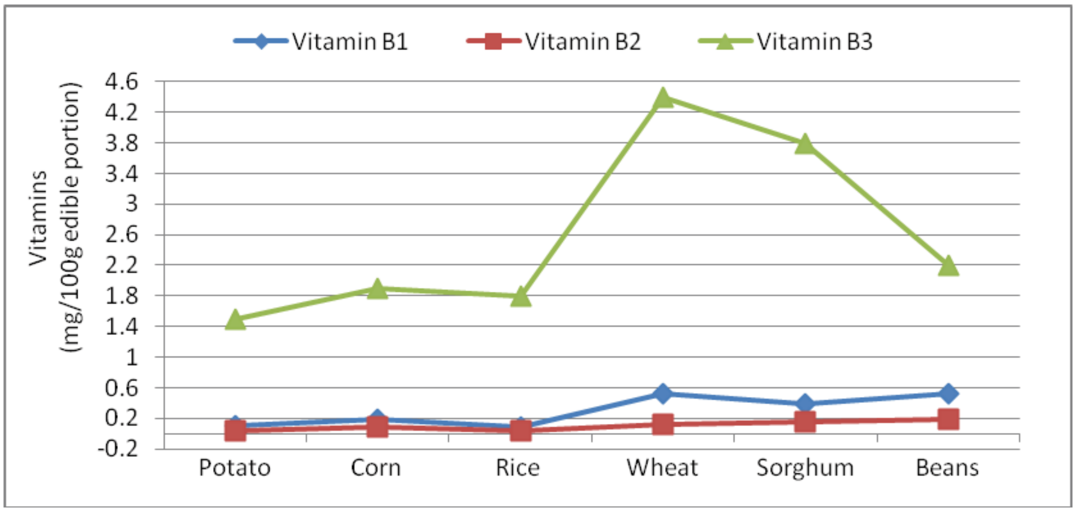
Vitamin B_2: Potato contains 0.01 mg riboflavin per 100 g freshly harvested potatoes. It is also used for treating riboflavin deficiency, acne, muscle cramps, burning feet syndrome, carpal tunnel syndrome and blood disorders.

Vitamin B_3: Being an important source of niacin (Vitamin B3) potato provide 1.2 mg niacin per 100g freshly harvested potatoes. Niacin is involved in both DNA repair, and the production of steroid hormones in the adrenal gland.

Vitamin B_5: Pantothenic acid is an essential nutrient. Potatoes contain 0.3mg pantothenic acid per 100g of freshly harvested potato. Pantothenic acid is required to synthesize coenzyme-A (CoA), as well as to synthesize and metabolize proteins, carbohydrates, and fats.

Vitamin B_6: Potatoes are a good source of vitamin B6 (pyridoxine). Vitamin B6 plays important roles in carbohydrate and protein metabolism. It helps the body to synthesize nonessential amino acids needed to synthesize various body proteins. It is also a cofactor for several enzymes involved in energy metabolism, and it is required for the synthesis of haemoglobin – an essential component of red blood cells.

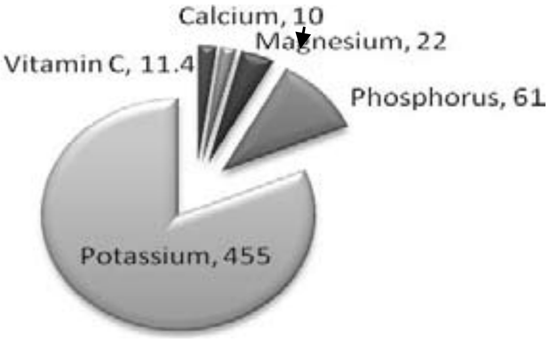
Vitamin B_9: Potatoes contain 14 mg folic acid per 100 g of freshly harvested potatoes. Folic acid is essential to numerous body functions. The human body needs folate to synthesize DNA, repair DNA and methylate DNA as well as to act as a cofactor in biological reactions involving folate. It is especially important in aiding rapid cell division and growth, such as in infancy and pregnancy. Children and adults both require folic acid to produce healthy red blood cells and prevent anemia.



B-Complex vitamins in raw potato and other plant foods

Potato has Good Cocktail of Minerals

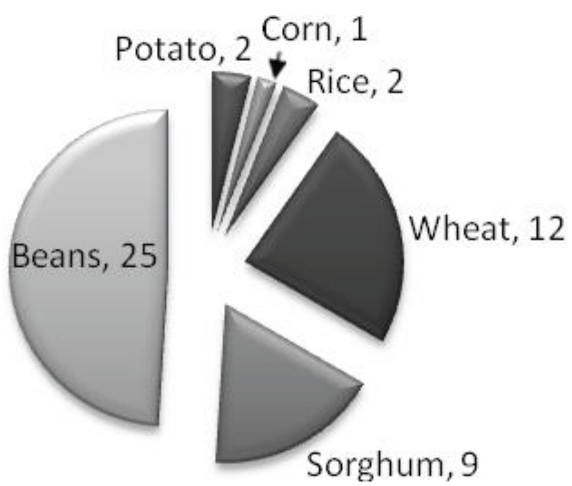
Important minerals and trace elements are present in potato. It is a good source of phosphorous. The phosphorous present in potato is more assimilable than the phosphorous present in other food crops because of the relatively small percentage of phytic acid in potato. The lower phytic acid content of potatoes makes a large part of potato phosphorous available to human body and is also helpful in allowing greater availability of calcium, iron and zinc. The potassium content of potato is also relatively high. Because of high potassium content, potatoes are not included in the diet of patients with renal failure. On the other hand the sodium content of potato is very low. Potatoes are a good source of iron and their iron content is comparable to most of the other vegetables. Potatoes provide a good source of magnesium. Zinc is an important trace element found in potato. Though zinc content of potato is not very high but its availability is high because of the low phytic acid content. Potato can supply at least part of daily requirements of trace elements like copper, manganese, molybdenum and chromium.



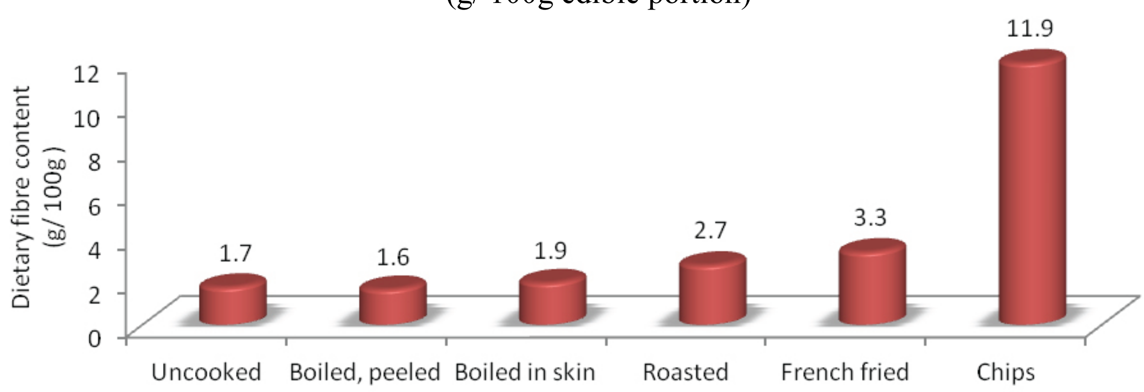
Mineral content of raw potato (mg/100g edible portion)

Dietary Fiber in Potato helps in Digestion

Dietary fiber content in raw potato tuber ranges from 1-2 g/100g FW. Unpeeled potatoes contain more dietary fibers than peeled potatoes. The dietary fiber from potato tuber comes mainly from its cell walls that constitute about 1.2% of the fresh weight of the tubers. To increase the dietary fiber intake, potatoes must be consumed along with its peel. More than half of the dietary fiber in potato is in the form of pectic substances which improves the quality of potato dietary fiber and thus helps in lowering cholesterol levels. One medium potato with the skin contributes two grams of fiber or eight percent of the daily value. Dietary fiber is a complex carbohydrate and is the part of the plant material that cannot be digested and absorbed in the bloodstream. Dietary fiber has been shown to have numerous health benefits, including improving blood lipid levels, regulating blood glucose, and increasing satiety, which may help in weight management.



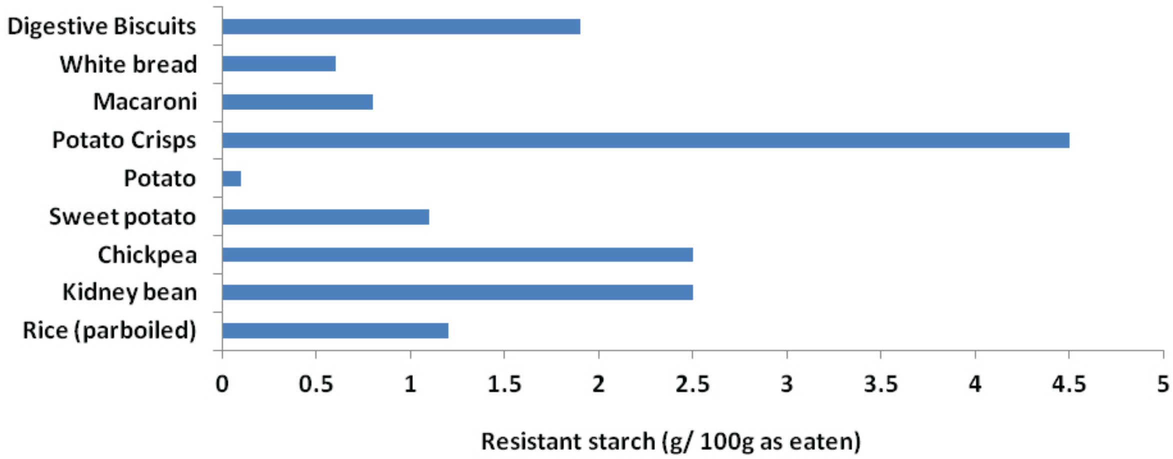
Dietary fiber content of raw potato and other foods
(g/ 100g edible portion)



Dietary fiber content of potatoes when cooked by different methods Source: Ezekiel et al (1999) CPRI Technical Bulletin No. 49

The main components of dietary fiber are non-starch polysaccharides (NSP), lignin, resistant starch and non-digestible oligosaccharides. Potatoes are a good source of resistant starch.

Resistant starch are 'starch and starch degradation products that escape digestion in the small intestine of healthy individuals'. They act in similar fashion as fibers. Resistant starch is found naturally in foods such as legumes, bananas, potatoes and some unprocessed whole grains.



Resistant starch content of different food materials

Source: Englyst et al (1996) Measurement of rapidly available glucose in plat foods: a potential in vitro predictor of glycaemic response.British J Nutrition 75: 327-337

Natural resistant starch is insoluble, fermented in the large intestine and a prebiotic fiber (i.e it may stimulate the growth of beneficial bacteria in the colon). Other types of resistant starch may be soluble or insoluble and may or may not have prebiotic properties. Resistant starch appears to exert beneficial effects within the colon. The amount of resistant starch found in potatoes is highly dependent upon processing and preparation methods. For example, cooking and then cooling potatoes leads to nearly a two-fold increase in resistant starch. Even processed potatoes (e.g. potato flakes) appear to retain a significant amount of resistant starch with the potential to confer health benefits. Resistant starch is considered as the third type of dietary fiber, as it can deliver some of the benefits of insoluble fiber and some of the benefits of soluble fiber.

Potatoes are Rich Source of Antioxidants

Along with Vitamins and minerals, potatoes contain a number of small molecules, many of which are beneficial phytonutrients such as phenols, flavonoids, kukoamines, anthocyanins and carotenoids. Coloured potatoes may serve as a potential source of natural anthocyanin pigments and also a powerful source of antioxidant micronutrients. Potato antioxidants have potential role in immune function and disease prevention. Potatoes are a good source of carotenoids, which are in the category of xanthophylls. Lutein, Zeaxanthin, violaxanthin and neoxanthin are the major carotenoids present in potatoes and β-carotene has been detected only in trace amounts. The orange colour of the tuber flesh is due to zeaxanthin, whereas the yellow colour is due to lutein.

Glycoalkaloids: An Anti-nutrient Factor

Potatoes when exposed to sunlight form some alkaloids called glycoalkaloids and the main constituents are chaconine and solanine. Normally, they contain less than 5 mg solanine per 100 g fresh weight which is far lesser than the safety limit of 20 mg/100 g and glycoalkaloids content of potato is so low that it is not even perceptible by taste. However, if the potatoes become green, they might contain higher glycoalkaloids resulting in health threats and therefore, it is not recommended to consume greened potatoes. It is a fallacy to say that potato glycoalkaloids can be poisonous to human beings. Moreover, most of the glycoalkaloids (80%) are found in outer layer and therefore can be easily removed. With precautions, bad effects of glycoalkaloids may be avoided.

Health Benefits Associated with Potato Consumption

Potatoes contain a complete range of nutrients, including those necessary for growth and development of human beings. They are rich in vitamin C and thus prevent scurvy. More than half of dietary fiber in potato is in the form of pectic substances, which helps in lowering cholesterol levels in human. Moreover, the dietary fiber dilutes highly caloric components in food, stimulates peristaltic movement and improves digestion. Because of its low sodium content, potatoes can be used in diets given to patients with high blood pressure. Potato is a good source of vitamin B6. Many of the building blocks of protein, amino acids require B6 for their synthesis, as do the nucleic acids used in the creation of our DNA. Because amino and nucleic acids are such critical parts of new cell formation, vitamin B6 is essential for the formation of virtually all new cells in the body.

Raw potato juice is regarded as an excellent food remedy for rheumatism. Potato is a good source of resistant starch. Natural resistant starch helps maintain a healthy colon and a healthy digestive system via several mechanisms and prevents colorectal cancer and type 2 diabetes. Resistant starch is a valuable tool for formulators of reduced-calorie foods. Resistant starch may also help to burn fat and may lead to lower fat accumulation. Resistant starch contributes to oral rehydration solutions for the treatment of diarrhea. It is predicted to help maintain "regularity" with a mild laxative effect due to increased microbial activity in the large intestine. Consumption of natural resistant starch by humans has been shown to result in decreased glycemic response in healthy individuals, decreased glycemic response in diabetics, increased insulin sensitivity in healthy individuals, individuals with Type II diabetes as well as insulin resistant individuals. When resistant starches are included in a meal, it slows down the absorption of sugars from other foods. That means there is more gradual rise and fall in blood sugar levels after eating. That's particularly helpful for diabetics, who need to keep their blood sugar levels steady.

Common Misconceptions About Potatoes

There are many misconceptions prevalent in society concerning the nutritional value of potato. The most common misconception is that potatoes are fattening. With a fat content of less than 0.1% and very low calorie content, by no means it can cause obesity. Potatoes are known to absorb considerable amount of fat while frying which is a common way of consuming potatoes in Indian recipes. Hence, potato is wrongly blamed of causing obesity, while the real culprit is the fat which it might have absorbed at the time of frying. Another common misconception is that potatoes can cause or worsen diabetes. Resistant starch present in potato helps in more gradual rise and fall in blood sugar levels after eating and hence potatoes are not an unhealthy food for diabetics. In western countries, potatoes are consumed by one and all. One more misconception is that all of the potato's nutrients are found in the skin. While the skin does contain approximately half of the total dietary fiber, the majority (> 50 percent) of the nutrients are found within the potato itself. As is true for most vegetables, cooking does impact the bioavailability of certain nutrients, particularly water-soluble vitamins and minerals, and nutrient loss is greatest when cooking involves water (boiling) and/or extended periods of time (baking). To protect most of the nutrition in a cooked potato, steaming and microwaving are the best methods of cooking potatoes.

"With the removal of misconceptions among populations, potatoes might play the role of nutritious source of food and become 'bread of life'"

Summary

Potato is a nourishing food. It's low energy density is advantageous when eaten without much added fat. Potatoes contain high quality protein rich in essential amino acids. It is a rich source of vitamin C and is far superior in this respect to most other vegetables and cereals. Considerable quantities of some of the B group vitamins are also present in potato. Potatoes contain many minerals and trace elements and simultaneously are low in fats. Hence, potato as such is a wholesome food and anyone can live by eating potatoes alone. With ever increasing population, potatoes are destined to be very crucial for providing food and nutritional security to populations in the developing countries including Indian masses.

Don't under-estimate the power of a potato

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Technological Challenges for Targeted Production of Vegetables in Smart Horticulture

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Smart horticulture is an innovative approach to improve traditional method of horticulture by applying new techniques suitable to mankind. Greenhouses have developed towards high-tech factories that are highly automated. It is also very active in business and in the standardisation of information exchange. Despite this good basis, horticulture domain faces major challenges due to the increasing international competition, recent food incidents such as the EHEC crisis, and fast advances in (information) technology, among others. One main answer to these developments is to innovate towards more information-based and knowledge intensive production systems and supply chains. It will provide an opportunity to use best practices in the horticultural sector and to explore potential synergies with other agricultural sectors such as arable and livestock farming.Following are the various challenges in targeted production of vegetables in smart horticulture.

Global G.A.P.

Globa G.A.P. is a private sector body that sets voluntary standards for the certification of production processes of agricultural (including aquaculture) products around the globe. This standard is primarily designed to reassure consumers about how food is produced on the farm by minimizing detrimental environmental impacts of farming operations, reducing the use of chemical inputs and ensuring a responsible approach to worker health and safety as well as animal welfare. The basis is an equal partnership of agricultural producers and retailers who wish to establish efficient certification standards and procedures.

Good agricultural practices (GAP) are practices that address environmental,economicand social sustainability for on-farm processes and result in safe and quality food andnon-food agricultural products (FAO 2003). In simple language, stands on four pillars (economic viability, environmental sustainability, socialacceptability and food safety and quality). In recent years, the concept of GAP has evolved to address the concerns of different stakeholders about food production and security, food safety and quality, and the environmental sustainability of agriculture.The importance of implementing good agricultural practices (GAP) and good manufacturing practices (GMP) as important steps to reduce the impact of possible hazards throughout the production and distribution chains of vegetables.

The concept of GAP evolved recently as a result of the big concern about food safety and quality, and the environmental sustainability of agriculture. GAP offers benefits to farmers and consumers to meet specific objectives of food security, food quality, production efficiency, livelihood and environmental protection. In a broad sense, GAP applies available knowledge in addressing environmental, economic and social sustainability for on-farm production and post-production processing, resulting in safe and healthy food and non-food agricultural products.

Maintaining Soil Fertility

GAP related to soil fertility improvement include maintaining and improving organic matter, appropriate crop rotation, manure application, rational mechanical and conservation tillage, maintaining soil cover, minimizing soil erosion losses by wind and water, and application of organic and inorganic fertilizers in amount and timing, and by methods appropriate to agronomic, environment and human health requirements.

Use of Fertilizers: Fertilizers are natural or synthetic substances that are added to the soil or plants to provide them with nutrients necessary for plant development. The use of fertilizers is a common practice to increase soil fertility and consequently the quantity and quality of fruits and vegetables

Food Safety: Food safety is defined as the assurance that the food will not cause harm to the consumer when it is prepared and/or eaten according to its intended use.(FAO/WHO, 1997)**.** Food safety is an obligation of all food sector operators (producers, processors,exporters, importers, etc.) to place on the market wholesome products that:

- Comply with current requirements
- Do not have a harmful effect on consumer health
- If defective, can be withdrawn from the market

Precision Horticulture

Precision Horticulture is the application of Precision Farming to horticultural production. It deals with the individual monitoring, control and treatment of horticultural products at the right place and right time in particular in cultivation and harvesting. Important enabling technologies are sophisticated sensors and sensor networks, automation/mechanisation and robotics. Precision Farming seems to focus on arable production. However, also in the vegetable sector there have been very innovative developments, e.g. in greenhouse climate control, remote pests monitoring, sophisticated harvesting robots, and dynamic simulation of crop growth. (International Conference Smart AgrimaticsSeminar Smart Horticulture June, 13 2012).

Vegetables the Smart Choice to Meet Global Food Challenges

The world will need 70 per cent more food, as measured by calories; to feed an expected global population of 9.6 billion in 2050, according to the United Nations sponsored World Resources Institute. The new report, titled World Resources Report: Creating a Sustainable Food Future highlights the efficiency of vegetable crops in providing calories for a growing global population, as well as recommending that modern farmers switch their focus towards sustainably managing existing production. “When you look at the amount of inputs such water, fertiliser and energy which is used to produce meat and dairy products, vegetables and horticultural products perform very efficiently as the plant does not have to be grown, fed to an animal then converted to food,” said AUSVEG Environmental Spokesperson Mr Jordan Brooke-Barnett. AUSVEG is the leading voice in horticulture, representing 6,000 vegetable and 3,000 potato growers. “The findings contained within the report reflect the priorities of Australian vegetable industry’s Environed program, which aims to promote environmental best practices,” said Mr Brooke-Barnett. “Meeting the challenges of environmental sustainability outlined in the report will challenge agricultural industry members and consumers alike to assess their consumption and production methods, promoting production methods and products which minimise environmental impact,” said Mr Brooke-Barnett.

According to the report, most of the world's people consume more milk and meat than nutritionally necessary and obtaining calories and protein through animal products is also highly inefficient in terms of resource use. The most efficient sources of meat such as chicken only convert around 11 per cent of the food and water they consume into human food, while beef is particularly inefficient at 1 per cent (www.ausveg.com.au.)

Grafting

For thousands of years various fruit industries around the world have been grafting trees to deal with many production problems like diseases, vigour, soil pests, and environmental effects. Commercial grafting of vegetables has only started recently, even though it has been documented in Japanese writing many centuries earlier. The practice is very popular in Southeast Asia. Last year, it was estimated that 20% of China's watermelon was produced from grafted plants and South Korea and Japan produced about 700 million seedlings each. However, since the early 1990s, vegetable grafting has been gaining steady popularity in the Middle East, Western Europe, and more recently in the US for several reasons. In Europe in 2009, Spain was the leading user with an estimated 129 million plants, followed by Italy with 47 million and France with 28 million plants. In the US, it is estimated that 40 to 45 million grafted plants were grown in 2005. Grafting is widely used in horticulture for a variety of reasons. In fruit trees like apple, dwarfing rootstock are used to control the size and vigor of the tree. With field grown vegetables, grafting is used to increase resistance to soil-borne diseases. Increasingly greenhouse tomato growers are using grafting to both decrease susceptibility to root diseases and to increase fruit production through increased plant vigor.

Grafting involves splicing the fruit-producing shoot (called the 'scion') of a desirable cultivar onto the disease resistant rootstock from of another cultivar.

There are three primary techniques used for grafting: tongue approach grafting, cleft grafting and tube grafting. Cleft grafting is generally used in brinjal and tomato and tongue approach grafting in Cucurbits.

General Grafting Tips

Expose plants to full sun and some water stress in the days before grafting to keep the plants short and to increase tolerance to water stress. Immediately before starting to graft, make sure plants have been watered and are turgid (not wilted). If grafting is done in the greenhouse, do it early or late in the day to avoid undue water stress and drying of the cut plants. Ideally, grafting should be done in a shady place, such as a work area out of the greenhouse that is sheltered from the wind and bright sun.When grafting, cut both the shoots (scion) donor plants and the rootstock plants on the same angle with a razor. Do not cut more plants than you can graft together in a few minutes since it is very important that you do not let the cut surfaces dry out or the scion wilt. Next match the scion with a rootstock of equal stem diameter and place the cut surfaces together in tight contact before clipping in place. The objective is to maximize the chances for the vascular bundles of the scion come into contact with the respective vascular tissues of the rootstock.

In conclusion, vegetable grafting is moving closer to becoming an accepted practice for commercial vegetable production. It has many advantages, but lack of information about the systems and the cost is still high for many growers

Hydroponics

Hydroponics or soilless culture is a cultivation technique for growing plant without soil. This technique has formally been known in Thailand since 1988 from the conference held by the Thai Society of Soil and Fertilizers(Koohakan*et al*, 2008). Hydroponics is a subset of hydro culture and is a method of growing plants using mineral nutrient solutions, in water, without soil. Terrestrial plants may be grown with their roots in the mineral nutrient solution only or in an inert medium, such as perlite, gravel, biochar, mineral wool, expanded clay pebbles or coconut husk. The general growing systems are nutrient film technique (NFT), deep flow technique (DFT), dynamic root floating technique (DRFT) and substrate culture. Among these, NFT is the most popular technique due to an attractive platform.

Hydroponic vegetable gardening has steadily gained popularity as a hobby that anyone can enjoy. If you have limited space and cannot form a full-fledged vegetable garden, hydroponic gardening would be a rewarding experience. With the help of hydroponics growing systems you can easily grow vegetables you desire without worrying about the outdoor setting or soil problems. It is important to provide plenty of lights for hydroponic indoor garden to get a good result. Some of the hydroponic gardening secrets to make vegetable garden healthy without much effort:

- In hydroponics, the plants roots are suspended in a solution of nutrient rich water solution to absorb essential nutrient from it
- When you are planning to make your own hydroponic vegetable garden, choose from the assortment of types of containers available in the market for hydroponic growing.
- Use rock wool as a growing medium because it provides roots with a good balance of water and oxygen
- Right amount of hydroponic nutrients for your vegetable garden is very essential for plants vigorous growth.
- Hydroponic vegetable gardens require plenty of lights for their growth
- Try to maintain grow room temperature and humidity level, to create an ideal environment for vegetables to grow.
- Even if you live in place where environment is not suitable for growing plants, with hydroponics systems you can make growing possible.
- Hydroponic vegetables are healthy, energetic, and consistently reliable.

Advantages

- No soil is needed for hydroponics.
- The water stays in the system and can be reused - thus, a lower water requirement.
- It is possible to control the nutrition levels in their entirety - thus, lower nutrition requirements.
- No nutrition pollution is released into the environment because of the controlled system.
- Stable and high yields.
- Pests and diseases are easier to get rid of than in soil because of the container's mobility.

- Ease of harvesting.
- No pesticide damage.
- Plants grow healthier.
- It is better for consumption.

Disadvantage

Without soil as a buffer, any failure to the hydroponic system leads to rapid plant death. Other disadvantages include pathogen attacks such as damping off due to *Verticillium wilt* caused by the high moisture levels associated with hydroponics and over watering of soil based plants. Also, many hydroponic plants require different fertilizers and containment systems.

Transgenic Male Sterility for Hybrid Seed Production in Vegetables

The development of strategies to improve crop plants by the production of hybrid varieties is a major goal in plant breeding. Hybrid progeny often have a higher yield, increased resistance to disease, and an enhanced performance in different environment compared with the parental lines. Availability of cost effective mechanism/ method to produce large scale hybrid seed utilizing selected parental line is one of the important factors which ultimately determine the commercial viability of hybrid varieties. Manual emasculation increased cost of production, so use of various genetic mechanism via; male sterility, self incompatible, gynoecious lines, use of sex regulators and chemical hybridizing agents based on relative importance in hybrid development. Among these, genetic emasculation tools male sterility is commonly used for hybrid production.However, the most significant development is the possibility of engineering male sterility by inserting cloned gene sequences which can disrupt any or more than one step during microsporogenesis. Male sterile transgenic plants can be obtained through genetic transformation with related genes destroying or interfering with pollen or anther development. Male sterile cauliflower, tomato, cabbage, etc. have been developed in this way, and some begin to be used to produce hybrid seed. Appling some techniques can also maintain and restore the male sterility. These related researches will effectively promote the heterosis utilization and the development of crop breeding.

Design and Construction of Greenhouse for Vegetable Cultivation

India is having different agro-climatic zones. The greenhouse and service facilities are to be properly designed and located at a site in which soil is properly drained and sunlight should be available in plenty. For maximum availability of sunlight, the ridge of the greenhouse has to be oriented in North- South direction.

Classification of greenhouse:

- ***Structure***
  - Quonset
  - Curved roof
  - Gable roof
  - Venlo
- ***Glazing/ Clading***
  - Glass, fibre glass reinforced plastic

- Plastic film
- Ultraviolet resistant low density polyethylene
- Net house
- Poly-carbonate

❖ ***Number of Span***

- Free standing or single span
- Multispan or ridge and furrow or gutter connected

❖ ***Environment Control***

- Naturally ventilated
- Evaporative cooled or fan and pad
- Heated greenhouses

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Challenges for Climate Smart Production of Banana

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Bananas and plantains are known for its antiquity and also interwoven with Indian heritage and culture. The plants are considered as the symbol of 'prosperity and fertility'. Owing to its greater socio-economic significance and multifaceted uses, they are referred as 'Kalpatharu' (plant of Virtues). Banana and plantain fruit is a wonder berry which forms the staple food of millions of people across the globe, providing more balanced food than any other fruit or vegetable. As a dessert, banana is more filling, easy to digest, fat free, rich source of carbohydrate with a calorific value of 90 Kcal per 100 g fruit and is free from sodium, making it a salt free food fruit. It contains various vitamins and has therapeutic values for the treatment of many diseases.

In North Eastern India, banana powder is used as baby food and being a good source of potassium is good for heart patients. Stem core juice is a well-recognized medicine for dissolving kidney stones. Plantains are rich in vitamin A (beta-carotenes) and they aid in digestion. Ripe fruits are being used in the treatment of asthma and bronchitis. Nectar from the flower buds are rich in vitamin, hence given for strengthening of babies. Juice from the male bud provides effective remedy for all stomach problems. The powdered peel of ripe banana have antiseptic properties and hence used in the healing of cuts and wounds. Banana as an industry has a wider applications. Frozen banana purees are being used in the manufacture of yoghurts, milk shakes, ice-creams, breads, cakes, banana flavored drinks, baby food and sauces. Banana flour obtained by drying and grinding the green fruit is easily digestible than the cereal flour. Banana juices are being used in the production of beer with low alcohol content and rich in vitamin B6 can helps to relieve stress and anxiety. Unripe banana and plantain can be dried and made into a meal, which can be used to substitute up to 70-80% of the grain in pig and dairy diets. Starch can be extracted from banana pseudostem and corms which is used for making glue, used in the manufacture of cartons for exporting fresh bananas. Banana seeds are used for making necklaces and other ornaments. Use of sap as a dye, fruit as a meat tenderizer and ash in the manufacture of soap and anti dandruff shampoos. Sap can be used as a natural film forming resin, which along with isopropyl alcohol produces better quality ink for inkjet printers. Dried banana peel contains 30-40 per cent tannin, making it suitable for leather processing. The production of floor wax and shoe polish from banana peels is also being explored. Under non-edible sector of banana products, fibre plays a major role. Banana yields a fibre, which is used extensively in the manufacture of certain papers especially where greater strength is required. The papers are also being used for making tea bags and currency notes like those of Japanese Yen. It has use in the textile industry, for making ropes and handicrafts.

World Production Trend

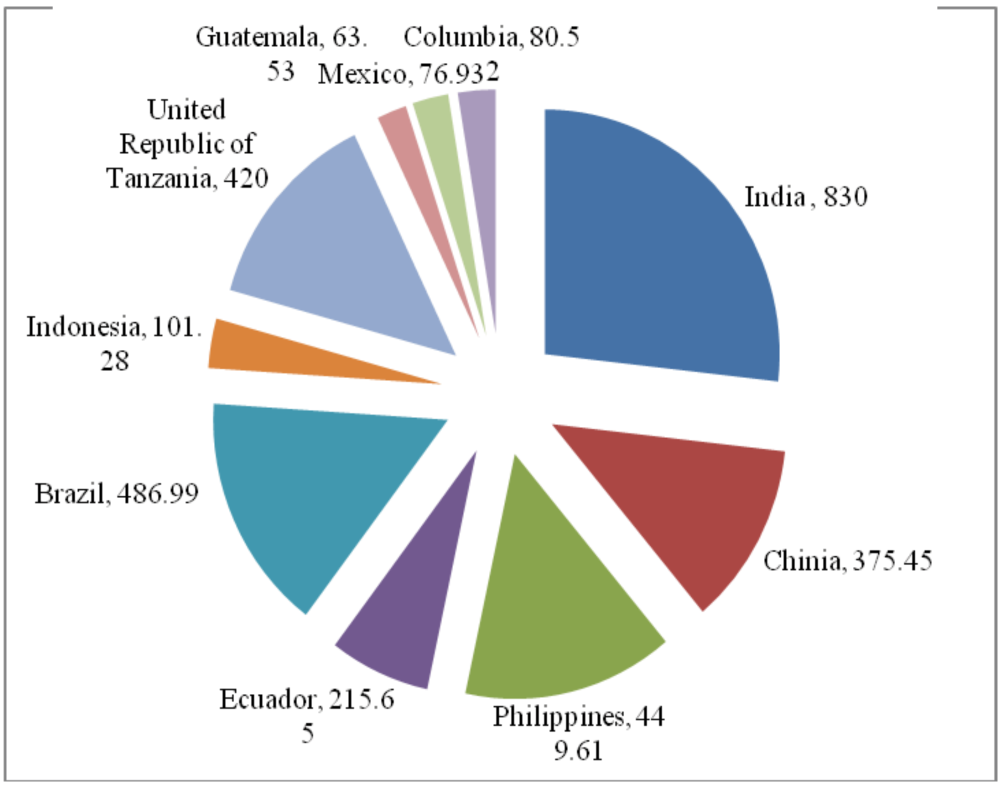
India shares nearly 830 metric hectares of banana cultivating area in the world followed by Phillipines and Brazil with 449.61 and 486.99 Mha respectively. Among the banana growing countries of the world, India ranks first in total banana production with 29.7 million tonnes followed by Uganda and China with 11.1 and 10.7 million tonnes. India shares 29.19% of total banana production in the world (FAOSTAT 2010). China, Philippines and Ecuador have witnessed steady growth owing to the entry of contractual production through banana grants like Dole and Chiquita.

In comparison with the leading banana producing countries in the world, Indonesia ranks first with 56.83 MT/ha followed by Guatemala and Ecuador with 41.52 MT/ ha and 36.78 MT/ respectively. India productivity has ranked to about 35.88 MT/ha. Per capita consumption is the highest in Uganda followed by Burundi, Rwanda, Gabon, Ecuador and Ghana.

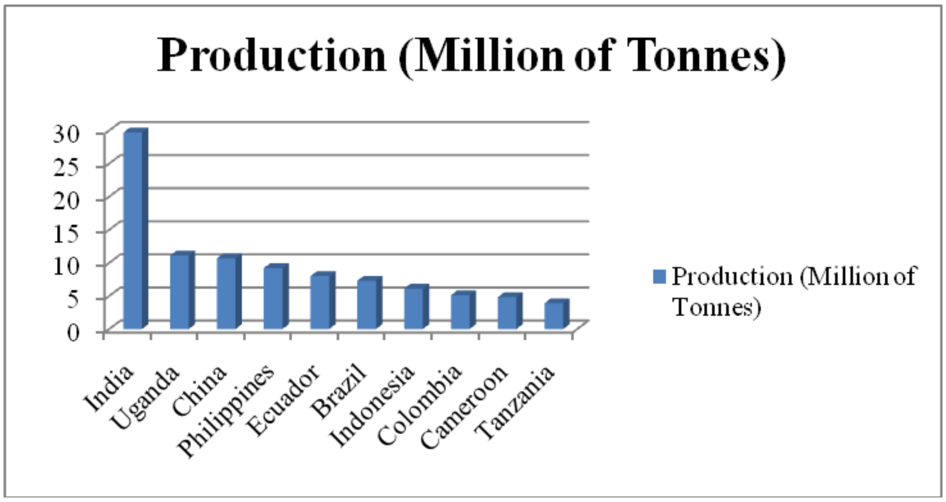
Banana Production Statistics

Uttar Pradesh has been observed to have an increase in growth and production of banana (35.77%) with area under sugarcane being shifted to banana cultivation. Mizoram has recorded a better growth rate in terms of area (14.78%), production (34.95%) and yield (17.57%) in the last decades suggesting virgin hilly terrains could be better exploited for banana production.

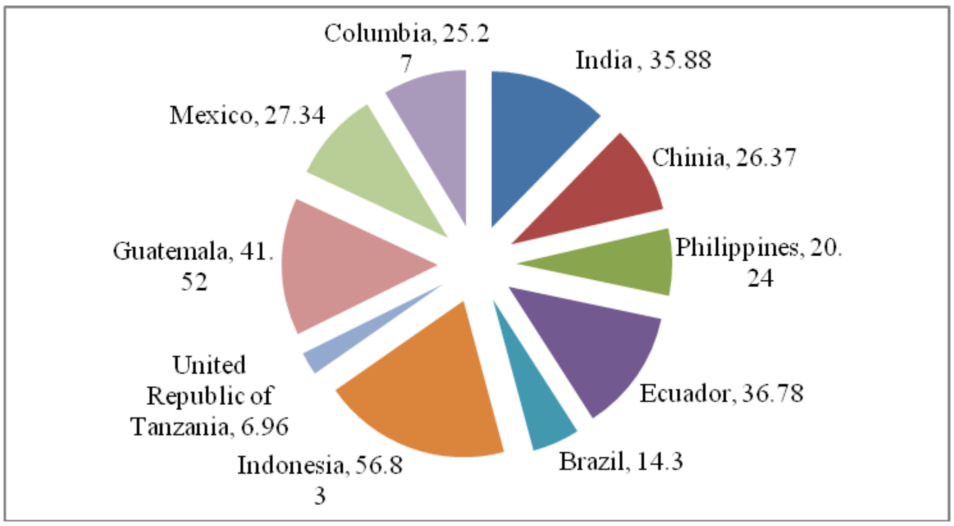
Area shared by major banana producing countries (00ha)



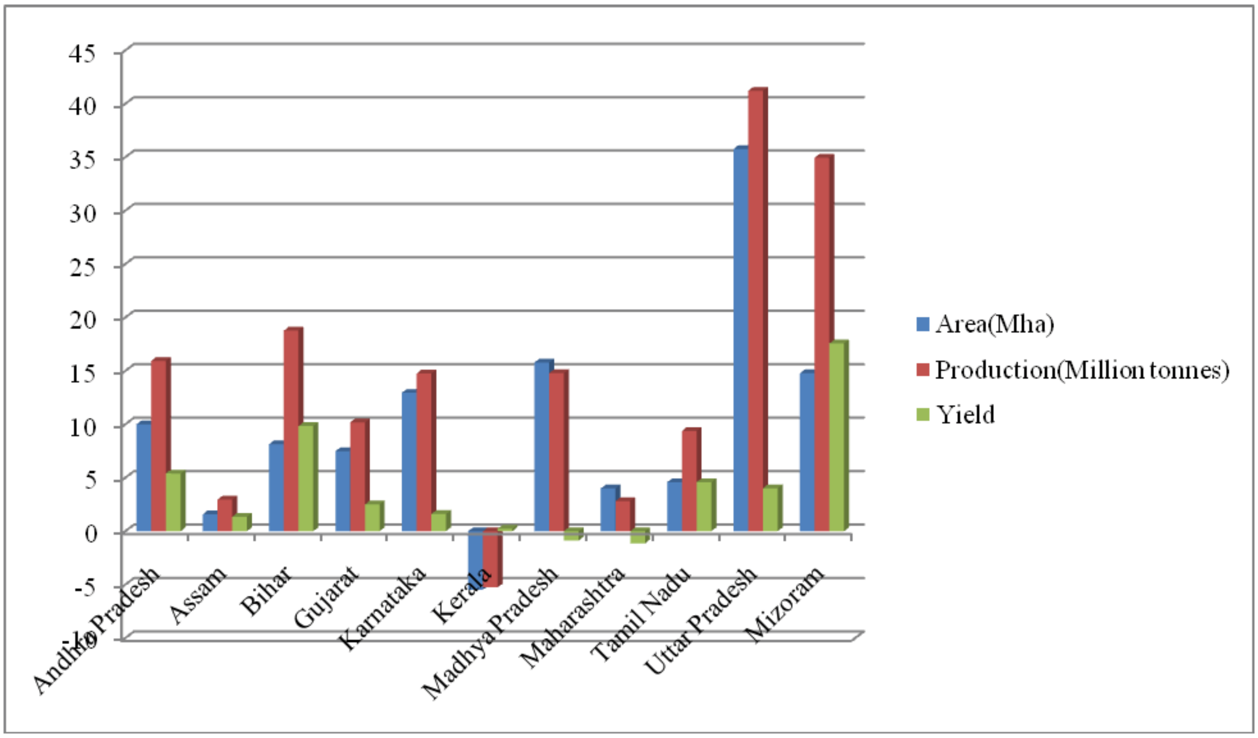
Production in major banana producing countries in the world



Productivity of major banana producing countries (MT/ha)



Rate growth in area, production and yield of banana in the last decade.



Tamil Nadu has shown stagnant growth during the last decade while Kerala has shown a significant decrease in area and production. Similar trends are observed with Madhya Pradhesh and Maharashtra. Other states like Andhra Pradesh, Bihar, Gujarat and Karnataka have been recorded to have a consistent growth throughout the years.

Growth of Banana in the Last Decade in Major Banana Growing States of India

In India banana is cultivated in a total area of 8.3 Lakh ha and the total production accounts to 29.77MT. Banana production in Maharashtra has increased mildly from 2003-2004 with an average of 4692.74MT and there has been a sudden increase in 2010-2011 with 8.25MT followed by slow decline. In Tamil Nadu the average production has accounted to 2514.70-666.04 MT during 2003-2009 followed by a decrease in average to about 1346 MT and has reached its height in 2012-2013 which has recorded to be 3808.02 MT. Andhra Pradesh has shown a steady increase in banana production (1223.90-3210.69MT) in the last decades.

Banana Production Trends in Leading Indian States in Last 5 Years

During 2010-2011, Maharashtra has recorded the highest production rate of about 8253.0 MT but in the recent years the production rate has been decreased. Tamil Nadu, a major banana producing state had a production rate of 6667.04MT in the year 2008-2009 which decreased gradually and then increased and attained its level in 2012-2013. Gujarat and Madhya Pradesh was found to be largest producer of banana in India, whereas Assam and West Bengal were found to be the least producers of banana throughout the years.

Musa Genetic Resource Management in India

Genetic Resource Management in Banana

Domesticated Banana is basically a tropical crop but successfully acclimatized to subtropical regions. Similarly their progenitors, wild Musa species are also found to occur from tropical to subtropical climate with altitudes ranging from mean sea level to 1800m above MSL. Most of wild species are sheltered at an altitude between 500-1000m above MSL in the sub Himalayan mountains and Western Ghats. Survey in India suggests that Musa has diversified conveniently at medium altitudes of 500-700 m above MSL over several years and moved either way towards higher and lower elevations and distributed without much problems. This has been the case especially in North-Eastern India in Khasi, Jaintia, Naga, Patkai and Garo hills. While in Western Ghats, two centres of diversity, namely Agasthiarmalai and Silent Valley are under moist tropical evergreen forests where a parallel evolution of Musa species has taken place along with North-Eastern zone. But urbanization has led to severe genetic erosion leading to the loss of many Musa species and wild relatives. Same is the case in countries where Musa has its origin and diversification. This has been considered a serious issue and experts across the world were consulted leading to the development of Musa conservation strategy document (Anon 2011) with the objectives like,

Ensure the secured conservation of the entire Musa genepool by assessing the diversity conserved and filling gaps, with an emphasis on threatened material.

At national level, The NRCB, Trichy has this responsibility along with other state Agricultural universities for collection, conservation and utilization of Indian Musa germplasm. After thorough morpho-molecular characterization, has successfully established a core banana collection of 363 accessions (313 indigenous and 50 exotic) which included different genomes namely AA (26), AAA (26), AAAA (1), BB (20), AB (23), AAB (99), ABB (103), ABBB (7), Rhodochlamys (5), lesser known species (3) are being maintained in field genebank. Complementary strategies like *in vitro* and cryopreservation have been successfully attempted in conservation of banana germplasm in the recent past.

The FAO-in trust global collection of Musa is held at International Transit Center (ITC) [formerly known as International Network for Improvement of Banana and Plantains (INIBAP) Transit Centre] at Katholieke Universiteit Leuven (KUL), Leuven, under the aegis of Bioversity International, in the form of 1,212 accessions held as slow growing in vitro cultures (Garming et al., 2010). It is committed to the long-term conservation of Musa genetic resources under the auspices of the FAO in the context of a global conservation strategy. The successful use of low cost alternatives in the tissue culture media without affecting the genetic fidelity has been demonstrated through field evaluation and molecular characterization. Cryopreservation of *Musa* germplasm is being done at NRCB and NBPGR in a collaborative mode. NRCB provides virus indexed cultures/suckers to NBPGR while NBPGR has standardized cryopreservation protocols using vitrification technique and proliferating meristems as explants. Till date, 60 accessions have been successfully cryopreserved.

Status of Varietal (Mono and Polyclonal) Situation in India

Banana is one of the few crops where man-made hybrids failed to excel the natural hybrids. Most of the present day bananas grown both nationally and internationally are the natural hybrids, which have evolved and acclimatized to various agro-ecological conditions. Globally till 1970, Gros Michel was the popular export variety, which was wiped out due to Fusarium wilt and substituted, by Grande Naine and other Cavendish ecotypes in the last few decades. Presently Grande Naine is the ruling variety in the global banana industry. Situation is almost the same in India, where Cavendish clones like Robusta, Dwarf Cavendish, Shrimanthi, Giant Governor, Mahalakshmi etc., are being commercially cultivated. Present survey has indicated an alarming situation by commercialization of few selected varieties inadvertently. The distribution of Cavendish clones was only 50-55% until 1980's, which has increased to 70% in 2005-06. This is owing to high productivity, good economic returns and wide market acceptability. Although it has elevated the living standards of the banana farming community in the country, it is always tagged with the possible problems associated with monoculture. Cavendish clones and its high susceptibility to various pests and diseases especially leaf spot and heart rot can result in repeat of the history, where Gros Michel was wiped out because of *Fusarium* wilt.

In India situation is slightly relaxed owing to polyclonal situation where more than 20 varieties are grown to cater to the local markets. They include some of the hardy varieties like Poovan (Champa), Karpuravalli (Cheeni Champa), Kunnan, Ney Poovan (Elakki Bale), Thella Chakkara Keli, and so on. By and large, Central, Western and Northern India have adopted Grand Naine cultivation which has spread even to non conventional areas of U.P, Punjab etc.. Pisang Awak has been a hardy variety adopted in marginal areas of Bihar, West Bengal, and most of the north Eastern States. Poovan has been another hardy clone well suited for coastal areas of Maharashtra and southern states has been doing well where Sigatoka (*Mycosphaerella eumusae*- Eumusae leaf spot) are rampant. Elakki Bale or Ney Poovan has been time tested in drought and marginal soils has well adapted to subtropical and tropical zones of Karnataka and Maharashtra. There are many more traditional varieties and landraces grown in different Indian states cushioning the ill effects of monoculture are provided in table 1. Kothia, Chakia, Muthia are some of the cooking varieties of northern India while Monthan and Bluggoe are ruling the southern markets as culinary varieties.

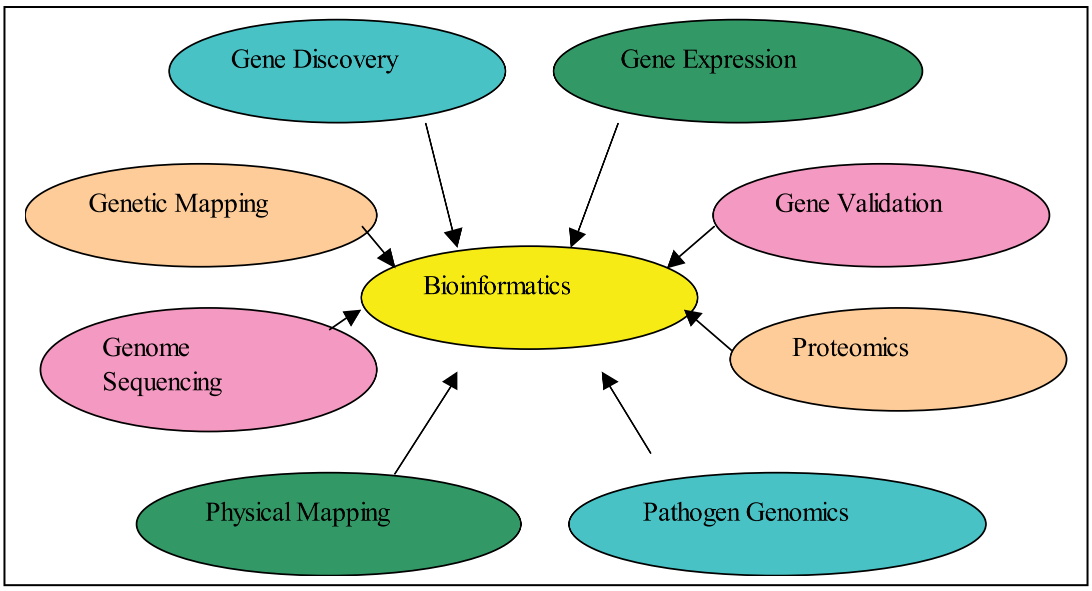
Breeding of new hybrids with most commercial Cavendish genetic background (AAA) is also very difficult because all Cavendish clones are mostly both male and female sterile. In view of the present situation, an alternative strategy has to be developed to promote the traditional varieties which are elite and location specific as substitutes for Cavendish. Some of the potential introductions for commercial cultivation are presented below.

Research and Development

BIOVERSITY INTERNATIONAL, earlier known as INIBAP (International Network for the Improvement of Banana and Plantains) was established in 1985 as a programme of IPGRI, Rome to cater to the research and co-ordination needs of people across the world. The mission of Bioversity's research group is to help people, especially small scale producers and their communities, to improve their well being through effective use of banana diversity. This includes management of pest and diseases in an environmentally friendly way and to use biotechnological tools to improve banana production and productivity. Bioversity recognizes priorities; generate new technologies and achieve impact through networks and partnerships. It has major programmes under Genetic conservation, Crop Improvement, Sustainable Production and Processing and marketing.

It has global IMTP programme (International *Musa* Testing Programme) which pools together the improved hybrids with resistance to pests and diseases, from the global breeding programmes and evaluate in various national programmes to cater to the needs of poor banana community. It has the responsibility of safe guarding of global Musa germplasm, which is being carried out at International Transit Center (ITC) in Belgium where more than 1200 accessions are being store under slow growth conditions. Bioversity has also launched Global Musa Genetic Consortium (GMGC) which is an international network of researchers committed to establishing Musa as a model crop for studies of comparative genomics and for gene discovery, leading eventually to sequencing of the banana genome. This consortium has 37 institutions from over 24 countries. GMGC has demonstrated the success of networking, partnership, benefit sharing and targeted approaches can give better dividends which will benefit the stake holders and the small holders in the long run. It has following thematic programmes

GMGC WORKING GROUPS



Conventional Breeding Strategies

Banana production is mainly constrained by many biotic stresses. Research on biotic stresses has drawn sufficient attention world wide while abiotic stresses have got little attention. Among the abiotic stresses, drought, salinity and heat are the most important. Banana is the only crop, where hybrids are not popular as local varieties and landraces. The absence of improved hybrids even after six decades of research on banana and plantain is attributed to inherent problems like polyploidy, parthenocarpy, male and or female sterility and vegetative propagation. Agronomic traits like crop duration make banana and plantains more difficult to improve through classical breeding and their eventual large-scale field evaluation. Major global breeding programmes are in progress at FHIA, Honduras; IITA, Nigeria; IITA, Cameroon; IITA, Uganda; CIRAD, France and CARBAP, Cameroon. Indian programmes are being carried out at NRCB, Trichy; TNAU, Coimbatore; BRS, Kannara and IIHR, Bangalore. The major bottle necks in breeding bananas are: male and / or female fertility of desired parents, cross incompatibility among various genomic and ploidy status, poor seed set and poor seed germination.

Production and Management

Banana being a tropical crop, has acclimatized to subtropical, semi-arid and to some extent arid conditions. Depending on the longevity and the method of production system, it has been classified an annual, biennial and perennial cultivation. Plantains and Cavendish clones are replanted annually, but recent results have indicated the suitability of Cavendish clones for one plant crop followed by two ratoons which has resulted in substantial reduction in the production cost of banana.

Quality planting material is the key for successful production of banana. On an average, the requirement of fresh planting material works out to be 25 billion / annum, at a planting density of 2500 plants / ha which is an enormous demand. 99% of the planting material requirement is met by suckers and the rest by tissue cultured planting material. Presently 15-20 viable companies are involved in the production of tissue cultured banana with an annual production of 2 - 5 million plantlets.

To ensure the quality of tissue culture multiplied plants, certification standards have been developed by DBT for virus indexing and genetic fidelity. Recently DBT has recognized NRCB, Trichy as the Accredited lab for fidelity testing and virus indexing. The strict certification standards will help the banana growers in getting quality planting materials. On the other hand, the planting material as suckers, has serious implications on the profitable production of bananas due to the lack of quality certification.

High Density Planting (HDP)

High density planting is one of the successful approaches for increasing the production / unit area. Under Indian conditions, 2500 plants is the normal density which can be increased to 4500-5200 plants / ha under high density planting. The reduced per plant yield is compensated by the increased number of bunches produced per unit area Fertigation, a technique where the fertilizers (N and K) are applied daily to the roots of individual plants in small quantities through irrigation water. HDP coupled with fertigation increased the yield by 2-2$^{1}/_{2}$ times. In Robusta, 1.8 x 1.8m spacing with weekly fertigation of 75% of recommended dose of N & K produced highest yields with a mean bunch weight of 35.5 kgs / plant. Similarly paired row planting recorded 23.3% higher yield than conventional planting. In Rasthali, 20% higher yield was recorded under paired row planting system with 50% recommended dose of fertilizers. Saba a cooking, banana also responded positively for the paired row planting and fertigation with 50% recommended dose of N & K recording 24% higher yield.

Banana and plantains are fertilizer intensive crops and respond well for organized and spaced application of nutrients. It is established that a crop yielding 50t/ha/yr of fresh fruits, about 1500kg of K/ha/yr is extracted from soil. Study indicated thetfield grown plants status of other nutrients is N-450, P-60, Ca-215, Mg- 140,S-75, Mn-12, Fe- 5, Zn-1.5, B-1, Cu-0.5 kg/ha/yr (Jeyabaskaran and Kumar, 2014). Effective nutrient management includes, timely application, need based replenishment and timely rectification of nutrient deficiencies. With change to correct the deficiencies and changing scenario in banana production, efficient nutrition management system needs emphasis for reduced cost of production and increased productivity.

NRCB has developed effective micronutrient mixture and providing access to growers at subsidized cost. Similarly targeted yield concept has been attempted using various fertilizer adjustment equations for commercial varieties for maximizing the profitability. DRIS chart has been constructed trough extensive nutrient indexing surveys which has helped input monitoring and maintaining different nutrient ratios at optimal level for better productivity in banana.

Organic banana have created a niche market both at the national and international levels. Although, organic cultivation is not profitable in the initial years, it has been found promising in the long run. The sources of organic manures to be used in the organic farming have been defined by the International certification agencies. Among the organic manures, compost, vermicompost, neem-cake and poultry manure (2.5+1+1+2.5kg respectively) at 3rd, 5th and 7th month after planting recorded better yield per unit area. Interestingly, these organic sources have a positive effect in controlling Sigatoka and nematode infestations extended the shelf life and quality of fruits. Among the alternate sources of inorganic nutrients explored for use in banana cultivation, Cement Kiln Flue Dust (CFKD) is found to be a best supplement for K in banana. Among various biofertilisers used to enrich soil, phosphobacteria is found superior to *Azospirillum* and VAM. Application of rice husk ash is superior to vermicompost and poultry manure in increasing the bunch weight.

Targeted yield concept has been attempted using different fertilizer adjustment equations for commercial varieties for maximum profitability. DRIS chart has been constructed through an extensive nutrient indexing survey, which help in input monitoring and maintaining of different nutrient ratios at optimal level for better productivity in banana.

Precision Farming

Increasing efficiency in management system is the key aspect in Precision farming especially in small holdings by better management of farm resources. It is basically information and technology based management system, which includes Geographical Information System (GIS), Geographical Positioning System (GPS), yield monitoring devices, soil, plant and pest sensors, remote sensing etc. This technology allows the farmers to identify, analyse and manage the spatial and temporal variability of soil and plants for optimum profitability, sustainability and environmental protection. Precision farming in banana should include soil fertility status, weather data, forecasting models for yield, pest and disease outbreak, controlled irrigation and fertigation for a profitable and sustained production.

Plant Health Management

Pests

Banana production in India is affected by few major pests and they are location specific with production system playing a major role. Banana weevil (*Cosmopolites sordidus*) is of major concern in Kerala with little incidence in Andhra Pradesh and Assam. Pseudostem borer (*Odoiporus longicollis*) is the major menace on a number of varieties including Raja Vazhai, Nendran, Cavendish and other clones. It has wider distribution in all Southern States and N-E region. Systematic control measures by using chemicals, use of tolerant cultivars and appropriate production system has helped in check the spread. Though mites (*Tetranychus sp*) and thrips cause considerable damage to flowers and fruits, the situation is not alarming. Banana aphid, (*Pentalonia nigronervosa*) is a cause of concern as vector in transmitting Banana Bunchy Top Virus (BBTV) in areas with perennial cultivation. But in India, most of the commercial cultivars like Cavendish clones and Plantains are under annual cultivation, while Pome, Silk, Mysore are under 1+2 production cycles with effective controls to check the built up of aphids. Scarring beetle (*Besilepta subcostatum*) is serious only in North-Eastern states. The fruits affected by this pest have poor market acceptability, but chemical control methods have been standardised (Anon, 1995). Pouring of 30 ml of 0.05% monocrotophos in whorl is found effective.

Corm weevil (*Cosmopolites sordidus*), pseudostem borer (*Odoiporus longicollis*) and nematodes are the major pests threatening banana production and productivity in the recent years. Corm weevil is globally important, infesting most of the commercial varieties. In India, it is more prevalent in Kerala and Nendran is the most susceptible commercial cultivar. Nendran under perennial system of cultivation is highly vulnerable to the attack by weevils and causes great yield loss. Chemicals have been successfully used to control corm weevil infestation but they are expensive and not eco-friendly. Hence, bio control and ecofriendly control methods have been identified and standardized in banana.

Pseudostem borer is becoming a serious pest in all commercial varieties of late and Cavendish bananas are being the most susceptible varieties followed by plantain. Cut pseudostem of 3 feet length is used as the delivery system for the bio-control agents (Beaweria bassiana) and entomopathogenic nematodes *(Heteriodora Oryzicola)* for monitoring and to control the pests. Semio chemical based Kairomones have also been identified. It is being tested under laboratory conditions as an effective trap. Controlling of pseudostem borer using pseudostem trap has been successfully demonstrated under highland production system as an ecofriendly approach.

Banana rust thrips (*Chaetanophothrips signipennis*) is becoming a serious concern. Polythene sleeves impregnated with 0.1% Chloropyrifos + paraffin oil + adjuvant controlled the thrips attack by 25-30%. Bell injection (flower bud injection) immediately after shooting with Imidacloprid 0.001% has controlled the rust infestation to a greater extent. Scarring beetle (*Besilepta subcostatum*) is serious only in North-Eastern and Eastern states. The fruits affected by this pest have poor market acceptability. It can be controlled using 0.05% Monochrotophos sprays. Survey and identification of effective new biocontrol agents and their effective utilization in controlling banana pests needs immediate attention.

Nematodes

More than 36 species of nematodes are affecting banana, of which four species namely *Radopholus similis*, *Pratylenchus coffeae*, *H. multicinctus* and Meloidogyne incognita are of global importance. Nematodes cause yield losses ranging from 30 to 50%. Most nematodes are inhibit nematodes activity only for a shortwhile as most of the compounds are not toxic to the nematodes. The repetitive application of non fumigant nematicides in long run leads to worldwide biodegradation syndrome. Nematodes are usually controlled by using nematicide like Carbofuran, which has high residual toxicity. So, focus is now on the development of eco-friendly management strategies like use of neem based formulations like Nimbicidin and Econeem @ 30ml / plant. Biocontrol agents like *Pseudomonas flurescens*. *Paecilomyces lilacinus, Verticillium chlamydosporum, V.lecanii, Baccillus subtilis, Trichoderma harzianum and T.viride* have been effectively used for the management of banana nematodes. Use of VAM (*Glomus fasiculatum* and *Glomus mosseae)* at planting and after 3 months effectively reduced the infestation of nematodes and increased the growth of the plants. Use of AMF (Arbuscular Mycorrhizal Fungi) are obligate symbions colonizing in roots and know to reduce the effect of impact of soil borne pathogens. Though mechanism of action is still debated but induced resistance is demonstrated. Some non-pathogenic Fusarium oxysporum endophyles have shown the ability to reduce pathogen population both in controlled and field conditions.

Fungal Diseases

Among the fungal diseases, *Fusarium* wilt and Sigatoka leaf spot complex are quite serious and *Erwinia* rot is gaining significant importance in tissue culture plants of Cavendish group. *Fusarium* wilt is serious in cultivars Rasthali, Karpuravalli, Pachanadan and Virupakshi. Foc race 1 is more widespread than race 2 while tropical race 4 only affecting the Cavendish clones which is not yet reported in India. Though chemicals and other cultural methods have been reported to control the disease, current emphasis is on biocontrol agents and botanicals. Fusaric acid detoxifying strain of *P.flurescens*, *T.viride* and *Bacillus subtilis* @ 10g / plant each at the time of planting, 3rd and 5th MAP reduced the wilt incidence.

Fungicides such as Propiconazole, Mancozeb and Bavistin have been found effective in controlling the leaf spot diseases during winter period. Biocontrol agents like *T.viride* and *P.flurescens* and botanicals such as Solanum, Emblica and Jatropa effectively controlled the pathogen.

Sigatoka Leaf Spot Complex

Mycosphaerella leaf spot diseases are the biggest constraint to commercial banana production throughout the world. The three main causal agents are *Mycosphaerella musicola* (Sigatoka disease, also known as yellow Sigatoka), *Mycosphaerella fijiensis* (black leaf steak disease, BLSD, also known as black Sigatoka) and *Mycosphaerella eumusae* (eumusae leaf spot disease). These species are closely related and have very similar morphology. These three major species attack all commercial varieties of banana with species specificity. At the global level, Black Sigatoka or referred as Blask Streak Disease is very serious on Cavendish clones and in the export oriented western farms, 40-45 sprays are undertaken to control the disease. Petroleum oil, dithiocarbamates, chlorothalonils, strobilurin are the major chemicals used to control Sigatoka along with Benomyl. But strategic resources like some of the chemical forecasting models, logistics, inoculum management curative effects using carrier and adjuvant and post pathogen sensitivity studies will help to control the Sigatoka in a more sustainable way.

Septoria leaf spot (*Septoria eumusae*) eye spot (*Drechslera* sp.) and pitting disease have been recorded for the first time in India. Erwinia rot is becoming a serious problem especially in tissue culture plants of banana for which two effective bacterial antagonists have been identified.

Viral Diseases

In the recent years knowledge on these viruses has expanded but some of the fundamental epidemiological question remains unanswered. Five viral diseases have been reported in India and among them BBTV, BBMV, CMV and BSV are considerably important. Occurrence of BBTV has wiped out large area under hill banana cultivation. It has been recorded even in wild bananas of Arunachal Pradesh. BBTV isolates of North Eastern states and lower Pulney hills exhibited more than 90% similarity which indicated that it is quite prevalent in the hilly tracts also. Now, it is possible to do indexing of hill bananas against BBTV for large scale sucker multiplication and supply to the hill banana growers.

BBMV is another devastating viral diseases affecting plantain and many important commercial varieties. In Robusta and Ney Poovan, application of higher dose of fertilizers (150%) increased the yield in BBMV infected plants. Often Bract mosaic virus is confused with sugarcane mosaic strain of Abaca. It might have alternate hosts in its epidemiology.

CMV occurs in almost all banana growing states. Control can be achieved only through effective legislative measures and quarantine procedures.

Banana Streak Virus (BSV) is present in every banana-producing region worldwide (Jones, 2000). BSV infections can lead to severe decline in yield especially in Poovan varieties. BSV is the main constraint for germplasm movement, breeding and tissue culture of *Musa acuminata* x *M. balbisiana* interspecifichybrids and species due to the presence of infectious BSV endogenous pararetrovirus (EPRV) sequences in the genome of *M. balbisiana*. Tissue culture techniques trigger the activation of infectious BSV EPRV in such interspecific hybrids and species, giving rise to infectious viral particles (Dallot *et al.*, 2000). Therefore meristem tip culture, which was widely adopted for generating virus free germplasm from infected plant material cannot be used safely for generating virus free hybrids.

Two new virus Banana Mild Mosaic Virus (Ban MMV) and banana virus X (BVX) have been reported from the west. There is indirect evidence that Ban MMV is transmitted between plants in the field but no vector is identified. But Ban MMV is expected to have synergistic effects with other viruses.

ELISA based techniques have been developed for the detection of BBTV and CMV. Polyclonal antiserum has been produced for the Indian strain. This has facilitated the development of effective diagnostic kits to check the disease spread in tissue cultured banana. Diagnostic kits are currently available for all the four banana viruses and are being used commercially. PCR technique has been developed to simultaneously detect two (Duplex PCR) or three banana viruses (Multiplex PCR) i.e., BBTV, BSV and BBMV. But worldwide genuine identification of BSV is reported to be y IC-PCR and multiplex IC-PRC will be able to detect other strains of BSV in one go. Genomes of BBTV and BSV have been completely characterized while those of BBMV and CMV have been partially characterized. These would facilitate the development of PCR based markers for the detection of viruses at early stages in the nursery. Currently, protocols have been developed to detect viruses even in vectors. This would be helpful to study the epidemiology of banana viruses.

Post Harvest Technology

Banana being a highly perishable fruit and the post harvest losses are estimated to be 8-9% at farmers level, 20-25% at wholesaler's level and 15% at retailers level. Physiological loss in weight, spoilage and fruit drop are the major factors contributing for the loss. As far as the post harvest diseases are concerned anthracnose, crown rot and cigar end rot are the three major diseases affecting banana fruits. Propiconazole is recommended for the control of the post harvest diseases. Similarly biocontrol agents like *Trichoderma viride*, *Pseudomonas* sp. and botanical *Solanum torvum* have been found effective against post harvest pathogens. Spraying of Bavistin (0.2%) and bunch covering at shooting, gave protection from insect pests, improved the quality and appearance. Usually, bunches are harvested at 90% maturity for the local markets and 75% maturity for distant markets. Hydro-cooling, use of ethylene absorbent, waxol treatment and packing with polythene wrapping increased the green shelf life. Combination of heat shock, modified atmosphere packaging, storing in CFB box in cold storage at 13.5^{o}C extended the storage life up to 126 days in Rasthali and 136 days in Robusta. The cold stored fruits ripened normally after treatment with Ethrel (500ppm).

Banana can be processed into different value added products. The NRCB, Trichy has developed protocols for more than 14 value added products and 4-5 products have been commercialized already. Aseptically packed pulp has high demand for export. Banana puree has maximum application in dairy products, bakery, beverage and baby food. Blending of banana (70%) with pineapple (30%) juice recorded maximum organoleptic value. Banana flour is also becoming popular. Banana flour based functional foods like Chapathies, bread and health drink are found to control the blood sugar level on par with other diabetic food available in the market.

Plantains are usually processed into chips. For every ton of chips produced, 3-4 quintals of raw banana peel is generated as waste. A technology has been developed at NRCB to convert the waste into pickle of acceptable quality. Preparation of pickle from male bud of banana has been standardized. This technology has been transferred to several entrepreneurs for commercialization.

The disease scenario at global level is also alarming with devastating black Sigatoka complex (*M.fijiensis, M.musicola, M.eumusae*), Moko disease, and *Fusarium Oxysporum f.sp.cubense* (race 1 on silk, race 2 on Bluggoe and race 4 on Cavendish clones) and other minor diseases. In India, disease situation is well under control due to selection of varieties, varied agroclimatic conditions, season and production systems involving crop rotations. Cost of banana cultivation in India is comparatively cheaper compared to the global level with availability of manpower in abundance, extensive area for cultivation and availability of raw material and inputs for cultivation. On an average production cost of an average bunch works out to be Rs 45-50 for marginal cultivars like Poovan and Rs 65-80 for intensively cultivated Cavendish clones which amounts nearly one US dollar. For the production of export quality bunches production cost be slightly higher with more emphasis on quality. This situation is very attractive entrepreneurs to to take up export oriented banana production in India. With experience gained by selected Indian exporters, varietal diversity seems to be a better choice to capture niche markets.

Summary

The status of banana has been uplifted from a mere backyard fruit to a high value crop both in national and global scenarios. Consumption has proportionately increased with the magnitude of production. India being the largest producer has witnessed 120% increase in production and 70% in the productivity in the last three decades, in due to the adoption of improved production technologies. Simultaneously, the pests and diseases attacking banana have increased and also in their complexity. Sustainable solutions are limited in view of the constraints in developing improved hybrids through conventional breeding where biotechnological approaches seem to play a major role. Single solutions are to be replaced with integrated, sustainable and participatory approaches. Availability of clean planting material, either as suckers or as tissue-cultured plants, should be given priority. Development of certification standards for the tissue culture companies by the DBT, New Delhi is a positive approach. Some of the emerging opportunities for organic banana production for local and export market, varietal diversification for export have to be considered seriously to surge ahead in the global market. During this process, development of feasible environment and market policies, understanding of innovative systems, improved capacity building, adoption of knowledge are expected to long term dividends.

Emerging Issues and Strategies

1. Identification of climate smart banana varieties

    - Gros Michel, the export variety taught a lesson to banana export economies about the disease outsmarting the producers. With existing spectrum of diseases and pests and newly emerging ones, there is a definite need for the identification of climate smart varieties which can be relied upon in case of eventualities.

2. Virus cleaning and re-establishment of accessions

    - While identifying the climate smart varieties, the focus is on status of field gene banks being affected by BBTV or BBrMV, and least research on cleaning of valuable germplasm from inherent viral diseases. This leads to in accessibility of original clean mother plants for large scale production. Hence alternative strategy of virus cleaning on centralized regional basis needs to be planned.

3. Access to quality planting material

    - Presently 15-20 viable companies are involved in the production of tissue cultured banana with an annual production of 2 - 5 million plantlets while total requirement is more than 200 millions. There is a need to devlop a holistic system for certification of tissue culture labs, certification standards, incentives etc. For India this system need to be extended to sucker planting material as well. This needs to be complemented with strict internal quarantine to avoid spread of localized pests and diseases.

4. Strategies for future research Widening bio diversity and Genetic enhancement and establishment of National gene banks, cryo preservation.

    - Synergies of frontier sciences like – Biotechnology, Nanotechnology, GIS, Molecular profiling including genome sequencing of important cultivars, varieties and hybrids Marker aided selection for the desired traits and identifying genes controlling superior quality traits, pest and disease resistance Molecular mechanisms of host-pathogen interactions

5. Cost effective nutrient budgeting through integrated nutrition management (INM) for targeted production and organic farming strategies through effective recycling of bio mass residues Development and popularization of cost effective technologies (INM/IPM) for increasing the productivity.

6. Good agricultural practicesincludingIntegrated cropping / farming system and mixed farming system, systems and nutrient management practices

7. Canopy architecturing and crop modeling - management to suit the requirement of different plant High density planting system to increase productivity.

8. Banana is one of the best sources for carbon crediting and hence carbon sequestration studies could be more rewarding.

9. Developing techniques for integrated pest and disease management

10. Developing value added products, niche products and by product utilization for which technologies are to be developed along with popularization, encouragement of SHG, NGO's etc. .
11. Value addition, wealth and nutritional benefits of banana need to be popularized, which should go with branding banana and plantains as neutraceutical, pharmaceutical and cosmoceuticals.
12. Bio-risk management - Surveillance, identification and characterization of new invasive pests and pathogens, Pest risk analysis, Development of rapid and reliable diagnostics against pests and pathogens including invasive species and Management of new invasive pests and pathogens.

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Spices- An Option for Medicine, Heath and Wealth

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Introduction

The word food is derived from the word '*feed'* the prime source that keeps all the living things to continue their healthy living. Since time immemorial, spices and herbs have been used by many cultures around the world not only for food but to treat illness.

Spices and Herbs as Food and Ethnic Medicines

Indians are the pioneers in the knowledge of spices and have been supplying these food processing agents for over 3500 years. Herbs and spices have tremendous importance in the way we live, as ingredients in food, alcoholic beverages, medicine, perfumery, cosmetics and colouring. They prevent food spoilage due to the action of microorganisms, help quick digestion of the food, create a cooling sensation in the body due to their diaphoretic action, excite sex centres and keep urine sterile when they are used moderately. Excessive use of spices cause irritability in gastro-intestinal and urinary tract, therefore, they are contra-indicated in their respective diseases. They are not recommended in gall bladder diseases and gout. They also have antioxidant, antimicrobial pharmaceutical and nutritional properties. In addition to the known direct effects, the use of these plants can also lead to complex secondary effects such as salt and sugar reduction, improvement of texture and prevention of food spoilage.

The basic effects of spices when used in cooking and confectionery can be for falvouring, deodorizing/masking, pungency and colouring. They are also used to make food and confectionery more appetizing and palatable. Some spices like turmeric and paprika re used for imparting an attractive colour. Because of their antioxidant and antimicrobial properties, spices have dual function – in addition to imparting flavour and taste, they play a major role in food preservation by delaying the spoilage of food.

Many herbs and spices have been used in cosmetics, perfumery and beauty and body care since ancient times. The toiletries and allied industries use spices and herbs and their fragrant oils for the manufacture of soaps, toothpastes, face packs, lotions, freshness sachets, toilet waters and hair oils. They are essential ingredients in beauty care as cleansing agents, infusions, skin toners, moisturizers, eye lotions, bathing oils, shampoos, hair conditioners, cosmetic creams, lotions and creams for improvement of complexion and purifying blood. Spices form an important component in quite a few alcoholic beverages and beers.

Herbs and spices have been an essential factor in health care through ages in all cultures. They are prepared in number of ways to extract their active ingredients for internal and external use. Extracts from herbs and spices are used as infusions, decoctions, macerations, tinctures, fluid extracts, teas, juices, syrups, poultices, compresses, oils, ointments and powders. Many medicinal herbs used in Ayurveda have multiple bioactive principles. The most commonly used spices, herbs and their major medicinal properties and uses are given in Table 1.

Table 1: Important spices and their medicinal properties

Sl. No.	Common name	Botanical name	Medicinal Uses
1	Ajowan	*Trachyspermum ammi* L. Sprague ex. Tussil	Antispasmodic, stimulant, tonic and carminative. Administered in flatulence, dyspepsia, diarrhea, cholera. Effective in relaxing sore throat and in bronchitis. External application of fruit paste recommended in asthma. Used in preparation of ointment for checking chronic discharge. It is diuretic and carminative.
2	Allspice	*Pimenta dioica* (L.) Merr	Used to treat flatulence, dyspepsia and diarrhea, Rheumatism and arthritis. Remedy for depression, nervous exhaustion and stress. has antioxidant properties
3	Angelica	*Angelica archangelica* L.	Antispasmodic, aphrodisiac, anticoagulant, bactericidal, carminative, diuretic, expectorant, nervine, stimulant and tonic properties. Used in stomach complaints, vomiting, leucoderma, and reduces accumulation of toxins.
4	Anise	*Pimpinella anisum* L	Carminative with good flavour and fragrance.
Sl. No.	Common name	Botanical name	Medicinal Uses
5	Asafoetida	*Ferula asafetida* L.	Stimulant to mucus membrane, carminative, antispasmodic, expectorant, laxative and digestive. Also used in asthma, bronchitis and whooping cough.
6	Basil	*Ocimum basilicum* L	Carminative and anti microbial used against gas, nausea and dysentery.
7	Black caraway	*Bunium persicum* (Bosis) B Fedtsh	Stimulant and carminative. Used in treating diarrhea, dyspepsia, fever, flatulence, stomachic, hemorrhoids and hiccups.
8	Black cumin	*Nigella sativa* L.	Seeds are carminative, stimulant, diuretic, emenagogue, galactogogue, used in mild cases of puerperal fever, skin eruptions. Alcoholic extract shows antibacterial activity. Also used as preservative.
9	Black	*Brassica nigra*	Used against lung congestion, bronchial problems

	mustard	(L)Koch	and inflammation.
10	Black Pepper	*Piper nigrum* L.	As aromatic stimulant in cholera, vertigo, coma, stomachic in dyspepsia and flatulence. Externally valued for its rebefacient properties. Used as protective in filaria.
11	Capers	*Capparis spinosa* L.	Reduces flatulence and have anti- rheumatic and antioxidant properties, used as hepatic stimulants, diuretics, kidney disinfectants, vermifuges and tonics.
12	Caraway	*Carum carvi* L.	Antispasmodic and used against gas pains.
13	Cardamom	*Elettaria cardamomum* Maton	As adjuvant to carminative drugs, as stomachic and in dyspepsia. Home remedy for indigestion, nausea, halitosis, bronchial infections, skin diseases, inflammations, itching and poisons.
14	Capsicum	*Capsicum annum* L	Source of capsasin, capsorubin vitamin C,A and E it has health enhancing effects in clearing lungs, increase flow of digestive juices, triggering brain to release endorpins (pain killers) and anti oxidantand as a muscle relaxant. Used in flavoring, and colouring food products.
15	Celery	*Apium graveolens* L	Carminative and sedative used againest gas pains and as a tonic.

Sl. No.	Common name	Botanical name	Medicinal Uses
16	Cinnamon	*Cinnamomum verum*	Carminative, antispasmodic, aromatic stimulant, diuretic, haemostatic, astringent, stomachic and germicide. Used in pain balms, cold, cough, gastric troubles. It also has anti microbial and anti oxidant properties.
17	Clove	*Syzygium aromaticum* Merr & Perry	Aromatic, stimulant and carminative, used in gastric irritation and dyspepsia. Administered in powdered form to relieve nausea and vomiting, to correct flatulence. Oil used as local analgesic for hypersensitive dentine and carious cavities. Has antiseptic and pain relieving qualities.
18	Coriander	*Coriandrum sativum* L.	Fruits carminative, diuretic, tonic, stomachic, antibilious, laxative, refrigerant, aphrodisiac. Fruits and leaves used against colic, dizziness, kidney stones, indigestion, sore throat.
19	Cumin	*Cuminum cyminum* L.	Seeds are stimulant, carminative, are stomachic,

			astringent and useful in diarrhea and dyspepsia and veterinary medicine. Is an appetite stimulant and good digestive. Used for common gastro intestinal upsets.
20	Dill	*Anehtum graveolens* L	Folk remedy for infant cholic and digestive disorders.
21	Fennel	*Foeniculam vulgare* Mill	Anti spasmodic and used in indigestion and stomach cramps.
22	Fenugreek	*Trigonella foenum-graceum* L.	Seeds are carminative, tonic, antiarthritic and galactogogue. Used externally in poultices as emollient for intestinal inflammations. Aqueous extract shows antibiotic activity. Used in treatment of chronic bronchitis, disbetis, hepato and splenomegaly.
23	Galangal	*Kaempferia galanga*	Stimulatory, expectorant, carminative and diuretic. Also used for dyspepsia, headache and malaria.
24	Garlic	*Allium sativum* L.	Has a significant carminative effect with a release or nausea. It brings about a decrease in triglycerides and cholesterol. Oil drops used in earache. Preparations given in pulmonary phthisis, bronchiectasis, gangrene of the lung and whooping cough. Used in laryngeal tuberculosis, lupus and duodenal ulcers, pulmonary tuberculosis. Used in dyspepsia, flatulence and colic. Antiseptic, ntispasmodic and used in lowering cholesterol, reducing hyper tension.

Sl. No.	Common name	Botanical name	Medicinal Uses
25	Ginger	*Zingiber officinale* Rosc	Carminative, stimulant, remedy for flatulence and colic, adjunct to stimulant remedies. Contains antihistaminic factor, remedy for diarrhea and constipation, anorexia and indigestion. Ginger tea is used for colds , coughs, flu and hangovers. Ginger compresses are used to relieve sinus congestion, kidney problems, menustral cramps, and various aches and pains. Its is also rubefacient.
26	Greater galangal	*Alpinia galangal* L.Willd.	Rhizomes are bitter, acrid, thermogenic, nervine tonic, stimulant, carminative, stomachic, disinfectant, aphrodisiac, bronchodilator and tonic properties. Also known for antimicrobial, antifungal, antiprotozoal and expectorant activities. Used in skin diseases, indigestion, colic, dysentery, enlarged spleen, respiratory diseases, cholera, mouth and stomach cancer.

Sl. No.	Common name	Botanical name	Medicinal Uses
27	Horse radish	*Armoracia rusticana* Gart.	Antimicrobial, diuretic, stimulant, diaphoretic. Used in treatment of arthritis, respiratory and urinary infections and fevers.
28	Juniper	*Juniperous communis* L	Diuritic and carminative.
29	Kokkam and cambodje	*Garcinia indica* Chiocy *Garcinia cambogia* Desr.	Source of natural red pigment and hydroxycitric acid which reduces cholesterol and used as anti obesity agent. It is used against bilious infections, dysentery, mucous diarrhoea, etc.
30	Lavender	*Lavendula officinalis* Chaix	Carminative, spasmolytic, tonic and antidepressant. Used in headache, neuralagia, rheumatism, depression etc.
31	Longpeppe r	*Piper longum* L.	As an stimulant, anticolic, anti-tussive and inducing resistance to infections. Fruits and roots used in respiratory tract diseases, as counter-irritant and analgesic; as a snuff in coma and drowsiness, sedative in insomnia and epilepsy, as a cholagogue, emmenogogue and abortifacient, as ingredient in rejuvenating medicine.
32	Lovage	*Levisticum officinale* W.D.J.Koch	Used against gas pains and breath deodorizer.
33	Marjoram	*Marjorana hortensis*M	Source of sweet marjoram oil .antioxidant antispasmodic, anti microbial , carminative, stimulent and nerve tonic. Used in asthma, coughs. Indigestion, rheumatism, tooth ache and heart conditions.
34	Mints	*Mntha piperita L (*pepper mint*),M. spicata* (spear mint)	Pepper mints menthol is added in many medicines for its therapeutic effects. They have carminative and emmenagogue effects. They make refreshing herbal teas.
35	Nutmeg	*Myristica fragrans* Houtt.	As stimulant, carminative, astringent, aphrodisiac, tonic, electuaries and forms constituent of preparations prescribed for dysentery, stomach ache, flatulence, nausea, vomiting, malaria, rheumatism, sciatica, early stages of leprosy. Mace has been recommended for treatment of inflammations of bladder and urinary tract. Butter is a mild external stimulant in ointments, hair lotions. Used in helminthiasis, cough, asthma, amenoohoea, dysmenorrhoea etc.
36	Onion	*Allium cepa* L	External anticeptic has many medicinal properties. Also used in reducing intestinal

			disorders, hypertension, diabetes, cholesterol, fat in the blood, and inflammation.
37	Oregano	*Origanum vulgare*	Rich in Vitamin E, B6, riboflavin, niacin, pantothenate and biotin. Is an antioxidant, carminative, stomachic, diaphoretic and expectorant. Used in colic, coughs, headaches and irregular menstrual cycles.
38	Parsley	*Petroselenium crispum* Mill	Used as liver tonic, laxative, carminative and against kidney stones. Relieves flatulence and colic. Rich in minerals and vitamins A, C.
39	Pomegranate	*Prunica granata* L.	Astringent, anthelminthic and used against tapeworm, cooling and refrigerant and used against dysentery and diarrhoea.
40	Rosemary	*Rosemarinum officinalis* L.	Carminative, antidepressant, anticarcinogenic, antispasmodic, rubefacient, antimicrobial, anti-inflammatory. Used in pulmonary diseases, antidiarrhoeic, antidiabetic, antispasmodic and antidepressant.
41	Sage	*Salvia officinalis* L	Used for excessive swetting, fever and nervous disorders. Carminative and antiseptic.
42	Saffron	*Crocus sativus*	
43	Star anise	*Illlicium verum* Hooker	Antimicrobial, carminative, diuretic and stomachic. Used in digestives disturbances, cough mixtures and colic pain.

Sl. No.	Common name	Botanical name	Medicinal Uses
44	Summer savory	*Satureja hortensis* L.	Aromatic, carminative and expectorant properties.
45	Sweet flag	*Acorus calamus* L.	Constituents of tonics, also has antacid, purgative, antioxidant, antimicrobial and anti-insecticidal properties. Used in skin and hair care and also as stimulant.
46	Tarragon	*Artemisia dracunculus* L.	Diuritic, stimulant and emmenagogue.
47	Thyme	*Thymus vulgaris* L.	Used in bronchitis, whooping cough, has antimicrobial, antifungal, antioxidant, spasmolytic and anti-inflammatory activities.
48	Turmeric	*Curcuma longa* L.,	As an ingredient of curry powders, improves flavor and functions as antiseptic, anti poison factor. Aromatic stimulant tonic, carminative and anthelmintic. Paste of turmeric and neem leaves

	is applied to facilitate the process of scabbing. Used in treating eosnophilia. Ingredient of recipes intended for promotion of health and intelligence of children. As stomachic, tonic, blood purifier, antiperiodic, alterative etc. Anti oxidant and has anti carcinogenic and anti AIDS properties.

Source : Ravindran *et al*., (2004); Peter (2004), Reader's Digest (1986)

Functional Properties

In addition to their use as medicine, food additives for flavoring and preserving foods and beverages herbs and spices have nutritional, antioxidant, antimicrobial, insect repellent properties. They are rich source of proteins vitamins -A, C, B and E and minerals such as calcium, prosperous, sodium and iron etc. the nutritive values of a few spices are given in Table 2.

Of late there is increased awareness of the impact of natural foods and plant based medicines on the well-being and health of a person and the role herbs and spices play within this food chain. The World Health Organization (WHO) estimates that 80% of the world's population uses some form of herbal medicine, revealing the importance of herbs as medicinal plants. The number of practitioners of holistic medicine in the developed countries is increasing rapidly. This will stimulate demand for products made in the developing countries. Retail outlets for herbal products are increasing rapidly. The usage of some herbs will grow as the popularity of the schools of medicine in which they are used becomes progressively popular. The opportunities, however, are considerable, fuelled by the strong interest in the developed countries in health and well being, and the strong growth in expenditure in this field.

In the pharmaceutical field many drugs owe their origin to natural herbal ingredients. The greatest markets for herbal medicines, both in terms of manufacturing and consumption, are in Europe followed by Asia and Japan. Asian sales represent approximately half of the sales levels achieved in Europe.

Herbs in Flavors and Cosmetics

An increasing demand exists for herbs and herb derived products for a variety of applications other than phytomedicinals. These include food flavourings, cosmetic and personal hygiene products including fragrances, creams, and lotions, industrial chemicals, and feeds. The majority of herb and spice products (80%) are found in the form of tablets, although other applications include teas, tablets, capsules, tinctures, creams, oils, syrups, inhalants and liquids. The more popular herbs are those that address the same symptoms as do the top-selling, over the counter drugs. Best-selling herbs are those that can be used for antacids, flu and cold relief, laxatives, diuretics, stress reducers, mental clarity, energy, menstrual cycle relief or support and sleep aids (http://www.gov.mb.ca/).

Table 2. Nutritional Profile of few important herbs and spices (Source : Compiled from information on http://www.whfoods.com)

Table 2. Nutritional Profile of few important herbs and spices (Source : Compiled from information on http://www.whfoods.com)

Spice & herbs	Basil, Ground 2.00 tsp 7.52 calories				Cinnamon, Ground 2.00 tsp 11.84 calories				Pepper, Black 2.00 tsp 10.88 calories				Turmeric, Ground 2.00 tsp 16.04 calories			
Nutrient	Amount	DV (%)	Nutrient Density	World's Healthiest Foods Rating	Amount	DV (%)	Nutrient Density	World's Healthiest Foods Rating	Amount	DV (%)	Nutrient Density	World's Healthiest Foods Rating	Amount	DV (%)	Nutrient Density	World's Healthiest Foods Rating
Iron	1.28 mg	7.1	17.0	very good	1.72 mg	9.6	14.5	very good	1.24 mg	6.9	11.4	very good	1.88 mg	10.4	11.7	excellent
Calcium	63.40 mg	6.3	15.2	very good	55.68 mg	5.6	8.5	very good								
Vitamin A	281.24 IU	5.6	13.5	very good												
dietary fiber	1.20 g	4.8	11.5	good	2.48 g	9.9	15.1	very good	1.12 g	4.5	7.4	good	0.96 g	3.8	4.3	Good
Manganese	0.08 mg	4.0	9.6	good	0.76 mg	38.0	57.8	excellent	0.24 mg	12.0	19.9	excellent	0.36 mg	18.0	20.2	Excellent
Magnesium	12.68 mg	3.2	7.6	good												
Vitamin C	1.84 mg	3.1	7.3	good												
Potassium	103.00 mg	2.9	7.0	good									114.48 mg	3.3	3.7	Good
Vitamin B6													0.08 mg	4.0	4.5	Good
Nutrient	Thyme, Ground 2.00 tsp 7.92 calories				Peppermint Leaves, Fresh 1.00 oz-wt 19.85 calories				Oregano, Ground 2.00 tsp 9.16 calories				Rosemary, Dried 2.00 tsp 7.28 calories			
Iron	3.56 mg	19.8	44.9	excellent	1.44 mg	8.0	7.3	very good	1.32 mg	7.3	14.4	very good	0.64 mg	3.6	8.8	good
Calcium	54.16 mg	5.4	12.3	very good	68.89 mg	6.9	6.2	very good	47.28 mg	4.7	9.3	good	28.16 mg	2.8	7.0	good
Vitamin A					1204.31 IU	24.1	21.8	excellent	207.08 IU	4.1	8.1	good				
Dietary fiber	1.08 g	4.3	9.8	good	2.27 g	9.1	8.2	very good	1.28 g	5.1	10.1	very good	0.92 g	3.7	9.1	good
Manganese	0.24 mg	12.0	27.3	excellent	0.33 mg	16.5	15.0	excellent	0.16 mg	8.0	15.7	very good				
Magnesium					22.68 mg	5.7	5.1	very good								
Vitamin C					9.02 mg	15.0	13.6	excellent	1.52 mg	2.5	5.0	good				
Potassium					161.31 mg	4.6	4.2	good								
Vitamin B6																
TRyptophan					0.02 g	6.3	5.7	very good								
Folate					32.32 mcg	8.1	7.3	very good								
Omega 3 fatty acids					0.12 g	4.8	4.4	good	0.12 g	4.8	9.4	good				
Vitamin B2 (riboflavin)					0.08 mg	4.7	4.3	good								
Copper					0.09 mg	4.5	4.1	good								

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Health foods, Nutraceuticals and Medicines

Awareness of the benefits of a healthy lifestyle and the knowledge of the role played through nutritious eating has contributed to the renewed interest in incorporating herbs and spices into the health and eating regimes of people in developed countries. Increased awareness of calcium in the prevention of osteoporosis, dietary fibre in the prevention of colon cancer, importance of antioxidants (eg. Vitamin E, Vitamin C, Beta Carotene) in the diet, and the role of essential fatty acids. It is important to increase the utilization of herbs and spices and use of natural flavourings. The role of curcumin as anti oxidant anti carcinogenic and anti HIV are fast changing our acceptance of herbal components in pharmaceuticals. The lower incidence of adverse reaction to Herbal medicines and decreased cost as compared to conventional pharmaceuticals are driving national health care institutions to consider plant medicine as an alternative to synthetic drugs. Pharmaceutical firms recognize the potential of natural products to provide novel drugs as well as templates for the development of improved versions of the existing treatments for human illnesses.

Bio prospecting of natural resources has impetus around the world, for search of new and novel molecules as therapeutic agents. Studies indicate that around 60% of the antitumour and anti-infective agents are in later stages of clinical trials have plant origin.

Health foods, based on herbs and spices have been developed. A blend of herbs and spices was prepared as a chewing food that provides vitamins and fibres to the body, controls mouth odour and conditions intestinal functions. Nutmeg (Myristicin) has anti carcinogenic, Garcinia (HCN) has anti obesity, Cinnamim and Fenugreek as anti diabetic, Star anise has anti viral properties. The antidiabetic and hypocholosterolemic effect of fenugreek ensures its use in various antidiabetic preparations. A composition based on plant extracts and essential oils usable in therapy, cosmetics and dietics has been developed. Ginger is used as an antiemetic for cancer chemotherapy. The hypoglycemic and hypocholesterolemic properties of black caraway (*Carum carvi*) oil have been reported. Rosemary oil, improves chronic circulatory weakness on external application. Peppermint oil, spearmint oil and extractsso fnatural products have been reported to be effective as helicobacterial inhibitors. The antioxidant activity of spices and their extracts is due to the presence of phenolic compounds. Plant phenols may scavenge free radicals involved in lipid peroxidation as has been documented (Madsen et al., 1996).

World Market Trends

The major importing markets for medicinal plants are the EU and USA. In these countries, increased demand for medicinal plants is being fuelled primarily by consumer interest in natural products and remedies, as well as by increasing concerns about the possible side effects of allopathic medicines. Major developing countries such as China and India are exporting medicinal plants, herbal tonics, cosmetics, perfumes etc. However, markets in developed countries for herbal medicine – especially in Europe and the USA – are highly regulated and are very difficult to penetrate, particularly for developing countries and LDCs whose products have not undergone the stringent tests applied by developed country pharmaceutical manufacturers before mass production.

Total global herbal market is of size 62.0 billion dollars, in this India's contribution is only one billion dollars. European union is the biggest market with the share 45% of total herbal market. North America accounts for 11%, Japan 16%, ASEAN countries 19% and rest of European Union 4.1%. Countries like Japan and China have successfully marketed their traditional medicines abroad. When compared to the Chinese and the Japanese level of penetration in the global market India is not at all figuring anywhere. The forecast is that the global market for herbal products is expected to be $5 Trillion by 2050. Herbal remedies would become increasingly important especially in developing countries and India has a tremendous potential and advantage in this emerging area.

At global level, the production of spices is estimated at 23million tonnes grown over an area of 7.8 million ha. Global spice industry is to the tune of 1,050000 MT in volume accounting for US$ 2.75 billion in value. India's share at global level is47.7% in volume and41.75% in value .During 2011-2012, India exported 5,75,270 Mt valued around US $ 2037.76 million (Spices Board, 2012).Thus India still remains as a major hub of World Spice trade .

Recent research has helped propel the knowledge of other plants from around the world and this has helped accelerate the development of new supplements and medicines. The market share of herbal products made in developing countries remains comparatively low. The major successes have been achieved by Chinese products, mainly herbal supplements. The EU and the US regulations have special provision for herbal medicines that do not use mixtures of herbs. In this respect their regulations are, comparatively, relaxed. But if the exported products contain herbal mixtures and claim curative properties, the rules become much stricter. For medicines, product trials need to be carried out that cost several millions of dollars.

As markets grow, the search for a wider variety of ingredients is increasing. 'Phytomedicines' have already started to link traditional medicines with modern (allopathic) medicine, with research and development primarily funded by large pharmaceutical manufacturers.

However, there is still a general lack of knowledge within the world market about the whole range of traditional remedies available, and demand will grow as knowledge increases. The issue of consumer safety is increasingly important with the USA recently prohibiting the sale of some Chinese products. The developing countries will need to pay increasing attention to this.

Constraints

Medicinal herbs have received low priority in national investment, research and export development. Despite large import potential for spices as medicinal plants, market development is constrained by several factors like meager R&D facilities and investments, unlicensed un regulated markets, poor local technology as well as skill shortages and inadequate post harvest handling, storage, processing, and packaging resulting in poor quality and low unit values for exports, lack systems of measurement, standards, testing and quality (MSTQ) required by exporters to ensure their products meet international standards for hygiene, product specification and quality and lack of knowledge of supply and the lack institutional capability to advise on policy and regulatory mechanisms to provide consistently high-quality products. Know-how in processing technologies is also deficient, as is the availability of sustainable production processes. There is also limited knowledge of the medicinal properties of the herbs and spices beyond traditional knowledge and belief. This restricts the use and marketability. A systematic approach is requires to identify, validate and market high value compounds from various spices to have a larger share in global spices and pharma and cosmetic market.

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Spices Propagation – Challenges and Opportunities to Meet Changing Climate

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Introduction

India cultivates more than 50 spices out of 109 spiceslisted by ISO, this is possible because of diverse agro-ecosystems present in the country. Spices export have registered substantial growth during the last five years, registering acompound annual average growth rate of 23% in value and 11% in volume and Indiacommands a formidable position in the World Spice Trade. During the 2012-13, a total of 7,26,613 tons of spices and spice products valuedRs.12112.76 crore (Table 1) (US$2212.13 Million) has been exported from India, registering anincrease of 26% in volume and 24% in rupee terms and 8.5% in dollar terms of value compared to previous year.

Table 1: Export of spices from India (2012-13)

Item	Quantity(Tonnes)	Value (Rs. in Lakhs)
Pepper	15,363	63810.29
Cardamom(S)	2,372	21215.04
Cardamom(L)	1,217	6254.59
Chilli	3,01,000	238060.90
Ginger	22,207	18725.14
Turmeric	88,513	55487.70
Coriander	35,902	20182.59
Cumin	85,602	115306.61
Celery	5,171	2977.26
Fennel	13,811	10466.12
Fenugreek	29,622	10488.12
Other Seeds (1)	18,442	11178.60
Garlic	22,872	6868.14
Tamarind	17,950	10753.15
Nutmeg & Mace	3,231	22591.87
Vanilla	55	682.73
Other Spices(2)	16,293	18773.15
Curry Powders/Paste	17,436	27515.66
Mint Products(3)	20,039	3,94,049.95
Spice Oils &Oleoresins	9,515	155888.19
(1) Include Mustard, Aniseed, Ajwanseed, Dill Seed, Poppy Seed Etc.		
(2) Include Asafoetida, Cassia, Saffron Etc.		
(3) Include Mint Oils, Menthol & Menthol Crystal.		
Total	**7,26,613**	**12,11,275.80**

Source : DGCI & S, Kolkata/Shipping Bills/Exporters return (Spices Board)

India is a traditional spice producer and supplier to the world spice market, in addition to its strong domestic consumption.On a global scale, the annual growth rate in spices consumption is estimated at around 10%. At this rate, the India's demand by 2050 will be around 16.6 million tonnes. Estimated target of selected spices for 2050 are given Table 2. Each state cultivates one or other spice and India is known as 'Land of Spices'. During 2012-13, we had 3.2 million ha in spices with a production of 5.9 million tonnes (Table 3). Andhra Pradesh, Rajasthan, Gujarat, Karnataka, Madhya Pradesh, Tamil Nadu, Assam, West Bengal and Uttar Pradesh are important spice producing states in India (Table 4). Like in many other crop production sectors, spices production also facing several challenges like competing crops, price fluctuations, no buyers in remote production centres like north east, less labour availability, non- adoption of available mechanisation due to undulating terrain/topography or crop architecture, climate change, soil degradation, less water availability for irrigation in certain spice zones, etc.,. Above all, non-availability of diseases free quality planting material in sufficient quantity is an important constraint that hampers the sustainable spice production in the country.

Table 2: Estimated production target for spices in India (Qty. in '000 tons)

Area	Total demand by 2050	Extra to be produced over the present production	Productivity to meet the total demand by 2050 (t/ha)
Black pepper	239.25	197.25	0.94
Cardamom (S)	79.07	63.20	0.99
Ginger	2152.49	1380.30	9.35
Turmeric	2882.15	1819.70	10.03

Table 3. Area and production of important spices in India (2012-13)

Crop	Area('000ha)	Production ('000tonnes)
Pepper	200.279	40.62168
Ginger	155.063	755.6178
Chillies	804.792	1276.301
Turmeric	218.646	1166.843
Garlic	242.491	1228.324
Cardamom	89.006	15.816
Coriander	557.87	532.947
Cumin	593.98	394.328
Fennel	99.554	142.949
F. Greek	93.605	115.929
Ajwan	35.376	26.778
Dill / Poppy /Celery	33.47	32.642
Cinnamon /Tejpat	2.944	5.035
Nutmeg	17.485	12.57351
Clove	2.387	1.1051
Tamarind	58.428	202.574
Saffron / Vanilla	7.095	1.07421
Total	3212.471	5951.458

Table 4: State wise area and production of spices (2012-13)

State	Area('000ha)	Production ('000tonnes)
Andaman Nicobar	1.65	2.98
Andhra Pradesh	292.82	1129.31
Arunachal Pradesh	10.05	61.60
Assam	93.05	261.56
Bihar	13.01	12.54
Chhatishgarh	11.67	8.32

Goa	0.73	0.23
Gujarat	551.67	882.14
Haryana	12.80	61.69
Himachal Pradesh	4.77	19.26
Jammu & Kashmir	4.15	1.08
Karnataka	265.12	502.46
Kerala	254.55	112.80
Madhya Pradesh	299.91	461.17
Maharashtra	116.52	106.47
Manipur	10.47	24.14
Meghalaya	16.84	74.82
Mizoram	20.65	114.98
Nagaland	9.77	39.17
Odisha	123.92	187.50
Puducherry	0.09	0.12
Punjab	18.37	68.21
Rajasthan	730.51	871.64
Sikkim	24.38	54.41
Tamil Nadu	157.33	426.38
Tripura	5.68	18.04
Uttar Pradesh	58.29	201.97
Uttarakhand	6.60	38.77
West Bengal	97.12	207.70
Total	3212.47	5951.46

SWOT analysis on spices production

A. Strength	B. Weakness
a. Large number of genotypes and improved varieties b. Enthusiastic farmers/entrepreneurs c. Domestic demand and Export potential d. Easy improved method / techniques for planting material production	a. Unorganised b. No-steady demand c. Distance in transport d. Price fluctuation
C. Opportunity	**D. Threat**
a. Export potential b. Intercropping c. Scope of nursery in production centre **d.** Value addition	a. Abiotic and biotic stresses b. Competing countries c. Destruction of habitat d. Indiscriminate use of pesticides

Spices Propagation

The life span of spices vary, crops like black pepper, cardamom, tree spices are perennials, ginger and turmeric is annual and some are seasonal. Most of the perennials and annuals propagated through vegetative means like cutting, grafting, budding, rhizome etc.,. The spices propagated vegetatively should not harbour any disease or pest. Traditional methods of planting material production may not be sufficient to meet large scale demands and also may carry pathogens and pest, to overcome this problem new ways of production is perfected.

Challenges in Propagation

- Viral diseases in black pepper and cardamom
- Rhizome rot complex in Zingiberaceous crops
- Low multiplication rates in conventional methods of seed/planting material production
- Large quantity of seed material requirement in ginger and turmeric
- Long distance transportation of seedlings/seed
- Sex problem in nutmeg

Black Pepper

The 'cutting' is the main mode of propagation for commercial cultivation of black pepper. Seedlings take much longer to come to bearing than cuttings or layers and show genetic segregation. Farmers collect cuttings from 10-15 year old plants for field planting. Three node cuttings are taken from runner shoots of disease free plants after the pre-monsoon showers and planted at a distance of 30 cm away from the standard. These cuttings will get established after about three months when new shoots emerge. Establishment of cuttings depends on the prevailing climatic conditions. The rapid multiplication through bamboo method for production of large number of rooted cuttings under nursery conditions was developed (Bavappa and Gurusinghe, 1978). In this method, healthy and high yielding mother plants in the age of 5-12 years are selected during October – November and the runner shoots are kept coiled at the base of the vines to prevent any direct contact with soil and these runner shoots are removed during February – March and cuttings are taken and used for further multiplication in nursery. Split bamboos of 1.0 to 1.2m length of about 8-10 cm in diameter are arranged crisscross at an angle of 45º on the central support of horizontal poles placed along the length of nursery structure. The bamboos are then filled with a mixture of cattle manure and coir dust. The three node or single node cuttings rooted in the nursery is placed in the trench below the bamboo splits filled with potting medium and trained onto bamboo. The growing shoots are tied close to the medium filled in the bamboos to ensure proper contact for rooting. When the vines reach the top of the support the growing point is excised and 2 weeks later, shoots are severed near the base and divided into single-node rooted cuttings. The single nodes with sufficient root growth are planted in polythene bags filled with potting mixture. The multiplication ratio is 1:40. Another novel propagation technique in black pepper is the serpentine method. Rooted cuttings planted in polythene bags (20 x 10cm size with 200 gauge) are allowed tocreephorizontally and polythene bags with potting mixture are kept below the each node, the nodes are pressed into the mixture with small 'V' shaped midribs of coconut leaves. Once twenty nodes get rooted in the bag, first 10 nodes are separated individually by cutting at the inter nodes and cut endsare pushed back into the potting mixture as it also produces roots. The polybags are watered daily. After three months these cuttings are ready for planting in the main field. The multiplication ratio is 1: 60. The advantages are- it is simple, cheap and quick and suited to small and marginal farmers, and sprouting is betterthan rapid multiplication technique (Thankmani et al. 2004). A new method of soil-less nursery mixture for black pepper multiplication using plug-trays (Fig 1) was standardised using composted coir pith and vermicompost fortified *Trichodermaharzianum* as potting medium forblack pepper nursery(Prasath *et al*. 2014).Use of *T. harzianum* andvermicompost enriched coir pith in blackpepper nurseries minimizes useof chemicals.

Fig 1. Black pepper multiplication with plug-trays

Fig 2. Black pepper vines on beds containing rooting medium

In this method the vines are allowed to be trail horizontally on a bed of rooting medium (Fig 2) and individual nodes are separated after sufficient growth. Yet another modification is to grow the vines on vertical columns that ensures faster growth (Fig 3) and this method hastens the production of lateral branches.

The major advantages of soil free rooting medium is the avoidance soil borne pathogens such as *Phytophthora capsici, Radopholus similis* and *Meloidogyne incognita*. Thus production of pathogen free quality planting material is assured. As the potting mixture is light and porous enhanced rooting all along the medium occurs and ensures better establishment in the field. As the roots are compactly packed in the soft rooting medium it also prevents abrasions of roots during long distance transport. As the weight of the cutting is less compared to potting mixture filled bags, it can be easily carried after uprooting from trays.

Fig 3. Black pepper vines on vertical column containing

Cardamom

Cardamom is propagated either through seeds or vegetative means and being a cross-pollinated crop the seedling population is not uniform. Only 35 per cent of the plants are good yielders in a plantation raised from seedling population. Hence, vegetative propagation is normally adopted for multiplication of elite clones(Fig 4). Vegetative propagation can be either through suckers or tissue culture. Suckers from elite clones can be used for establishing plantations capable of high productivity. Plants raised from suckers come to bearing earlier than suckers. Suckers should not be used in areas where*katte* and other virus diseases (such as *Kokke kandu* and Niligiri necrosis) are common. High yielding varieties/selections are generally multiplied in isolated clonal nurseries. Virus free high yielding plants are selected and subcloned for further multiplication. For rapid multiplication following timely agro techniques has to be followed (Korikanthimath 2002).

Fig 4. Cardamom nursery

Ginger & Turmeric

Ginger and turmeric (Fig 5) are propagated vegetatively by portions of rhizomes known as seed rhizomes and among inputs, seed material requirement vary between 1500 to 2500 kg ha^{-1} or even more depending on rhizome size and seed alone accounts for about 40% of total cost of production(Anandaraj and Sudharsshan 2011). In order to obtain good germination, proper storage of early season seed rhizomes is essential. The seed rhizomes should be stored appropriately so that rotting, shriveling, dehydration and sprouting can be avoided until the next season. 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.

Turmeric

Ginger

Fig. 5. Conventionally grown seed crop of turmeric and ginger

In order to reduce the seed requirement, a new method of raising seedlings (Fig 6) from a seed piece (5 to 10 g) with single or double buds placed on a plug trays filled with rooting medium and kept for a month. This method enables easy long distance transport of diseases free seedlings and other advantages of reduced seed rate and better establishment without yield reduction in a lesser duration (by 30 days) in the main field compared to conventional method.

Fig 6. Ginger seedlings in pro-trays

Nutmeg

The nutmeg is propagated both by seeds and vegetatively by grafting or budding(Fig 7). Nutmeg is a dioecious plant occasional monoecious plants have been reported and seed propagation is not in vogue. Fully ripe, tree-burst fruits are to be used for raising nurseries. Farmers can also use grafted plants. *Myristica beddomei* and *M. malabarica* are related to nutmeg also can be used as rootstocks besides nutmeg. For raising seedlings for planting or as rootstocks, naturally split healthy fruits are harvested during June-July and the seeds are extracted and sown immediately.

Since the orthotropic and plagiotropic shoots can be used for grafting the resultant plants have a different growth pattern. Orthotropic shoots give rise to erect growing plants whereas plagiotropic (lateral) shoots give rise to bushy spreading plants. However, these may be induced to develop orthotropic shoots by bending above 90 degrees. Bush grafts are advantageous for high density crops. Grafts of elite high yielding trees can be prepared by epicotyle grafting instead of planting seedlings. Wherever seedlings have been established and trees are poor yielders or predominantly male, top working by budding or grafting can be done to get desired trees.

Vegetative propagation of Nutmeg

Summary

India is a traditional spice producer and supplier to the world spice market, in addition to its strong domestic consumption. On a global scale, the annual growth rate in spices consumption is estimated at around 10%. At this rate, the India's demand by 2050 will bearound 16.6 million tonnes. Climate change in terms of erratic monsoon and increased summer temperature are immediate challenges for black pepper. The severity of virus symptom expression is attributed to temperature stress. Starting the nursery with virus indexed mother vines is the starting point for production of healthy plantations.Non-availability of diseases free quality planting material in sufficient quantity is an important constraint that hampers the sustainable spice production in the country. Efficient production techniques for various vegetatively propagated spices are standardised. In this endeavor it is also essential to supply pest and disease free quality seed with proper certification to avoid disease spread particularly virus. The various methods of detecting pathogen and pest and standards for quality of spices planting material are elucidated in the recent book on diagnostics (Singh *et al*. 2013). A holistic approach in this direction is essential to supply quality material to farmers. 'Seed village' concept is also being adopted in many places to enhance the production of these materials.

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Technological Challenges for Production and Utilization of Spices

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Abstract

Spices are high value export oriented crops extensively used for flavoring food and beverages, medicines, cosmetics, perfumery etc. India is a major exporter of spices and spices products and during 2012 - 2013 India has exported 1,77,625 tons of spices valued Rs 2,71,147 registering 13% increase in value though there is 9% decrease in volume. In the quality front, the major consuming countries like Europe and USA are demanding more and more quality compliance by the producing countries. To meet this challenge we have to equip ourselves to produce, process and market high quality spices, with internationally accepted food safety standards. Role of Research in Sustainability, Food safety and Spices Industry needs immediate attention. There are many positive developments which can increase Spices production. They are,Good genetic diversity except in seed spices, (over 7000 accessions), over 250 improved varieties of spices suitable for various regions, availability of high production, INM & IPM technologies in most crops reasonable marketing network and industry capability and product development initiatives. In addition the demand and awareness about spices is growing and spices are finding newer applications in functional food, cosmetics and nutraceuticals. Indian spice industry is making excellent progress $ 2.04 Billion in 2011-2012 and is expected to grow to $ 3.0 billion by 2017.

However there are many challenges like, declining productivity, reduction of area under spice cultivation, increasing cost of cultivation, low international pricing and non availability of farm labour affecting spice industry. In addition, contaminantslike - illegal dyes (Rhodamine B, Sudan Red), Pesticides (BHC, Ethion), Aflatoxins, Salmonella etc. reducing the value of spice raw materials resulting in stringent food safety standards to regulate the spice trade. Development and harmonization of Global Standards on Good agricultural practices (GAPs) and food safety needs immedixte attention. Sustainability of supplies to bridge the Demand and Supply imbalances without adversely affecting the environment involving producers, traders, industry and consumers and adjusting to emerging Market Trends are other priorities. Climate change is another overriding factor affecting the production, productivity and quality. The other issues of importance are International competition, bio piracy and patenting.

Keeping these things in view the its important to focus our research on Development of climate resilient varieties resistant to biotic and abiotic stress, tag agronomically important characters and using them in Marker assisted selection- reducing breeding time, make available quality, healthy, disease free certified planting material, use of environment friendly botanicals, microbials (bio control agents, PGPRs and bio-fertilisers) which would be synergistic that would ensure greater sustainability of these crops, development of organic spices with no pesticide residues, cropping system approach for greater sustainability and to overcome market fluctuations and to mitigate climate change, mechanisation to overcome the shortage of farm labour, post harvest technology and value addition to reduce post harvest loses, reduce mycotixins, adulterants etc. development of Efficient storage and processing

methods, identification and validation of new biomolecules from spices for various pharma products, Functional foods, dietary supplements and nutraceuticalsetc are important.

Establishment of more storage, incubation facilities, Spices Parks and Enabling infra structure to develop – end-to-end capability and Up gradation of technology across the entire supply chain – a key driver of growth with Sustainable and equitable participation of all concerned.

Impact of Technology in Improving Production and Productivity of Horticultural Crops

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Sustainable, viable & cost effective technologies, whenever adopted results in increased income and employment adding to the over all farm welfare. However, technology adoption is not necessarily uniform across growing regions and appears to be influenced by a number of factors. In the national agricultural system continuously many technologies are being developed by the various ICAR Institutes, SAU's etc., Usefulness of these technologies could be known when they are demonstrated extensively and impact of them is assessed. Objective assessment of impact is a useful tool for identifying the constraining factors impending technology adoption and hence growth. Technology development and disseminating agencies need to evaluate the process of technology adoption and its impact from time to time, to be able to refine their technologies for better impact. Documentation of accrual of benefits/profits due to technology adoption is essential for assessing investments and to plan research road map for optimization of future research resource allocation. Above all, impact of technology adoption is of prime importance to investors, for assessing the returns to investment into research and for efficient allocation of scare resources and its prioritization.

Ideally, technology adoption and impact require twin assessments, before and after or with and without the technology. Economists' frame work for impact assessment is categorized based on the time of evaluation as, *the ex ante, concurrent and ex post*. Ex ante, assessment is an objective assessment for justifying the need for the specific research agenda. From a R & D point of view, such an assessment is essential for optimizing the allocation of limited research resources for generating outcomes that are absolutely useful. Concurrent evaluation is undertaken while the project is underway, primarily to identify research gaps and constraining factors that impede quick and uniform adoption of research outcomes. Such an evaluation provides scope for refinement and fine tuning of technology for specific clientele. An ex post evaluation process is the most ideal and essential when undertaken after a gap of time post implementation to understand the effectiveness of research outcomes. It provides and acid test for the significance, relevance and usefulness of the technology. Outcome of each stage of assessment is valuable as they provide justification, scope for mid course correction as well future direction for investment opportunities into R & D efforts.

During last four decades nearly 200 varieties and 300 management strategies have been developed at IIHR, Bangalore in various crops. The emphasis on varietal development was initially on enhancing productivity but however in later part of the period it was on quality and multiple diseases tolerance. Production technologies initially aimed at standardizing spacing, nutrient and water requirements but in due course emphasis was given on Integrated nutrient management, integrated insect & disease management, use of plant growth promoting microorganism, organic farming protocols, use of male annihilation technique (MAT) & semio-chemical for pest management, use of diagnostics for disease screening etc., The impact of some of the important IIHR technologies is given below..

Impact of IIHR Vegetable Varieties

During last four decades, IIHR has developed 197 varieties which included 97 in vegetables. Many of the vegetable varieties of IIHR are performing well under farmer's field. Some of the varieties like Arka Anamika in Bhendi, Arka Komal & Arka Suvidha in French Bean, Arka Kalyan & A. Niketan in onion and Arka Manik in watermelon have performed extremely better and covering nearly 20-30 percent other total area in the respective crops. The details of the varieties released are given in Table 1.

Table 1: Varieties/Hybrids released.

Crops	1971-80	1981-90	1991-2000	2001-11	Total
Fruit Crops	5	1	20	2	28
Hybrids	5	1	16	2	24
Varieties	-	-	4	-	4
Vegetable Crops	1	38	20	38	97
Hybrids	-	2	6	5	13
Varieties	1	36	14	27	72
National Level Release	-	10	8	6	24
Ornamental Crops	29	7	21	6	63
Medicinal Crops	2	1	3	2	8
Mushroom	-	-	-	1	1
Total	37	47	64	49	197

Okra (*Abelmoschus esculentus* (L.) Moench.) Variety Arka Anamika developed and released by IIHR has made tremendous impact at the national level. It is a derivative of an interspecific cross between *Abelmoschus esculents* (IIHR-20-31 Susceptible to YVMV) x *A.manihot* spp. *tetraphyllus var. tetraphyllis* (Resistant to YVMV). Colchicine induced F_1s amphidiploids were further back crossed with cultivated parent and in BC_3 F_{10} generation, high yielding, YVMV resistant line was selected and released as Arka Anamika in 1992. At the national level it was released and notified by the government of India in 2006 for the all the zones. Arka Anamika plants are vigorous growing, tall and erect bearing fruits in two flushes. Fruits of first flush are borne on the main stem and are ready for harvest in 40-45 days. While the in second flush, fruits are borne on short branches. Fruits are 15-20 cm long, spineless, lush green and tender and the fruit yield is 20 t/ha. in 130-135 days. The variety is resistant to yellow vein mosaic virus disease(YVMV). It has a wide adaptability to different agro-climatic zones and is cultivated in all the states. In the last 20 years, around 15000 kg of breeders' seeds were produced at IIHR and distributed nationwide to developmental departments like state horticultural departments, seed corporations and agricultural universities resulting in the large scale production of foundation and certified seeds. Besides, Arka Anamika seed is also produced in large quantities by the small, medium and large multi-national private seed companies . Of the total 5.18 lakh ha area in which okra is grown, it is estimated that Arka Anamika alone occupies 1.75 lakh ha with 33.8 percent coverage (Table 1). Thus, okra variety Arka Anamika has made a very high impact at the national level both in the vegetable seed industry as well as at the farmers level contributing immensely to the horticultural economic growth.

In french bean (*Phaseolus vulgaris*), two varieties namely Arka Komal and Arka Suvidha developed and released by IIHR have made tremendous impact at the national level. Arka Komal was a selection from IIHR 60 a germplasm collection from Australia. It was released at the institute level in the year 1984 and at the national level it was released and notified by the Government of India in 1990 for the all the zones. In this variety plants are bush, photo insensitive, pods mature in 45 days, pods are straight, 17 cm long, flat, light green, crisp, pod yield 19.0 t/ha in 70 days. This variety has a wide adaptability and is cultivated in many of the states. In the last six years itself, around 12760kg of breeders seeds were produced at IIHR, and distributed nation wide to state departments and subsequently these seeds have gone in the seed production chain into foundation and certified seeds. Of the total 1.18 lakh ha area in which french bean is grown, it is estimated that Arka Komal alone occupies 47200 ha with 40.0 percent coverage. Arka Suvidha is another variety which has made significant impact at the national level. This variety was developed at IIHR by pedigree method of selection by crossing Blue crop and Contender. It was released at IIHR in the year 1998 and at the national level it was notified by Government of India in the year 2006 for the Zone-I and VIII. Arka Suvidha is a high yielding, bush, photo-insensitive variety with oval, nearly straight, medium long(17 – 18 cm), green, stringless fleshy with smooth pods, pod yield 19.0 t/ha in 70 days. In last six years at IIHR, nearly 9000 kg of breeders' seeds were produced and distributed to state departments for subsequent multiplication and production of foundation and certified seeds. Out of 1.18 lakh ha area in which French bean is grown, Arka Suvidha is produced in around 23600 ha., covering 20.00 per cent of the French bean growing area. Thus, both Arka Komal and Arka Suvidha varieties together cover around 60 % of the total french bean growing area in the country have made huge impact at the national level.

In onion(*Allium cepa* L), two varieties namely Arka Kalyan and Arka Niketan developed and released by IIHR, made very huge impact at the national level. Arka Kalyan was developed through vigorous mass selection from IIHR-145. It was released and notified by Governement of India in the year 1990. Bulbs in Arka Kalyan are medium large and globe shaped with deep red outer scales and fleshy succulent internal scales. Average bulb weight 130-180 g. Pungent with TSS 11-13%. Moderately resistant to purple blotch disease caused by *Altermaria porri.* Arka Kalyan has wide adoptability in the country and is suitable for cultivation in *Kharif*. Out of total onion growing area of 10.87 lakh ha, Arka Kalyan is culativated in an area of 54350 hectares which is five percent of total area making a high impact at the national level. Another variety, Arka Niketan, was also developed at IIHR, through mass selection from IIHR-153. It was released and notified at the national level by Government of India in the year 1990. The medium size bulbs are globe shaped with thin neck, with attractive red outer and inner scales arranged in tight concentric rings. Average bulb weight 100-180 g. Bulbs are very firm, highly pungent with 12-14% TSS. It has excellent keeping quality of up to four months. Duration of the crop is 145 days. Arka Niketan is highly suitable for *rabi* (Sep-Oct) season. Presently it occupies 86960 ha which is eight percent of the total onion growing area. The variety has made huge impact in the states like U.P, Maharashtra and Madhya Pradesh. Both Arka Kalyan and Arka Niketan together constitute 13 % of the total onion growing area.

Employment Generation Due to Spread of French Bean Varieties

In sharp contrast to that of the hybrid seed production of tomato and Okra, which are highly labour intensive providing additional employment opportunities, the French beans seed multiplication is one of labour saving one, thereby reducing the working capital requirements for the growers. In other words, the farmers restrain from harvesting operation in case of seed multiplication and harvest the whole plant once after it is dried up and collect the seed by shaking the dried leaves off.

Table 2: Impact of IHR vegetable varieties in improving national production

Sl.No.	Crop	Area (Lakh ha.)*	Name of the varieties	IIHR Var./hybrid area in ha.	Impact in percent of area covered
1	French bean	1.18	Arka Komal	47200	40.0
			Arka Suvidha	23600	20.0
2	Okra	5.18	Arka Anamika	175000	33.8
3	Onion	10.87	Arka Kalyan	54350	5.0
			Arka Niketan	86960	8.0

* Source: NHB data base 2011-12(from www.nhb.gov.in)

The seed multiplication activity is thus helpful in delaying the harvest there by reducing the peak labour stress and also labour saving on the whole. A total of 221.21 man days of employment is generated from one hectare of vegetable cultivation of French beans, as against 162.22 man days from seed multiplication.

Table 3: Employment generation in French bean commercial –vs- seed production

Sl. No.	Operation	French beans commercial production			French beans seed production		
		Labour (Man days)		Total cost (Rs.)	Labour (Man days)		Total cost (Rs.)
		Owned	Hired		Owned	Hired	
1	All operations other than Harvesting and cleaning etc	18.13	119.95	6274.99	18.66	92.92	5519.08
2	Harvesting, cleaning and packing	1.31	81.82	4043.18	0.96	49.69	2406.85
	Total	19.44	201.77	10768.18	19.61	142.61	7925.94

Contribution to Income

French beans cultivation is preferred also for the net addition to farm income. The average farm size in the selected study area was around 4.4ha. French beans seed multiplication purposes was one of the important activity accounting for over 13.24 percent of the total cultivated area. Next in preference were French beans for commercial cultivation, followed by Mulberry, carrot and Onion. In terms of contribution towards total farm income, it could be seen that Carrot was the first in preference fetching around Rs.37,175 from an area of 0.65 ha, while the seed purpose crop of French beans provided Rs.24,603 from an area of 0.79ha, as compared to the other crops.

Economic Impact of Use of 'Dogridge' Rootstock in Grape Cultivation

Research efforts by scientists from IIHR and NRC grapes has resulted in standardization of 'Dogridge' as the most accepted rootstock for grape cultivation across four growing states. The technology which was tested on farmers' fields during mid 90s (1996-97) gained popularity by the early millennium and has been widely adopted by grape growers across growing regions. Its adoption gained momentum since 2002 in Karnataka and AP, while Tamil Nadu growers started adopting the technology since 2007-08.

The state of Maharashtra, which leads in grape cultivation, has over 75 percent adoption for this technology, while it is the range of 4 to 25% in other states like Tamil Nadu, Karnataka and Andhra Pradesh. The technology ahs been adopted by 54.6 percent of the grape growers from Maharashtra, Karnataka, Tamil Nadu and Andhra Pradesh (1996-97 to 2007-08). Grape cultivation in these four states has diversified into different products, starting from fresh grapes for the domestic sale to exports, raisin making and now for wine making as well. Root stock technology impact is distinctly visible in all these products as well.

Impact of Rootstock at Individual Farm Level

The economic impact due to use of root stock has been assessed for different products such as for fresh sales in the domestic market and exports; on farm conversion as raisins and for wine purposes. The average annual cost of maintenance was in the range of Rs.98,560/ha to Rs.2,10,000/ha for purely domestic or wine production to export oriented production. The production expenditure as well as the yield irrespective of the type of production (root stock or own root) or for different purposes is the highest in Maharashtra as compared to all other regions. In almost all cases, cultivation on root stock has shown higher yield realization, in the range of 3.2 to 20 percent respectively for domestic –vs- raisin making; 9.3% reduction in cultivation expenses for export, 21% increased price in recognition of the higher quality.

The gross returns and net realization were distinctly higher for the root stock grown grapes. The BCR also was found to be in the range of 2.3 to 5.26 depending on the region and type of production. This analysis thus brings forth the definite superiority of the technology and suggests that all grape growers irrespective of the purpose should adopt this technology in the future as well.

Estimation of Economic Surplus from Rootstock Adoption

Economic surplus generated due to the adoption of root stock technology in grape cultivation has been assessed using the Alston's model. The aggregate stream of costs and returns per unit area, total research costs, market price and elasticity of production and demand, shift in area and productivity due to technology adoption have bee compiled for four major grape growing states.

The results indicated that the adoption of root stock technology in grape cultivation has generated an over all economic surplus of Rs.790 crores, with an Internal rate of return of 55%.

Research Costs, Adoption and Returns

Research Cost	
PV of research cost	Rs.1.62
Rate of Adoption	54.5%
Maharashtra	85%
Andhra Pradesh	20%
Karnataka	4%
Tamil Nadu	0.5%
Economic Surplus	
Net present value	Rs.790 Crores
IRR	55%

Use of Micronutrient Foliar Formulations

Nutrient management plays an important role in productivity and quality of horticultural produce. By and large majority of soils across the country are deficient in one or the other micronutrients. Balanced nutrition particularly management of macro and micro nutrients in a judicious way will help to not only enhance the yield but also quality of horticultural crops. Micronutrients play important role in cell development they are integral part of enzymes and help in insect & disease tolerance. By seeing the importance of micronutrients in horticultural crops, IIHR has developed various micro-nutrient formulations useful in crop like vegetables, Banana, Mango and Citrus, these products, have been demonstrated in farmers field in various agro climatic zones of the Country with highly encouraging results.

Banana being high nutrient demanding crop responds very well to micronutrients. The technology has been popularized among farmers through KVKs and sales through IIHR, ATIC. The technology also been distributed through the different state horticultural departments for the benefit of farmers. Keeping in view the innovative value of the technology, the technology has been submitted for 'patenting'. The Institute technology management unit has entered into memorandum of understanding with National Research and Development Corporation (NRDC) for commercialization of technology since September 2009. The technology has been sub-licenses to Ms. Rainbow technologies for further commercialization among farmers.

Since 2003, IIHR has generated over Rs.31.32 lakhs from the sale of Arka banana special through its Agricultural Technology Information Centre. The Banana special has been adopted in an area of 2110 hectare with a net benefit of 1413 lakhs.

Table 4 : Details of the sale of Arka Banana Special, area covered and amount realized

Year	Quantity Sold (Kgs)	Amount Realized (Lakh Rs.)	Estimated area covered by banana special (ha)	Estimated net Total benefit (Rs.Lakhs)
2003-04	1321	1.32	90	59
2004-05	1586	1.58	110	70
2005-06	2155	2.15	145	96
2006-07	1754	1.74	116	78
2007-08	3354	3.16	223	149
2008-09	4013	4.11	274	185.0
2009-10	9773	9.77	651	439.0
2010-11	3490	3.49	234	157.0
2011-12	4005	4.00	267	180.0
Total	31551	31.32	2110	1413.0

Table 5: Costs, returns and profits with and without Banana special usage (in Rs./ha)

Particulars	With foliar Nutrition		Without foliar nutrition	
	Main Crop	Ratoon Crop	Main Crop	Ratoon Crop
Cost of Cultivation (Excluding foliar nutrition)	99250	85652	99250	85652
Cost of Foliar Nutrition	3322	3100	-	-
Total Cost	102572	88752	102572	88752
Yield Kg/ha	67017	42240	59925	38400

Gross return	451367	264000	391310	230400
Net return	348795	175248	287531	144748
B:C ratio	4.40	2.97	3.81	2.59

The perusal of the data on economic analysis of use of banana special indicated that with the use of foliar formulation the yield enhancement was to the tune of 7092 kg/ha with extra monitory benefit of Rs.61,264/ha.

Impact of IIHR Bio-pesticide Technologies in India

Biological control of pathogenic nematodes, fungi and bacteria assume great significance in these days as the soil sickness has increased in alarming proportions due to indiscriminate use of chemical pesticides.

Chemical pesticides are expensive, affect useful soil micro flora and fauna. The excessive chemicalization of agro ecosystems has resulted into various hazards. In this scenario augmentation of bio-pesticides in the agro ecosystems offer sustainable solutions to this perennial problem.

Keeping these facts in view, extensive research has been carried out for the last two decades in the Nematology Laboratory of Indian Institute of Horticultural Research (IIHR). Consequently various protocols of mass production of bio-pesticides were standardized.

Relevant data on the bio-efficacy and bio-safety were also generated. Since 2006 onwards the bio-pesticide technologies were transferred to various industries in India. Altogether 224 industries (beneficiaries) took these technologies form IIHR, Bangalore.

For the last 4 years 200 to 250 crores of bio-pesticides were being produced every year by all these industries with the technology of IIHR. All these bio-pesticides are being used in 2 Million Hectares every year for the management of various soil borne pathogens in India.

These bio-pesticides were found to be very effective in the production of disease free nursery seedling or grafts. They are highly useful in organic cultivation of horticulture crops.

Use of these bio-pesticides have been found to improve the soil health and reduced the densities of soil borne pathogenic nematodes, fungi and bacteria in agro ecosystems. These bio-pesticides are being used in crops like capsicum, onion, cabbage, cauliflower, crossandra, carnation, roses, gerbera, banana, grapes, guava, acid lime, papaya, tomato, egg plant etc.

Use of these bio-pesticides is found to have increased the yield of the crops to the tune of 14 to 18%. This could give additional returns of approximately Rs. 3,500/- per hectare. The net benefit by the use of these bio-pesticides in 2 million hectares would be to the tune of Rs. 700 crores per year.

Use of the bio-pesticides has also reduced the consumption of chemical pesticides to the tune of 16% to 20%. The benefit which is accrued by the reduction of chemical pesticides could be to the tune of 100 to 150 crores.

The following five are the bio-pesticide technologies transferred from IIHR to various industries:

1. *Paecilomyces lilacinus* - 1% W. P.
2. *Verticillium chlamydosporia* - 1% W. P.
3. *Trichoderma harzianum*- 1% W. P.
4. *Pseudomonas fluorescens* - 1% W. P.
5. *Trichoderma viride*– 1.5% W. P.

Impact of Fruit Fly in India

Background Information

Mango is the most economically important fruit crop cultivated in India with the largest area and production in the world, but the productivity (less than 7 tons/ha) and export (less than 2% of total production) are abysmally low compared to other mango producing countries. Fruit flies also limit to supplying of quality fruit s to processing industries. This low productivity is mainly due to the serious infestation of fruit fly (*Bactrocera dorsalis*

S.No.	Name of the Bio-pesticide	Unique features	No. of Industries to which commercialize
1	*Paecilomyces lilacinus*	It is a bio-agent which effectively helps in the management of Root–knot nematode(*Meloidogyne* sp.), infecting horticultural crops such as capsicum, onion, cabbage, cauliflower, crossandra, roses, gerbera, banana, grapes, guava, acid lime, papaya, tomato, egg plant and Citrus Nematode(*Tylenchulus semipenetrans*) on acid lime.	53
2	*Verticillium chlamydosporia*	It is a bio-agent which effectively helps in the management of Root–knot nematode (*Meloidogyne* sp.)and Cyst nematodes (*Heterodera* sp.) infecting horticultural crops such as capsicum, onion, cabbage, cauliflower, crossandra, roses, gerbera, banana, grapes, guava, acid lime, papaya, tomato, egg plant etc.	**7**
3	*Tricoderma harzianum*	It is a bio-agent which effectively helps in the management of *Fusarium oxysporum*,*Sclerotium rolfsii*,Reinform nematode (*Rotylenchulus reniformis*)andRoot–knot nematode (*Meloidogyne* sp.) infecting horticultural crops such as capsicum, onion, cabbage, cauliflower, crossandra, roses, gerbera, banana, grapes, guava, acid lime, papaya, tomato, egg plant etc.	49
4	*Pseudomonas fluorescens*	It is a bio-agent which effectively helps in the management of *Ralstonia solaneacerum*,*Erwinia caratovora*, *Fusarium* sp., *Rotylenchus reniformis* &Root–knot nematode(*Meloidogyne* sp.)infecting horticultural crops such as capsicum, onion, cabbage, cauliflower, crossandra, carnation, roses, gerbera, banana, grapes, guava, acid	**55**

		lime, papaya, tomato, egg plant etc.	
5	*Trichoderma viride*	It is a bio-agent which effectively helps in the management of *Fusarium oxysporum*, *Rotylenchulus reniformis* andRoot–knot nematode (*Meloidogyne* sp.)on all horticultural crops such as capsicum, onion, cabbage, cauliflower, crossandra, roses, gerbera, banana, grapes, guava, acid lime, papaya, tomato, egg plant etc.	**60**

(Hendel) belonging to the family Tephritidae of the order Diptera. The loss caused in India ranges from 20 to 80% with the mean loss of 27%. Almost all the commercial, exportable and processing varieties of south India are affected by fruit flies. The most susceptible varieties are Alphonso (Badami or Apoos), Banganpalli, Mallika, Kesar, Dashehari, Neelum, Suvarnarekkha and Totapuri etc. are affected by fruit flies. Besides *B. dorsalis*, *B. zonata* and correcta are also pests of mango and many other fruits. To control these three rounds of insecticide sprays were recommended. This was fraught with the danger of high residue build up in mango, high cost of intervention, high labor intensive, health hazard to human, non-acceptance in international market due to detectable residues and serious environmental pollution (air, underground water and monor wild life etc) and destruction of non-target organisms. Further sprays were require din summer when there is extreme water shortage. Therefore the farmers were in many ways limited in terms of resources and difficultly in control of fruit flies control. Further it was found that excess use f insecticide also caused resistance in insects and inadequate control. This fruit fly management is a national grave problem. There were no environment friendly and economically viable IPM technologies available for the farmers. Hence it was felt that there was a need for developing environment friendly and economically viable IPM technologies for the control of fruit flies in order to enhance the productivity and export.

About Innovation of Fruit Fly Trap

Surveys conducted at the turn of millenium in several rural mango belts of India such as Kolar, Chikkaballapura, Dharwad, Hassan, Shimoga (Karnataka); Krishna, Chittoor, Cuddapah, Mehboobnaagar, Ranga Reddy, Vishakapatnam, Srikakaulam (AP). Krishnagiri, Vellore (TN) and Palghat (Kerala) showed productivity loss of potential yield from 5 tons per acre to 2 tons due to fruit fly infestation. Farmers plight was miserable because for every acre they lost Rs.20,000 to 1,00,000. This was responsible for their poverty, lowered social strata, lowered social status, poor education for children, inadequate medical capabilities, etc. Then fruit coming for processing industry were poor in quality in terms of pulp, affected by stone weevil and fruit fly. These both fruit fly and stone weevil being quarantine pests the industry was deprived of quality mangoes and they were paying less money to mango growers. This affected both industry and farmer. Indirectly women employment also was affected. Rural employment for youth, women etc was affected. Fresh fruit sent to Japan, Europe, Australia etc., were denied entry and consignments were returned either due to fruit fly detection or residues in fruits. This prompted the team led by Dr. Abraham Verghese and his team to take up pragmatic and strategic research. This intensive and inner-disciplinary supported by ICAR and Imperial College, London resulted in excellent IPM technology by 2005. From 2006 to 2008 IPM was validated in multi-locational mango belts of the country. And in 2008 onwards it was implemented on an area-wide basis also tang the help of private-public partnership mode through eight licensees under strict IIHR quality control and supervision.

Advantages of Fruit Fly Trap

The trap is cost effective. The farmer who spends approx. Rs. 500 on 6 traps per acre (inclusive of traps, additional lures, labor cost, toxicant cost, transportation charges, tying materials etc.) will realize an additional yield of 1000 kg per acre (keeping 25% savings considering the mean yield of 4 tons per acre) giving him an additional income of Rs. 10,000 per acre, assuming that he gets Rs. 10 per kg at the farm gate (He may get Rs. 40 per kg for Alphonso, Kesar; Rs. 30 per kg for Mallika, Banganapalli, Mulgoa, Rs. 20 for Neelum; Rs. 10 for Bangalora and other varieties).

This the B:C Ratio for this trap technology is 20:1. In other words every rupee invested in pheromone trap he realizes Rs. 20.

1. The technology is simple and doesn't need any training or special skills.
2. The farm women can also adopt the technology
3. Leads to production of high quality fruits suitable for exports (20% of total production) thus realizing additional revenue
4. Reduces fruit drop
5. Reduces infection of anthracnose and other secondary infections causing to rot and post harvest losses
6. Organic farming friendly technology since there is no spray of chemicals involved in this management of fruit flies
7. The trap can be safely reused for several seasons and the lures are biodegradable
8. The chemicals used are nontoxic to humans or animals
9. It attracts only targeted pests (fruit flies only causing damage to fruits) and no other insect is attracted. Thus it is environment friendly
10. The technology is highly cost effective, since every rupee invested by the farmer will realize an amount of Rs. 20 to 30
11. The re-usability of trap. Use of trap for both monitoring for academic purposes for estimating population density and in IPM mode for management of fruit flies
12. Can be used in organic cultivation of mango without interfereing the **certification** of farmer
13. Eco-friendly, since the ply is biodegradable and plastic bottle is reusable
14. The entrepreneur needs minimum floor area and labour man days for establishing the unit in commercial scale – thus the technology is business friendly
15. The technology is farmer friendly since it does not need any special training to adopt the technology.

Economic Gains of IPM of Fruit Fly Management

In the project "Popularising IPM of mango fruit fly …. in Kolar district", funded by NABARD,Bangalore,has been successfully implemented in Kolar, Belgaum and Dharwad districts by conducting 6 awareness campaigns. Total of 17,304 traps with 34,608 additional lures were distributed to cover an area of 2884 acres. The results have shown that more than 29% yield enhancement in Alphonso. Even if 25% of mango crop is saved from fruit fly damage, 2884 metric tons of additional fruits have reached market. At farm gate price of Rs. 20 per kg the farmers will realize Rs. 5.7680 crores as additional income from this project.

"Popularising IPM for stone weevil and fruit fly in mango …. economic upliftment of rural women" was received from DBT, New Delhi. We have Conducted 12 awareness campaigns for the farmers of Chittoor district and YSR district in Andhra Pradesh, Muddalamadu area of Palghat region of Kerala and Dharwad and Belgaum districts of Karnataka. A total of 6489 acres has been brought under IPM of fruit fly in this project. Even if 25% of their mango crop is saved from fruit fly damage 6489 metric tons of additional fruits are expected to reach market. The farmer even if he gets Rs. 20 per kg the farmers will realize Rs. 12.9780 crores as additional income from this project.

Under the National Horticulture Mission, Lalbagh, Bangalore, another project entitled "Conducting frontline demonstrations on IPM technologies for fruit fly …… in 13 places of Karnataka" was taken up. In this program we have conducted 42 awareness campaigns and 68 FLDs in six districts of Karnataka and an area of 34,892 acres has been covered under FLD of IPM of mango fruit fly and stone weevil. Even if 25% of crop is saved from fruit fly damage 34892 metric tons of additional fruits are expected to reach market. The farmer even if he gets Rs. 20 per kg the farmers will realize Rs. 68.740 crores as additional income form this project.

Looking at the success of Karnataka, Andhra Pradesh, Tamil Nadu and Kerala, the Government of Odisha has brought in nearly 12000 acres under IPM of fruit fly. Further, Jharkand has brought in 12000 acres or more under IPM of fruit fly.

In next 10 years we believe all the mango states will implement the IPM of fruit fly and save the damage and enhance the yield by 25% or more. If at least 50% of mango cultivation is brought under IPM then half of the 2.26 million hectares of the area will be covered under IPM. If 25% fruits are saved from fruit fly damage, considering 10 t/ha, the total savings from loss will be 2.825 million tons per year. Further, if the cost of mango is considered at Rs. 10 at the farm gate the additional money generated would be Rs. 28.25 million per annum.

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Genetic Diversity and Resource Management of Horticultural Crops in Saurashtra Region

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Horticulture is the broad spectrum involves many diversified crops like fruits, vegetables, flowers, ornamental plants, spices, medicinal, aromatic and plantation crops, has become a key drivers for economic development in many states of India. Nutritional and food security is the current and burning issue of the nation. Horticulture is the best alternate for nutritional security. The awareness and demand of horticultural produces are increasing. Saurashtra is the historical and cultural region of Gujarat state. It is rich in soils and climate including long coastal belts with red lateritic soils, hence, it is predominance for genetic diversity for many horticultural crops. There is immediate need to give attention for collection, conservation, documentation and utilization of genetic resources of various horticultural crops for production and popularization. Mango is the leading fruit crop of region possesses wide genetic diversity with indigenous varieties like *Kesar,Rajapuri, Jamadar, Dudhpendo and Khodi* and many others. Custard apple is another important fruit crop of Saurashtra with large germplasms and varieties, and the crop is exposing and becoming favorable due to its hardy nature and less cost of production. Jamun, used as an effective medicine against diabetes, heart and liver trouble. Due to its high value in terms of therapeutic and nutrition, the consumption rate is increasing fast, but no any known variety is exhaust in this region. However, few accessions have been identified for further study. In guava also, *Dholaka, Reshamdi* and *Bhavanagr Lal* are the important commercial indigenous cultivars reflexes the genetic diversity. Karonda and lasora are also very hardy plant, grown mostly in waste land as well as boarder planting. Lasora can be used as a shelter belts or wind break to overcome negative effect of climate change. Long coastal belt of region is suitable for coconut plantation having popular D x T hybrids as well as many indigenous varieties. In case of flower crops, rose, chrysanthemum, jasmine, gaillardia, marigold, golden rode, etc., are under cultivation, but very scarce varieties or genotypes have been identified. However, varieties of gerbera have been endorsed for protected cultivation. Similarly for vegetables, huge genetic diversity in different vegetable crops have been identified and used for crop improvement programme. Some indigenous genetic stocks like *Gholar* and *Reshm patto* chili; *Pili patti* and Mahuva *safed*onion; *Greengota, Junagadh Bhatta*, *Ghed Bhadatha* brinjal; etc. which are used for the commercial cultivation and became more favourable in traders, processors and consumers.

Introduction

Horticulture is the broad spectrum involves many diversified crops like fruits, vegetables, flowers, ornamental plants, spices, medicinal, aromatic and plantation crops, has become a key drivers for economic development in many states of our country. India contributes about 23.24 million hectors land under horticultural crops, out of which, fruits crops contribute about 6.70 million hector land with 76.42 million tones production. The area and production of vegetables in the country is 8.49 million hectors with 146.55 million tones, respectively. However, the productivity of fruits and vegetables in India is 11.7 MT/ha which is higher than the world leader China (10.70 MT/ha). Nutritional and food security is the current and burning issue of the nation. Horticulture is the best alternate for nutritional security. The awareness and demand of horticultural produces are increasing.In Gujarat, the area under horticultural crops is also increasing. The total estimated area under horticultural crops has been increased from 2.54 to 14.04 lakh hectors during year 1987-88 to 2010-11. The productivity in each branch of horticulture has also increased notable during last seven years.

Saurashtra is the historical and cultural region of a part of Gujarat. The peninsula of Saurashtra forms a rocky table land (altitude 300-600 meters) fringed by coastal plains with a central part made up of an undulating plain broken by hills and considerably dissected by various rivers that flow in all directions. The eastern fringe of Saurashtra is a low-lying ground marking the site of the former sea connection between the Gulfs of Kutch and Khambhat. Even under many unfavorable parameters like problematic soil, water scarcity, drought prone areas and some natural calamities, the farmers of Saurashtra region are working hard with great confidence. Hence, agriculture and horticulture are also developing with very fast rate in Saurashtra. During last decade, the popularity of the different horticultural crops is increased not only to the farmers, but also up to the consumer ends.

At present, total area and production of horticultural crops in Saurashtra is 5.29 lakh ha and 48.05lakh tones, respectively. During last seven years tenure, 24.76% area under agricultural crops has been divided to horticultural crops. Similarly, the production also has increased from 34.64 to 48.05 lakh tones. The productivity during 2005 was 8.16 MT/ha, which increased up to 9.50 MT/ha during 2007, but then recorded lowest 6.91 MT/ha in during 2008 and again it increased up to 9.08 MT/ha during the year 2011. It may be due to adverse climatic condition during the year 2008.

Genetic Diversity

Genetic diversity, the level of biodiversity, refers to the total number of genetic characteristics in the genetic makeup of a species. It is distinguished from genetic variability, which describes the tendency of genetic characteristics to vary. It can be also described as plant genetic resources of cultivated species and their wild relatives (Ford-Lloyd,2001). Saurashtra is rich in diversified soils and climate including long coastal belts with red lateritic soils suitable for many horticultural crops. Hence, it got rich diversity of different horticultural crops. The region is considered as a home of many land races or accessions of various crops.

Genetic Resource Management

Genetic resource management is the exploration, collection, domestication, conservation and documentation of genotypes of various crops. Plant genetic resources (PGR) are basic requirements in crop improvement programme and their importance has increased in recent years. It represents the inter- and intra-specific reservoir of potentially and useful genetic materials. Landraces or farmers' varieties constitute the basic material for developing any new improved variety or hybrids. Landraces are the varieties nurtured and cultivated by the farmers through traditional method of selection over the decades. The Biodiversity Act (2002) describes "landrace" as primitive cultivar that was grown by ancient farmers and their successors. A brief account of germplasm resources of horticultural crops and their wild types available in this region is discussed here.

Fruit Crops

The area and production of fruits are increased with fast rate in Saurashtra. Many farmers have adopted fruit cultivation by converting their land under orchards. Presently, 0.90 lakh hector area and 11.73 lakh MT productions is recorded. The productivity is also increased from 9.56 MT/ha (2005) to 12.94 MT/ha (2011) during the period, reflecting high potentiality for Saurashtra region. The increased area under fruit crops is due to acclimatizing as well as higher adoption of recommended production technologies. Saurashtra region has rich diversity in different fruit crops. Many land races or indigenous varieties are grown in different fruit crops like mango, custard apple, ber, pomegranate, guava, coconut, date palm, black jamun, etc.

Mango (*Mangifera indica* L.) the pride fruit of India, is one of the choicest fruit crops of tropical and sub-tropical regions of the world, especially Asia. Its place of importance can be understood from its being referred to as 'King of fruits' in the tropical world (Singh 1996). Because of its nutritive value, delicious taste, excellent flavor, attractive fragrance and health promising qualities, the mango has gained global popularity in the last two decades. Mango has been under cultivation since 4,000 years in the Indian subcontinent. Endowed with rich diversity the India is considered to be the center of origin (Ravishankar *et al.*2000). As of now, more than 1,000 mango cultivars are known to exist in the country (Karihaloo *et al.*2003).

Mango is the leading fruit crop of Gujarat and Saurashtra region also occupying nearly 35,551 hector land under cultivation, is the most important fruit crop covering about 6.71% and 39.44% area of total horticultural crops and fruit crops of Saurashtra, respectively. Major mango growing pockets are Talala (*gir*) and Vanthali of Junagadh, Dhari (Amreli) and Mahauva (Bhavanagar). Junagadh district is leading home of mango cultivation with an area of 20529 hectare and 1.56 lakh tones production followed by Amreli.

Only a single species of mango (*Mangifera indica*) is under cultivation. There is wide genetic diversity with nearly 60 genotypes or indigenous varietieswhich are exist in this region. The germplasms largely confined to the districts of Junagadh, Amreli, Porbandar, Bhavnagar, etc., may be broadly grouped into table, juicy and pickle types. They are characterized on the basis of a set of agro-botanic traits. However, there are only few indigenous genetic resource/varieties which have got commercial value. The landraces which are exist in region are *Jamadar*, *KesarDudhpendo, Khodi, Dadamiyo, Fajali, Giriraj,Rajapuri, Ashadhiyo, Barada deshi, Karangio, Kavaji Patel*, etc. Among these, Kesar is the most important commercial variety not only this region, but emerging as one of the leading variety of Gujarat also. It was selected from "*Sale bhai ni Amadi",* the indigenous variety. Kesar is the only variety which is grown under systematic orchards in Saurashtra region. Junagadh is considered as the center of origin of Kesar variety with interested history. It posses pleasant characteristics like saffron colored pulp, sweet and saffron taste, fiber less pulp, small & flat stone, yellow colored fruit, 150-200 g fruit weight, etc. Comparatively it is also high yielding variety. During year 2011, Gujarat state has registered for GeographicalIndication of Kesar mango as "*Gir Kesar"* with technical support of Junagadh Agricultural University**.** Twenty mango cultivars collected from *Gir* region of Saurashtra were examined by ISSR markers. According to the banding patterns obtained with 21 selected primers, all cultivars tested in this study except *Jamadar* and *Kesar* were distinguished from each other and showed ample genetic diversity. Based on 125 selected bands, all *Gir* mango landraces tested were clustered into a three big groups with *'Kaju'* and *'Khodi'* in first group; *Dudh Pendo, Sopari, Jamadar, Kesar* and *Ashadhiya* in second group; while the third cluster was composed of *Agargato, Amir Pasand, Pethal, Gajariyo, Chhappaniyo, Alphonso, Neelum, Jamrukhiyo, Kavasji Patel, Giriraj, Amrutiyo, Dasheri* and *Deshi* based on UPGMA analysis, indicating that some *Gir* landraces had a close relationship with each other, while some were drastically dissimilar from other landraces (Tomar *et al.* 2011).

There is narrow genetic diversity observed in citrus group. Acid lime (*Citrus aurantifolia*) of citrus is the second largest fruit crop of Saurashtra, which occupied 10,300 ha land under cultivation during the year 2011. It is only one of the leading species commercially cultivated with *Kagdi lime* cultivar in region. Bhavanagar and Surendranagar are the major districts for area, production and productivity. However, few farmers have started cultivation of *Citrus sinensis* cultivar known as *Pavali Chhap Mosambi* in scattered orchards. Some indigenous species like *Citrus medica, Citrus lemon, Citrus grandis*, etc., are grown as limited numbers of tree on corner of orchards.

Guava is the fourth fruit crops grown mostly in Bhavanagar and Amreli districts. The crop is hardy in nature more suitable for arid and semi arid zones of Saurashtra. The genetic diversity is also recorded in guava. *Dholaka* is the important indigenous cultivar grown in Dholaka and Bhavanagar region. The variety is with high bearing, big sized fruits, yellow colored skin with white pulp and sweet in taste. *Reshmadi* is another important indigenous variety grown in Bhavanagar district, having fruits with medium size, long neck with fine and thin skin. The pulp is light pink, flavored and less seeded. Red color is becoming more popular in world fruit market. Red pulp colored indigenous variety of guava is also available in Saurashtra region which is known as *Bhavanagar Lal* and is only grown in Bhavanagar region. The pulp color is red, flavored and sweet in taste. The variety is more popular and attractive and securing premium price in market. It is also suitable for processing of jam, jelly, etc. due to its retained red color. The known varieties of our country like L-49 (Sardar) and Alahabad Safeda are the preferred variety of this region. Recently, Red Apple and One Kg are also becoming popular among the guava growers for novelty.

Custard apple is new exposing fruit crop with higher commercial value. The *Annonaceous* fruits are the members of the family *Annonaceae* and genus *Annona.* There are over 120 species of *Annona* and several of these bear edible fruits, however, only six species have commercial significance. Among them,*A. squamosa* which is commercially grown in Saurashtra region known as *sitaphal*. Another species, *A. reticulate, A. cherimola, A. atemoya, A. muricata, A. diversifolia, A. scleroderma,* etc., have been marginalized as fruit-trees. Sindhan is the indigenous variety commercially cultivated in Saurashtra region. It is the variety with goodcharacteristics like big size fruit, attractive green color, sweet and pleasant taste of creamy white colored pulp, etc. However, affords have been made by the scientists of the university and collected different thirty genotypes from Saurshtra region of Sindhan. The germplasms was conserved and evaluated at university farm. After five year evaluation, the Junagadh Agricultural University has released a new variety in custard apple named Gujarat Junagadh Custard apple-1. It is released and developed as clonal selection from Sindhan during 2009. It has higher plant height and plant spread as compared to local. The fruit is attractive, green colored, oblong with medium size. The pulp is in higher quantity with white, agreeable flavor with sweet taste. The pulp contained 16.55% sugar and 23.49 TSS ^{o}B. Besides, it posses less number of seeds and higher pulp-seed & pulp-skin ratio as compared to Sindhan with more number of fruits per plant. The average yield of variety is higher than the Sindhan.

Black jamun is also important minor fruit crops grown in Saurashtra region. It belongs to family myrtaceae is an important but unexploited indigenous fruit crop of India. *Syzyguim cuminii Skeels*or *Syzyguim jambolana* or *Eugenia jambolana* are the synonymous species grown in region. Other important species of *Syzygium* are *S. javanicum* (water apple), *S. jambos* (rose apple), *S. samarangenes*, *S. malaccense* and *S. uniflora* (Surinam cherry) are not grown extensively, but limited only for boarder planting. The black jamun is known as *ravana, ravno, khiliyo, senjalia, zambudio, zambudi,katio, paras* in local language in

Saurashtra region. There is no known or popular cultivar, but local types are grown in region. A little affords have been made by Department of Horticulture, JAU, Junagadh to evaluate the various twenty accessions of region. During study, significant variation was found for fruit and quality parameters. Among the accessions evaluated, maximum fruit length, girth, fruit weight and pulp weight were recorded in accession VR-1. The size of fruit was reflected as genetic diversity in different accessions. Similarly, lowest seed weight was recorded in accession BS-1 (*Girnar* forest). For quality parameters, lowest acidity was recorded in accession JAU-2, whereas, ascorbic acid was registered highest in VB-1. Likewise, highest reducing sugar and total sugar were recorded in accession VMA-1, whereas, TSS in BS-1. Large variation in shape of fruit was also observed.

There is also great genetic diversity seen in ber. Some landraces are observed with variability in many morphological traits. The varieties like Gola, Ajmeri, Umran, Mehrun, Jogia, etc. are grown commercially. The dry ber known as *chauhara* have also great important. The local or *deshi* varieties known as *Randeri* is suitable for dehydration purpose. Uncultivated or wild type ber is naturally grown in waste land or farm boarder in Saurashtra region known as *Chani bor* have also been observed with wide variation. The plant is shrub type with very small sized red colored fruit. The fruit is with thinned skin and sweet acidic taste.

Coconut is only one of the leading plantation crops grown in coastal belt of Saurashtra region. Junagadh is the leading district for area, production and productivity followed by Bhavanagar. Recently, Department of Horticulture, Junagadh Agril. University has surveyed the coconut orchards of the state. The cultivars like WCT, Bona, Dwarf (*Gudajali/lotan*), NCD (*Vanfer*) and hybrids like D x T & T x D are grown commercially. Out of them, majority of coconut growers of the region are adopting the cultivar West Coast Tall and Dwarf (*Lotan*).Fruit Research Station, Junagadh Agril. University, Mahuvareleased two hybrids viz., D x T and T x D which are high yielder with good quality tender water. The yield potentiality of hybrids is better than WCT and local varieties. The hybrid D x T is short stature, early bearing with short bearing life as compared to hybrid T x D. However, the availability of planting material is the major issue for the adoption of any of hybrids in coconut.

Vegetable Crops

Nearly twenty vegetables are grown commercially in Saurashtra region, among them major are onion, garlic, okra, tomato, brinjal, chili, cucurbits, pulses, etc. Many indigenous vegetables, both cultivated and uncultivated have tremendous role in nutritional and food security as well as economy. These indigenous vegetables which have a wide genetic diversity is useful for crop improvement programme. The crops in which rich diversity occurs include cowpea (*Vigna unguiculata*), Okra (*Abelmoschus esculentus*), brinjal (*Solanum melongena*), Chilli (*Capsicum anum*), Cucurbits, onion (*Allium cepa*) and garlic (*Allium sativum*).

The Alliums includes onion and garlic are prized vegetables due to its food and medicinal value (Ram *et al.* 2007). Onion and garlic are leading vegetables grown particularly in Bhavanagar and Jamanagar district. In onion, variation is usually observed in plant type, bulb size, bulb shape, bulb color and pungency. Junagadh local known as *Pili patti* is good variety grown in Upleta and Bhayavadar of Rajkot district. The bulb color is yellowish orange with sweet taste. It is highly demanded for salad and culinary purpose. *Talaja Red* is also another important variety grown in Talaja of Bhavanagar district. The variety is with red or pink colored bulb with big sized and pungent in taste. Dehydration of onion is a notable processing industry around Mahuva area of Bhavanagar district which requires white onion. The *Talaja Safed* or *Mahuva Safed* is the indigenous cultivars of onion more popular with distinct characteristics. It is with strong creamy white colored bulb, bulb size is medium to big with high TSS and pungent in taste. The variety is highly suitable for onion processing industry for the preparation of onion powder, cubes, flakes, etc. Another improved varieties grown in region are Agri Found Light Red, Pusa White Flate-131, Nasik-53, etc. Vegetable Research Station, JAU, Junagadh have collected and conserved nearly 200 germplasms of red onion and 45 of white onion. The germplasm lines are grown every year for evaluation and selection under genetic resource management. The centre has released variety Gujarat White Onion-1(GWO-1),which is with big sized, white colored bulbs with TSS 15% suitable for processing industry.

Garlic is also important vegetable/spice crop of Saurashtra. Narrow genetical diversity is observed in this crop, however, some landraces are noted with variability in different traits. The local variety known as *Ladava* is grown in Kalawad of Jamnagar district which have big sized bulb. *Malepund* is also local variety cultivated in Visavadar of Junagadh district. Scientists of Vegetable Research Station, Junagadh have collected and maintained nearly 200 germplasms and released three varieties viz., Gujarat Garlic-2 (GG-2), Gujarat Garlic-3 (GG-3) and Gujarat Garlic-4 (GG-4).

There is large number of diversified cultivated landraces or traditional cultivars of brinjal or eggplant (*Solanum melongena*) are grown in region. There is a great variation in morphological characters of plant, flowering and fruiting, size-shape and color of fruit, etc. are usually seen. Some of the popular cultivated brinjal germplasms are Green *Gota* (Keshod), *Ghed Bhadatha* (Ghed region), *Kodinar local* (Kodinar), *Raval Deshi* (Jam Raval Dist. Jamnagar) have a big sized fruits with purple color; Black long (Jam Khambhalia),*Junagadhravaiya*, *Junagadh Bhatta*,etc. are cultivated in different region of Saurashtra with highly genetic diversity. Vegetable Research station, JAU, Junagadh released different varieties likeJunagadh long, Junagadh oblong, JBGR-1, GJB-2, GJB-3. Furthermore, 212 germplasms lines are collected, conserved and maintained for further crop improvement programme.

A large number of chilli cultivars (*Capsicum annum*) are available in Saurashtra region. A great variation is usually seen with respect to plant type, fruit size/shape (long, short, pointed, smooth, wrinkled), bearing habit, color and pungency. *Resham patto* single and double is the important indigenous cultivar from Gondal taluka of Rajkot district. The fruit is long and flat harvested only when become red. Both are used for dry powder. *Gholar* is also another important and popular landrace of Gondal of Rajkot district. Normally it is also used for dry powder purpose. However, the whole green fruit is used in *Bhajiya* the popular snack of Saurashtra. Another *Deshi* landraces known as *Bhugol* and *Jiniya* are also popular in dry powder trade grown around Jam Kalyanpur taluka (Coastal belts) which is with long fruit and more pungent. *Vadhavani* and *Chuda Marchu* are the indigenous cultivars grown in Vadhavan and Chuda of Surendra Nagar which are less pungent in taste.

Okra (*Abelmoschus esculentus*) the Indian origin vegetable grown since many years is an important vegetable crops of this region. It is Indian origin vegetable grown since many years. Broad genetic variability is also observed in okra with landraces or *Deshi* grown in different region of Saurashtra. The introduced varieties like Parbahni Kranti, Pusa Savani as well as the varieties released by Gujarat Agril. University like G.O.-1, G.O.-2 are grown. The germpalsms collected and maintained under genetic resource management in Junagadh Agril. University and released the varieties G.O.H.-2, G.J.O.-3, G.J.O.H.-3 which are high yielder and resistant against disease-pests.

The another important solanaceous vegetable in Saurashtra is tomato (*Lycopersicum esculentus*). The crop is more remunerative and popular in farming community. Determinants and indeterminants types are major genetic diversity. Some indigenous culture or *deshi* are grown and are popular in Kuvadava of Rajkot district. The fruits have a ridges on skin. The fruit is small, skin color is greenish yellow at the time of harvest and pulp has more ascorbic acid with sour taste. Under genetic resource management, the varieties like Junagadh Ruby, Gujrat Toamto-1 (GT-1) and Junagadh Tomato-3 have been released by Junagadh Agril. University. The variety Gujrat Toamto-1 (GT-1) is suitable for green house cultivation as it is indeterminant type.

Spice Crops

The most commercially important horticultural crops grown in Saurashtra region are spice crops. The area, production and productivity of spice crops are increased with 37.5%, 109.09% & 53.17%, respectively. The acreage are increasing very fast in Surendranagar, Jamnagar and Junagadh districts. The crops like cumin, coriander, fenugreek, ajwan, Isabgol, etc. are grown in region. The varieties like Gujarat Coriander-1, 3, 4; Gujarat Cumin-1, 2, etc. recommended. Affords has been also made to develop the genetic diversity in different spice crops. About 70-80 germplasms are collected and maintained of various spice crops including coriander, fenugreek, cumin and fennel in Junagadh Agricultural University.

Flower Crops

The area under flower crop is very low in Saurashtra region. However, it was found that the area and production is increased drastically from 459 hector to 1471 hector and 2479 tons to 10,051 tons, respectively during the year 2005 to 2011. Bhavanagar and Rajkot are the leading districts for the cultivation of different flower crops. The flower crops like, marigold, lily (spider), gaillardia, golden rod, chrysanthemum, tuberose, rose, etc. are major growing flower crops. Majority of the flower crops have been introduced with its known varieties. However, Deshi rose, gaillardia, marigold, golden rod etc. are grown with its local cultivars since many years. No systematic crop improvement work has been started in the region. Hence, the work of collection, conservation, maintenance and evaluation of germpalsms under genetic resource management is very scare. However, Department of Horticulture, JAU, Junagadh have endorsed variety of Chrysanthemum named IIHR-6. Similarly, another three varieties of gerbera viz., Dana Allen, Pink Elegance and Sawanha were endorsed for the protected cultivation.

Summary

Genetic diversity of horticultural crops is the future of horticulture field. As many land races or indigenous cultivars which are well popular, nutritionally important with positive characters should be identified. They should be collected, conserved and evaluated under genetic resource management programme. The management of genetic diversified traits leads the development of high yielding, qualitative and biotic and a biotic resistant variety.

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Protected Cultivation: Future Technology for Vegetable Crops

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Vegetables are the backbone of horticulture and best resource for overcoming micronutrient deficiencies and provide smallholder farmers with much higher income and more employment generation per hectare than staple crops (AVRDC, 2006). The worldwide production of vegetables has doubled over the past quarter century and the value of global trade in vegetables now exceeds that of cereals. India has a wide range of diverse climatic-conditions, but vegetable cultivation practices have generally been restricted to regional and seasonal needs. Although the vegetable production in India has increased to a level of 162.18 million tonnes from an area of 9.20 million ha (Anonymous, 2013) but national food security is becoming a matter of increasing concern and poverty is reflected in the nutritional status of the people. The present per capita availability of vegetables in India is only 210 g against the requirement of 300g/capita/day for normal health as per the Recommended Daily Allowance (RDA). Households in large cities in low-income countries spend 50-80 per cent of their incomes on food (Bakker *et al*., 2000) and nutritional deficits in macronutrients and essential micronutrients are common.

By the year 2050, nearly 80% of the earth's population will reside in urban centres and our growing global population will require an estimated 100% more food than we produce today. Applying the most conservative estimates to current demographic trends, the human population will increase by about 3 billion people during the interim. An estimated 10^9 hectares of new land will be needed to grow enough food to feed them. With the population growth rate at 1.58%, India is predicted to have more than 1.53 billion people, all set to take the numero uno position by the end of 2030.

Based on FAO projections, 13% more land in developing countries like India will be converted to agricultural use in the next 30 years. From a global perspective this amounts to a meagre 2% increase from the 38% of global land area used in 2008 to a total of 40%. This land expansion will account for only 20% of future increases in food production. Another 10% additional production can be projected from increased cropping intensity. Therefore for the rest 70%, we will have to call upon innovation of efficient technologies and also judiciously use the ones at hand. In addition to the fact that land is limited and reclamation is a slow process often coupled with environmental degradation, we are also losing land at an alarming rate due to climate change and desertification.

According to the USDA Economic Research Service, the development of new agricultural technologies including advances in genetics, nutrition, disease and pest control and livestock management was an important factor in the 20th century productivity improvements. Land resource is finite; the dilemma of allocation of this resource further complicates this problem. The first is the environmental dilemma and the need to minimise the negative environmental effects of agriculture particularly with regard to greenhouse gas emissions, soil degradation and the protection of already dwindling water supplies and biodiversity. A significant change in climate on a global scale will impact agriculture and consequently affect the world's food supply. Climate change *per se*is not necessarily harmful, the problems arise from extreme events that are difficult to predict (FAO, 2001). More erratic rainfall patterns and unpredictable high temperature spells will consequently reduce crop productivity. Developing countries in the tropics will be particularly vulnerable. Latitudinal and altitudinal shifts in ecological and agro-economic zones, land degradation, extreme geophysical events, reduced water availability, and rise in sea level and salinization are postulated (FAO, 2004).

Therefore we need to employ such agricultural technologies that have a neutral or positive impact on our environment. The second is the economic dilemma arising from conflicting goals to allocate crop-land from growing food to producing grains for bio-fuels. The problems of protecting the environment and balancing the world's need for energy and food require a complex and multifaceted approach.

Room for horizontal expansion is very little and the only available option is vertical expansion through increased productivity and cropping intensity using modern methods like protected intensive farming/vertical farming employing plant environment control measures, quality seeds, fertilizer, irrigation and plant protection. Protected farming is economically more rewarding in production of high value, low volume crops, seeds and planting materials, off season fruits and vegetables. With appropriate structures and plant environment control measures the constraints of environment prevalent in the region can be overcome allowing almost year-round cultivation, increased productivity by 25-100% and in certain cases even more, as well as conservation of irrigation water by 25-50%. Protected farming offers itself as alternate farming method with much higher carrying capacity. Vertical farming holds the promise of addressing these issues by enabling more food to be produced with less resource use.

The term green house is basically a concept of manipulating the crop mirco-environment. It is generally a house like structure where the natural sunlight, humidity, temperature and even the concentrations of greenhouse gases can be manipulated to meet requirements of a particular crop. Greenhouse technology is the most intensive form of commercial cultivation and could well be called as food factories. Greenhouses being the most efficient means to overcome climatic diversity, greenhouse vegetable production make the use of advances in technology to control the environment for maximizing crop productivity and increasing the quality of vegetable produce. Protected cultivation has the potential of fulfilling the requirements of small grower as it can increase the yield manifold and at the same time improve the quality of the produce significantly as per the demand of the market.

Current Status of Protected Cultivation

The greenhouse technology is more than 200 years old and Europeans were considered the pioneers in this field. Later, with the advent of plastics during the World War II, a new phase in the greenhouse technology emerged and greenhouse crops started to move to mild-winter regions such as Mediterranean Basin countries (in particular, Italy, Spain and Morocco). The rise in oil prices in the 1970s, which increased the heating costs, further enhanced the diffusion of greenhouse crops in the Southern countries. More recently, protected crops expanded to some Asian countries such as India, Korea and especially China (Jiang *et al*., 2004). The worldwide protected horticulture has witnessed 30-40% growth since 1991.

China started protected cultivation on 1990's and today the area under protected cultivation in China is more that 2.5 m ha and 90 per cent area is under vegetables. In China, low cost protected technology *viz*., plastic mulches, plastic low tunnels and walk in tunnels are being used on 80 per cent of the total area protected cultivation and perhaps this is the basic reason that today China is the largest producer of vegetables in the World. The Netherlands (Holland) has a long tradition of protected cultivation under glass shielded greenhouses growing flowers/ornamentals and vegetables in equal proportion. Globally there are about 20 m ha area under protected cultivation and is still on the rise. However, in Europe, Spain is the leader with 51,000 ha mostly under low cost polyhouses, about 150,000 ha under plastic mulches and over 20,000 ha under low tunnels and floating covers. Japan has about 54,000 ha under green houses/poly houses of which about 11,000 ha are under fruit crops. Brinjal, tomatoes, cucumbers, pumpkins, green pepper, strawberries, water melons, and lettuce are grown in greenhouses in Japan. India is way behind.

While greenhouses have existed for more than one and a half centuries in various parts of the world, in India use of greenhouse technology started only during 1980's and it was mainly used for research activities. This may be because of our emphasis, so far had been on achieving self-sufficiency in food grain production. However, in recent years in view of the globalization of international market and tremendous boost and fillip that is being given for export of agricultural produce, there has been a spurt in the demand for greenhouse technology. The National Committee on the use of Plastics in Agriculture (NCPA, 1982) has recommended location specific trials of greenhouse technology for adoption in various regions of the country.

The Centre for protected cultivation technology was established in the year 1998-99 as demonstration farm and commissioned as Indo-Israel Project in January 2000 as a project undertaken jointly by the Government of India, through Department of Agricultural Research & Education (DARE) & ICAR and the Government of the State of Israel, through the Centre of International Cooperation (MASHAV) & CINADCO. The project farm was aimed to demonstrate different technologies for intensive and commercially oriented peri-urban cultivation of horticultural crops for improved quality and productivity. The centre was emphasized to act as a nodal centre of R & D work and ToT on the above aspects.

In India, protected cultivation has been implemented in more than 58000 hectares till 2012-13. The states and union territories that have adopted protected cultivation in the country have increased from 9 states in 2007-08 to 30 states and union territories in 2012-13. The phase-wise implementation of protected cultivation has bolstered the adoption of protected cultivation across the country.

Combined efforts of the national boards such as NHM (National Horticulture Mission), NHB (National Horticulture Board) and RKVY (*Rashtriya Krishi Vikas Yojna*) have created awareness and are providing financial assistance to the farmers to adopt protected farming methods for horticultural cultivation. The states that have consistently expanded the area under protected cultivation for the period of 2007-2012 are Andhra Pradesh, Gujarat, Maharashtra, Haryana, Punjab, Tamil Nadu and West Bengal. Maharashtra and Gujarat had a cumulative area of 9126.23 hectares and 6924.42 hectares, respectively under the protected cultivation till 2012-13.

State-wise physical targets and achievements in protected cultivation under various Govt. schemes *w.e.f.* 2005-06 to 2012 to 2013

Sr. No.	State	Targets (ha)	Achievements (ha)
1.	Andaman & Nicobar	82.63	22.75
2.	Andhra Pradesh	4462.86	2835.29
3.	Bihar	878.65	547.42
4.	Chhattisgarh	12933.07	11405.73
5.	Delhi	1.10	240.62
6.	Goa	17.31	6.13
7.	Gujarat	5077.73	6924.42

8.	Haryana	2464.33	2073.36
9.	Jharkhand	3071.85	1900.15
10.	Karnataka	4745.94	4115.7
11.	Kerala	706.75	114.53
12.	Laksha Dweep	1.5	-
13.	Madhya Pradesh	6021.89	5889.08
14.	Maharashtra	9534.32	9126.23
15.	Odisha	1845.82	3306.86
16.	Pondicherry	13.28	5.5
17.	Punjab	1183.81	991.02
18.	Rajasthan	446.74	433.13
19.	Tamil Nadu	1105.98	975.85
20.	Uttar Pradesh	5395.22	6937.4
21.	West Bengal	970.13	806.44
	Total	**60960.91**	**58657.61**

Source:www.nhb.gov.in

The area under the greenhouses has increased at a CAGR of 49.16% from 2007 to 2012. With the rising involvement of the government national boards and the respective state agricultural agencies, the area under protected cultivation is expected to rise at a CAGR of 84.2% by 2017. The subsidy schemes, international associations with countries such as Israel are expected to act as a major boost for the protected cultivation in India. The only major challenge for the adoption of the protected cultivation is the cost of the methods and lack of awareness. If these aspects are taken care of by the industrial players and the policy makers, then the protected cultivation industry will showcase remarkable growth in the next 5 years.

Protected Horticulture

It refers to Horticulture with human interventions that create favourable conditions around the cultivated plants or animals offsetting the detrimental effects of prevailing biotic and abiotic factors. Plants in open field conditions experience short cropping season, unfavourable climatic conditions (too cold, too hot, too dry and cloudy ambient) impairing photosynthetic activities, vulnerable to predators, pests, weeds, depleted soil moisture and plant nutrients. In protected culture one or more of these factors are controlled or altered, to the advantage of plants or animals, where usually factors such as temperature, CO_2 concentration, relative humidity, access to insect and pest etc., are controlled to desirable limits. The factors controlled and range of control is decided by devises chosen and fitted on the structure.

Structures and environment control measurers employed isolate this cultivated space allowing cultivation in unfavourable ambient conditions in reasonably close to optimal conditions and offer several advantages, as given below:

- Cultivation in all seasons is possible
- Provides favourable micro-climate conditions for the plants
- Higher yield with better quality per unit area
- Conserves soil moisture thus needs less irrigation
- Most suitable for cultivating high value/off-season crops
- Easy management of pests and diseases
- Helps in hardening of tissue cultured plants
- Helps in raising early/ off season nurseries
- Round the year propagation of planting materials is possible

- Protects the plants from wind, snow, rain, birds, hail etc.
- Generates self-employment opportunities for educated youth
- Vegetable seed production
- Hybrid seed production

Principle

Basic principles involved in protected agriculture are greenhouse effect for heating cultivated space using sunrays and ventilation for cooling and air CO_2 regulation. Cultivated area is isolated and covered with plastic film or glass which is transparent to incoming short wave radiation from the sun impinging on outer surface but opaque (partially) to emergent long wave infrared radiation from soil, plant and structural surfaces, thereby trapping the heat. As a result enclosed space maintains higher temperature than the ambient. However, trapped heat is gradually dissipated through conduction, convection/ventilation and radiation. By incorporating heat sinks, reduced ventilation and application of radiation shields either rate of cooling is slowed down or a supplemental heat source placed inside.

Important Considerations for Successful Protected Cultivation

The growing Greenhouse horticulture sub- sector presents attractive investment opportunities, possibilities for environmental conservation and marginal land utilization. The technology is much more sophisticated than existing open-field cropping, thus requiring drastically more diligence and precision and attracting higher start up and operational costs. Several factors involved in greenhouse horticulture must be considered in deciding on one's investments in time, effort and money. These include:

1. Economics
2. Ecology
3. Technology
4. Physical infrastructure
5. Labour

Economics

Cost: Greenhouse horticulture involves huge start-up costs, due to the structures presently used. However, attempts have been made by farmers having less resources, to find more affordable yet effective structures, including the use of local timber/bamboos. This has actually been the development path of the industry in most countries, evolving from the use of wood to metal, over time. Advanced countries such as Spain and China still have significant numbers of wooden structures.

Capital: Lot of initiatives have been taken up by Government of India to promote protected cultivation through various schemes like National Horticulture Mission, *Rashtriya Krishi Vikas Yojna*. Under these schemes, farmers are provided with 50% subsidy and even more at State level e.g. 65 to 75% in Gujarat.

Market: Greenhouse horticulture allows consistent supply of high quality produce, a critical need of most markets. A comprehensive marketing policy must be implemented in order to reduce transportation costs, supply the market, in particular the big supermarket chains that are now prevalent in the urban areas with labelled and quality-certified products and stabilize their prices. It is becoming a common practice that big retail groups include in the contract with large producer organizations detailed growing protocols for the environmentally sound production of healthy commodities. Therefore, there is the need for grouping growers into large (co-operative) commercial organizations, in order to improve their ability to gel a satisfactory commerce, including a remunerative price of their products.

Market arrangements vary in factors such as produce chain requirements, payment time and duration of access. Despite the market potential for these crops, it is therefore essential that each potential grower identifies a market before undertaking production.

Ecology

Greenhouse horticulture was developed in the temperate countries to conserve heat for growing plants during cold periods. In the Tropics, this feature limits the use of the technology, giving tropical protected horticulture some markedly differing needs. Key ecological factors involved include solar radiation/ temperature, water, wind, relative humidity, flooding and pests.

Solar Radiation: For production of crop or growth of plants, it is important to know the mean daily sum of solar radiation energy for each month. This will provide the necessary information of difference of the mean daily sum of solar radiation between any two months. This information will help to plan proper greenhouse technology that can manipulate this solar radiation in favour of crop grown under it by controlling light intensity (irradiance), light duration and light quality. A minimum daily radiation of 500-1000 Wh/m^2/day is the limit for sufficient growth of a plant. In tropical region varieties suitable to shorter day length must be chosen for proper use of the high mean daily radiation.

Temperature: For greenhouse technology the temperature should be considered in two different ways. First, the outside temperature on which the structural design of a greenhouse depends. Second is the inside temperature, which is modified in favour of the crop grown under the greenhouse.

Outside or Natural Temperature: Season, altitude, latitude, wind condition and intensity of solar radiation commonly control the course of temperature prevailing in a specific location. Therefore it is difficult to make any generalization about temperature of a vast region. Even two places separated by a hillock may exhibit different temperature pattern, though in a minor scale.

The greenhouses in the climatic zones around 20° to 30° north and south latitudes may require both the cooling and heating mechanism to cultivate crops throughout the year to avoid problems at extreme temperatures and danger of frost. However, the local variation in micro-climate has to be examined properly to establish a greenhouse.

Inside Greenhouse Temperature: Generally the daytime inside temperature of a closed greenhouse is always more (about 20%) than that of outside. Now the openings provided in the greenhouse for ventilation can reduce such hike of temperature to an extent depending upon the ventilation efficiency of the greenhouse. Proper natural ventilation system can equalize the temperature of outside and inside if the design of the greenhouse is done properly. Some artificial forced ventilation (using fans) can reduce the inside temperature further in daytime. However, for further reduction of inside temperature proper cooling mechanism is required, e.g. general shading in very hot & humid condition and evaporative cooling mechanism in hot & dry condition are used for cooling the greenhouse in daytime.

As night approaches, the outside temperature gradually drops with withdrawal of solar radiation. If the mean night temperature goes below the level required for optimum biological activity (12°C), the night temperature inside the greenhouse can be increased by closing the ventilators of greenhouses at afternoon. This closed condition of greenhouse can retain the daytime high temperature for the night. If the mean daily outside temperature goes below 12°C then separate heating arrangement is required to increase the inside temperature at night.

Water: Greenhouses keep out rainfall, thus requiring a consistent supply of adequate quality water for efficient crop production. This water should be free of excessive solid particles (e.g. soil, algae) and a pH level of 6.5 to 7.2. For instance, tomato and sweet pepper plants use an average of 1.5 -2 litres water per day. Sufficient volumes must therefore be calculated for the duration of drought periods and appropriately-sized storage facility constructed. Significant volumes of rainfall can be harvested from the roof of greenhouses.

Relative humidity: The importance of air humidity for designing greenhouse for crop production is frequently underestimated. Both the humidity of air outside and inside of a greenhouse shall be meticulously evaluated and considered while planning a greenhouse. Furthermore, both absolute humidity and relative humidity has to be properly measured and shall be considered with due importance. Plant growth and production will slow down or stop when the humidity in air is lower than 30% or higher than 90%.

Technology

Selection of Variety: There are three aspects for crop selection for farming under greenhouse. These aspects are guided by combined output of some information.

1. Selection of type of crop depends upon Market, growth habit (indeterminate/viny), Differential capacity to increase yield in relation to open field, Off- season production, Status of greenhouse and climatic control mechanism.
2. Selection of groups of selected type of crop is dependent upon Climate, Physiological potentiality to increase yield.
3. Selection of variety of selected crop depends on Genetic capacity, Consumers demand and practical feasibility.

Selection of Growing Media

Soil-based root media: Most of the greenhouses for crop production use soil-based media. Traditionally, the soil-based medium is composed of equal parts by volume of loam field soil, coarse sand, rice husk and well-decomposed organic matter adjusted to proper pH level.
Soil-less root media: In initial stages of greenhouse cultivation, particularly in crop specific greenhouse, soilless root medium is popular for the following reasons:

1. Proper field soil is not available, and transportation of soil is not feasible.
2. Maximization of production through highest possible supply of nutrient, air and water to the media.
3. Reduce the weight of the medium (for potted plant) to suite the pot for long distance market and
4. Perfect application of automation in the greenhouse

Pasteurization or fumigation of growing media: Now-a-days it is an essential practice for all greenhouses. However, in warm conditions, where the inside environment of greenhouse does not freeze, humidity is high, temperature is warmer, the scope of development of disease causing organisms is more. Continuous culture of a single crop or cycle of a few crops, in a greenhouse provides a continuous host on which disease causing organisms build up. The problem of nematodes is also aggravated due to the reasons stated above.

Pasteurization may be accomplished by means of injecting steam, any suitable chemicals into the soil or soil solarization.

Drip Irrigation: It is the best and efficient method for growing any kind of horticultural crop both in open field and greenhouse.

Proper monitoring during installation and running of a drip irrigation system is necessary to avoid clogging, which imposes one of the major problems of this system. For that matter the following aspects should be taken care of.

Analysis of water not only provides the information about its applicability according to crop requirement but also gives an idea about the possible clogging problem in a drip-irrigation system. So it is essential to estimate water quality before making a plan for installation of a drip-irrigation system.

There are four factors associated with irrigation water that causes 90 percent of clogging in a drip irrigation system. Physical, chemical and biological aspects of irrigation water have been rated as 35, 22, and 37 percent responsible for clogging, respectively.

Fertilizer application and fertigation in greenhouse: It is mandatory to maximize the benefits of fertilization in the form of plant growth or yield in a greenhouse situation. Proper and optimum application of plant nutrients in natural or chemical forms most acceptable to plants is the basic job of fertilization. Generally liquid fertilizers containing specific plant nutrients are applied to plants of greenhouse through drip irrigation system in two different ways.

Constant feed: This application entails administering low concentration of fertilizer each time the plant is irrigated. It is the most popular method of greenhouse fertilization. Through this method plants receive a fairly constant supply of nutrients in the root medium for sustained growth and development.

Intermittent feed: Greenhouse plants may be fertilized according to a periodic schedule such as weekly, fortnightly or monthly. The disadvantage of this method is the level of nutrient available at the time of application, which is higher than that of plant requirements. This gradually decreases over time, and touches a lowest level just before the next application.

Crop Protection: Maintenance of crop health is essential for successful farming for both yield and quality of produce. Pest Monitoring measures such as sticky traps should always be in place for timely action. Unwanted visitors should be discouraged from entering the greenhouse. GAP (Good Agricultural Practices) should be adopted to protect the crops from pests.

Soft compounds for plant protection in GAP programme: Organic compounds or botanicals such as neem/products & their formulations, Horticultural/mineral oils, mineral compounds, ecological detergents *e.g.* Zohar-Lq 215 (registered in Israel as fungicide against powdery mildew), herbicidal soaps, fatty acid soaps *Bt*, NPVetc.

Cultural control measures: Plastic covers- using UV absorbing sheets, Insect proof nets, Enriched / Fortified / Suppressive compost, Color traps for pest monitoring:Yellow for white fly, Blue for thrips, Silver for aphids, Sanitation-clean area around greenhouses, Water heat system & good ventilation, Resistant varieties, Grafting-using pest resistant root-stocks.

Pesticide application: Integrated Pest Management (IPM) strategies, treatment of planting material, Use of only registered pesticides and avoid sub-standard ones, Use minimum chemical pesticides, Avoid indiscriminate use of chemical pesticides, Apply pesticides only when pest populations are large enough to cause economic losses, Apply pesticides according to label directions in terms of dosage, crop, canopy, time of application, waiting period etc., Use right kind of spray depending upon the pest and crop canopy, Dispose the pesticide container and polythene safely by burying, Do not use damaged containers, Avoid wrong disposal of left over pesticides, Maintain records of all pesticide applications properly, Persons applying pesticides must read the instructions carefully and comply with it, Use protective clothing while applying pesticides, Avoid repeating the same group of chemicals again and again, hence different chemicals may be rotated so that the insect pests do not develop resistance.

Canopy Management: It is the practice performed on a plant that gives a specific retainable structural frame to that plant by way of regular pruning. Actually the direction and spacing of selected branches or main stem of a plant is managed through pruning or otherwise in such a way that they provide a proper frame allowing more sunshine and air movement. This increases the efficiency of biomass and reduces the land area covered by canopy of that plant (to accommodate high density planting.

Tools and equipment: The use of specialized tools and equipment will allow much higher levels of efficiency. Items such as meters for measuring temperature, relative humidity, light, pH and electrical conductivity/plant nutrients will indicate the status of the greenhouse environment and guide management interventions to better suit plants. Computerization is the ultimate level as this can provide fully-automated systems, allowing for efficient management of larger facilities, even remotely from distance, using telecommunications or satellite technology.

Physical Infrastructure

Roads: Access between greenhouse sites, input suppliers and the market is critical for a successful protected horticulture industry. This must be assessed before establishing facilities. It is also imperative that where necessary, suitable locations for greenhouse horticulture be supported with this necessary infrastructure.

Energy: For most operations the greenhouse grower will require power for irrigation. This might be provided by electricity, solar power or fuel. Solar is most efficient despite initial high costs and is being pursued as a research area. The use of re-circulating nutrient solution systems is also critical to global energy savings, through more efficient use of water and fertilizer. This system requires strict nutrient solution monitoring and modification to ensure maintenance of proper plant nutrition and plant health.

Engineering facilities: Metal tunnel houses require machinery to bend arches for the roof. This facility is available at several engineering workshops and a few grower operations. Two similar high tunnel greenhouse models have been designed and constructed by local growers utilizing commercial and their own engineering facilities. Two other models from overseas have also been imported and comparisons are being initiated.

Labour

The skills needed for greenhouse horticulture differ greatly from that for traditional open field operations. This involves the regularity, timing and level of detail of operations. More technical skills are also needed and additional activities (e.g. more intensive pruning, trellising, pollination, measurement of P^H and electrical conductivity (EC), care in using double-doors) involved. For optimal efficiency, literacy and numeracy are critical. The females are generally more suited for most operations owing to their diligence and greater attention to detail.

The feasibility of relevant and appropriate structures for vegetable cultivation depends largely on climatic conditions of a particular location. Inspite of this, choice of these structures is also dependent upon various factors like economic status of a farmer, availability of assured market and electricity, type of soil etc. Normally the economics of protected cultivation directly depends upon the initial cost of fabrication of the protected structure, its running cost and the available market for high quality produce. Environmental controlled greenhouses, naturally ventilated polyhouses, walk-in-tunnels, insect proof net house, plastic low tunnels etc are being used in one or other part of the country for round the year and off-season cultivation of vegetables.

The following are the major protected cultivation methods in vogue:

1. Mulching
2. Floating Covers
3. Low tunnels / Row Covers
4. Cloches
5. Polyhouses / Greenhouses

Mulching: It is a practice of covering soil around cultivated plants to make conditions more favourable to the plants by conserving soil moisture, maintaining higher soil temperature, controlling weeds and keeping root zone more friable allowing soil aeration conducive to soil microflora and root growth etc. Covering materials could be natural, like leaves, straw, sawdust, peat moss, compost, gravel etc or synthetic, like polyethylene and PVC of different colours (generally black) and thickness depending upon ambient conditions and effects desired. Plastic mulches have several advantages

- Soil moisture is better conserved.
- Weeds are effectively controlled by blocking sun light.
- Soil fumigation is more effective.
- CO_2 enrichment around plant root zone.
- Permits cleaner crop produce.
- Early crops, higher yields and more income.

Floating Row Covers: A Floating Row Cover is a plastic film fabric used without any mechanical support to protect crops from insect vectors, sucking pests, hoppers and beetles. Floating covers are made of spun bonded or non-woven fabric of 10 - 50 g/m^2 density. Either single rows or a number of rows at a time are covered. Heavier covers of densities higher than 30 g/m^2 are used primarily for frost and freeze protection. The edges are secured by burying in the soil. For self pollinated crops, leafy vegetables, the floating covers can be had for the entire duration of the crops. The crops of musk melon, tomato, pea, carrot, cabbage, leafy vegetables, lettuce, green beans, cucumbers, watermelon, squash, and radish are grown under floating covers.

Low Tunnels / Row Covers: Low tunnels generally cover rows of plants in the field providing protection against low temperatures and frost, winds and insect pests. Clear plastic films or nets are stretched over low (up to 1.0 m high) hoops made of steel wires, bamboo strips or cane. Polyethylene films of about 50 micron thickness with ventilating holes (4% of surface area) are used. Sometimes PVC films are also used. Recently use of non-woven spun bonded porous lighter films has also come in practice. Low tunnel provides a passive control of plant microclimate. Plastic mulches and drip irrigation in conjunction with low tunnels have better effect. Low tunnels permit early crops with significantly higher yields of melons, cucumber, tomato, strawberry, capsicum, beans, summer squash etc.

Cloches: A cloche is a protective enclosure consisting of a structural frame and transparent or translucent glazing material for individual plants providing protection to young transplants in kitchen gardens, orchards and forests. After the plant is well established cloches are removed. Provision of natural ventilation is required to avoid excessive high temperature in clear sunny conditions.

Polyhouse / Greenhouse: It is a framed or inflated structure using transparent or translucent cover that creates greenhouse effect, allowing at least partial control on crop microclimate and is large enough to permit a person to work inside. The air temperature rise inside a polyhouse/greenhouse during winter is utilized to grow nurseries, planting materials and crops without supplementary heat. The enclosed space through controlled ventilation permits enrichment of air inside with higher $C0_2$ concentration which enhances crop productivity. Relative humidity and temperatures can be raised or lowered than ambient through shading and evaporative cooling or air-conditioning.

Classification of greenhouse based on suitability and cost

a. Low cost or low tech greenhouse: Low cost greenhouse is a simple structure constructed with locally available materials such as bamboo, timber stone pillars, etc. The ultra violet (UV) film is used as cladding materials. Unlike conventional or hi-tech greenhouses, no specific control device for regulating environmental parameters in-side the greenhouse is provided. Simple techniques are, however, adopted for management of the temperature and humidity. Even light intensity can be reduced by incorporating shading materials like nets. The temperature can be reduced during summer by opening the side walls. Such structure is used as rain shelter as well as to protect from low temperature for crop cultivation. Otherwise, inside temperature is increased when all sidewalls are covered with plastic film. This type of greenhouse is mainly suitable for cold climatic zone.

b. Medium-tech greenhouse: Greenhouse users prefers to have manually or semiautomatic control arrangement owing to minimum investment. This type of greenhouse is constructed using galvanized iron (G.I) pipes. The canopy cover is attached with structure with the help of screws. Whole structure is firmly fixed with the ground to withstand the disturbance against wind. Exhaust fans with thermostat are provided to control the temperature. Evaporative cooling pads and misting arrangements are also made to maintain a favourable humidity inside the greenhouse. As these systems are semiautomatic, hence, require a lot of attention and care, and it is very difficult and cumbersome to maintain uniform environment throughout the cropping period. These greenhouses are suitable for dry and composite climatic zones.

c. Hi-tech greenhouse: To overcome some of the difficulties in medium-tech greenhouse, a hi-tech greenhouse where the entire device, controlling the environment parameters, are supported to function automatically. At present computer based advance technology with full automaton for temperature, humidity, irrigation control is available which can be utilized for high value low volume vegetable for local consumption and long distance supply.

Future Thrusts

Research

1. Development of appropriate, efficient and affordable protected agricultural structures for crops and animals with appropriate, durable, efficient and economical cladding materials.
2. Identification and development of suitable varieties/hybrids of crops for protected cultivation both for high value vegetables.
3. Development of affordable agro-practices specific to protected cultivation particularly with respect to IPM, INM (water soluble fertilizers), IWM, Best Management Practices (BMP), and package of practice for organic farming.
4. Standardization of crop nursery practices under protected environment to make maximum use of available space and opportunity.
5. Development of post-harvest practices for handling, grading, packaging, transport and short term storage of produce from protected cultivation.
6. Development of tools, implements and machines for facilitating crop operations under protected cultivation.
7. Designing of location and crop specific structures for energy efficient micro-climate control for maximum crop productivity. This includes development of intelligent control systems for micro-climate maintenance.
8. Multi-tier protected farming techniques need to be developed to maximize productivity per unit of ground area to cope up with growing demands of vegetables, fruits, flowers, medicinal and aromatic plants in declining land holding scenario.
9. Identification of region specific and techno-economic feasible cropping sequences.
10. Development and use of new generation biodegradable polymers.
11. Identification of potential rootstocks and their use in protected cultivation.
12. Developing devices for monitoring through internet

Development

1. Human resource development through training of trainers, field extension workers, NGOs, village leaders and farmers. Rural artisans and craftsmen need to be trained in construction and maintenance of Plasticulture equipment and structure.
2. Large scale demonstration of proven protected cultivation practices in potential areas. Launching of schemes at state and central level with built-in incentives for the designs recommended by research institutions.
3. Create post-harvest handling, transport, storage and marketing infrastructure for protected cultivation produce ensuring better returns to farmers.
4. Networking of farmers/Self Help Groups (SHGs) for production, handling and marketing of produce from protected agriculture for domestic as well as export markets.

Policy

1. Create awareness and enabling environment for economic prosperity of stakeholders of protected agriculture.
2. Assured availability of cladding materials, other essential inputs-seeds, water soluble fertilizers, pesticides etc. at the divisional level.
3. Precision Farm Development Centers (PFDCs) should be well equipped and should create a role for themselves in protected agriculture.
4. State Agricultural Universities and KVKs in the region need to lay emphasis on teaching, research and extension of protected cultivation as major and important step towards strengthening livelihood base of small landholders.
5. Link the identified promotional schemes for protected agriculture with already existing State/National programmes. RKVY funds should be mobilized for promotion of protected farming in North-West Himalayan region.

Modern Concept of Protected Cultivation

The modern idea of vertical farming uses techniques where natural sunlight may be augmented with artificial structure. The idea of vertical farming has existed at least since the "*Hanging Garden of Babylon*". The concept of a Vertical Farm (VF) has existed theoretically since the early 1950s. The spectrum of various components in the urban and peri-urban ecosystem is also changing continuously. Intensifying indoor urban farming through the establishment of vertical farms (or high-rise farms) in urban centres is the likely solution to the swelling human population. Vertical farming or high-rise farming or sky farming is a proposed indoor, urban farming technology involving large-scale agricultural production in multi-story buildings. It is an intensive farming strategy which mainly employs advanced techniques such as hydroponics and Aeroponics to produce crops like fruits, vegetables and edible mushrooms continuously. It also includes the raising of livestock and fishes indoor.

How Will Vertical Farming Work?

According to scientific calculations, a single vertical farm that will occupy about one square block of a city and elevated up to 30 stories can provide enough food to supply the needs of about 10,000 people. Constructing these vertical farm units will develop a closed in system where waste products, air, water and minerals, needed by plants and vegetables to thrive, will be recycled within the building. It aims to generate energy, maintain a pesticide-free farming technology, effective waste management as a means of sustaining food production all within one vertical farm building. Channelling the city's wastes into its system which will undergo bioremediation process makes it a feasible integration to the farming technology.

There is still a long way to go in constructing these vertical farms, since the aim is to generate greater yields for every square foot that the system uses. Therefore, it requires intensive researches in various fields, like industrial microbiology, hydrobiology, engineering, physics, plant and animal genetics, waste management, public health and urban planning etc.

The researches have to support the concept of addressing food production in a modern city, where urban wastes, like black water will be composted, recycled and used for farming inside a standard tenement-like building.

The city's sewage sludgewill enter a machine called "SlurryCarb", to break down the sludge into carbon and water. The remaining slurry will be burned like coal to power steam turbines that will generate electricity. Part of the sludge will be treated with chemicals to kill the bacteria and will undergo heating and drying process that will convert the treated sludge into topsoil. Water extracted will undergo bio-remediation processes using cattails, saw grass and zebra mussels, until it becomes clean enough for agricultural use. It can also be subjected for further refinement until safe enough to be used as drinking water.

In consideration of the world forecast on population growth rate, food security, adverse effects of the continuing horizontal farming activities on the ecology and climate, health and nutrition and other factors, the advantages of this farming technology are summarized:

Increased and Year-round Crop Production

This farming technology can ensure crop production all year-round in non-tropical regions. 1 indoor acre is equivalent to 4-6 outdoor acres or more, depending on the crop. For strawberries, 1 indoor acre may produce yield equivalent to 30 acres.

Despommier suggests that a building 30 storeys high with a basal area of 5 acres (2.02 ha) has the potential of producing crop yield equivalent to 2,400 acres (971.2 ha) of traditional horizontal farming. Expressed in ratio, this means that 1 high-rise farm is equal to 480 traditional horizontal farms. Furthermore, indoor farming will minimize infestation and post harvest spoilage.

Protection from Weather-related Problems

Because the crops will be grown under controlled environment, they will be safe from extreme weather occurrences such as droughts and floods.

Organic Crops Production

The advantages of this urban farming technology can be further exploited by large scale production of organic crops. The controlled growing conditions will allow a reduction or total abandonment of the use of chemical pesticides.

Water Conservation and Recycling

According to Despommier, the vertical farming technology includes hydroponics which uses 70 percent lesser water than normal agriculture. Aeroponics will also be used which consumes 70 percent less water compared to hydroponics. Urban wastes like black water will be composted, recycled and used for farming inside the building. Sewage sludge will be converted to topsoil and processed for the extraction of water for agricultural use or drinking water.

Environment Friendly

Every land area that will be developed for this farming technology will reduce by a hundred fold the necessity of utilizing land for food production. These farms could be reverted to their natural state. This will promote the regrowth of trees which are effective in CO_2 sequestration.

Growing crops indoor reduces or eliminates the use of mechanical ploughs, and other equipment, thus reducing the burning of fossil fuel. As a result, there will be a significant reduction in air pollution and CO_2 emission that cause climatic change. Furthermore, CO_2 emission will be reduced from shipping crops across continents and oceans. A healthier environment will be enhanced for both humans and animals.

Lesser disturbance to the land surface will also favour the increase in the population of animals that live in and around farmlands. Vertical farming therefore favours biodiversity.

Energy Conservation and Production

Selling of the crops in the same building in which they are grown will significantly reduce the consumption of fuel that is used in transporting the crops to the consumers.

Vertical farms can also generate power. Although a 30-story vertical farm needs 26 million kwh of electricity, it is capable of generating 56 million kwh through the use of biogas digesters and by capturing solar energy (medicalecology.org).

Sustainable Urban Growth

Vertical farming, applied in a holistic approach in conjunction with other technologies, can allow urban areas to absorb the expected influx of more population and yet still remain food sufficient. The technology could provide more employment to the rural populace expected to converge to the cities in the years to come. However, traditional farming will continue because many crops are not suited to indoor farming.

Issues

1. The financial feasibility of vertical farming has not been established. A detailed cost-benefit analysis is yet to be made in order to support its advantage over the traditional horizontal farming. There is the possibility that the extra expenditure that will be needed for lighting, heating and power supply will be in excess of the benefits.
2. The advantages of vertical farming are partly based on food miles, the distance that food is transported from area of production to consumption. However, University of Toronto professor Pierre Desrochers revealed in a policy paper that only about 10 percent of the energy utilized in food production is attributable to transportation. He also argued that the environmental impact of transportation is minimal (Evans, 2009).
3. If fossil fuels will be used to power the vertical farms, the net environmental effect may be in the negative. It is possible that the traditional horizontal farms will burn less coal and contribute less to climatic change.
4. There is no certainty that vertical farms will reduce the area utilized for horizontal farming. It is possible that if ever it is implemented, it will merely become supplementary to the existing farms in producing food and bio fuel to meet the increasing demand. It will be more beneficial to grow many crops like corn, rice and wheat in open fields as compared to many fruits and vegetables.
5. There is an enormous requirement for energy in vertical farming. It is estimated that with 30 storeys, the supplemental light that needs to be supplied per square foot in every floor is ten to forty watts.

Bruce Bugbee, a crop physiologist at Utah State University in Logan, believes that vertical farming would be too expensive to implement and uncompetitive with traditional horizontal farms which use free natural light. He noted that crop growing needs about a hundred percent of light compared to man's requirement. To feed the Earth's swelling population, he insists: "Eat less meat." The grazing areas can then be sown with food crops. (Roach, 2009).

What will be the impact of vertical farming on the poor countries? Assuming that all the hindrances for the implementation of the technology have been removed, it is obvious that not all countries have the capacity to supply the needed capital. These countries will have no choice but to continue their traditional crop farming practices. The market of certain food products which can be produced in vertical farms will be adversely affected.

The whole idea may seem too ambitious and there are mixed reactions about the concept of vertical farming and the recycling of black water. The current state not only of our environment, but also of the world population's general health conditions leave us with no other choice but to try anything that offers even just a glimmer of hope. Vertical farming offers more than a glimmer, because its premises are all based from lessons of the past.

Today, several vertical farms have been erected between 2010 and the present. The first examples are mostly prototypes and are located in Japan, Korea, Holland, USA and England. **Japan** efforts are concentrated at the vertical farm in Kyoto, called Nuvege (www.Nuvege.com). This vertical farming is housed in a 4 story 'Quonset' hut-like building, the rough size of 2851 square meters. The company intent (big enough) is that their innovative Vertical Farming Techniques will provide a universal working model for safe and economical growth environments for the rest of the world. Nuvege's current corporate goals include efforts to establish branch operations throughout Asia and in urban centres throughout the United States.

South Korea's project(Seoul), located in building that is three stories tall and is designed to test various aspects of farming in a controlled environment on multiple floors. Lighting and automation are high on their list of things to work on. They are currently growing mainly leafy green vegetables using high tech LED lighting and they want to begin indoor aquaculture, as well. Next to the Vertical Farm is a much larger, newly built seed bank building *(Agro biodiversity*) that stores all varieties of crop seeds and native Korean plants. Seed viability testing will be facilitated by the vertical farm.

Another idea, developed by **Valcent**, a vertical-farming firm based in Texas, Vancouver and Cornwall, is to use vertically stacked hydroponic trays that move on rails, to ensure that all plants get an even amount of sunlight. The company already has a 100-square-metre working prototype at Paignton Zoo in **Devon (UK)**, producing rapid-cycle leaf vegetable crops, such as lettuce, for the zoo's animals. The VerticCrop system ensures an even distribution of light and air flow. Using energy equivalent to running a desktop computer for ten hours a day it can produce 500,000 lettuces a year, he says. Growing the same crop in fields would require seven times more energy and up to 20 times more land and water.

Plant Lab is located in Den Bosch, The Netherlands. It is currently under construction and is based on a smaller prototype that has been up and running for several years. Everything is grown by LED lighting, and they claim that their experiments, using a wide variety of LED fixtures, give a 3X increase in plant yield using precisely controlled frequencies of light in the visible red and blue spectrum.

A demonstration vertical farm of five stories is under construction in **Manchester, England**. It takes advantage of an abandoned warehouse and the designers plan to raise poultry in addition to the standard variety of indoor vegetables and fruits. The key notes about the project have been discussed on July 17, 2011 at **Manchester International Festival(MIF).** MIFplans an ambitious project to create the UK's first multi-storey vertical farm, located in a disused tower block right there in Manchester (http://mif.co.uk/event/vertical-farm).

A vertical farm of five stories is also planned for **Milwaukee**, **Wisconsin** by Will Allen's Growing Power organization, in collaboration with the Sweet Water Foundation*(Aquaponics components).*Milwaukee's vertical farm is in the final stages of fund-raising.

Despite the viability of those projects, and the proven results gained, some experts tell that the immediate opportunity for cities may simply be to take advantage of the space available on urban rooftops, and to pursue horizontal urban farming rather than vertical farming. For example, Bright Farms Systems, a commercial offshoot of NYSW, is working with Gotham Greens, another company to emerge from the Science Barge, to create the world's first commercial urban hydroponic farm in Brooklyn (NY). Gotham Greens' first greenhouse facility, in Greenpoint, Brooklyn, began harvesting in June 2011. The greenhouse will annually produce over 80 tons of premium quality produce, year-round, that will be available at select retailers, markets and restaurants across the city. In 2012, Gotham Greens plans to expand operations to grow an even more diverse range of premium quality leaf and vine crops.

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Technological Challenges in Post Harvest Management of Horticultural Crops

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Though the growth of IT, BT and manufacturing sectors have been increasingly contributing to the growth of national GDP, still agriculture contributed 13.7% to it. Horticulture accounts for 30 per cent of India's agricultural GDP from 8.5 percent of cropped area. Modern scientific technology and its products made great inroads into lives of the people. Yet 70% of Indians live in villages and more than 50% of population is dependent on agriculture and allied activities. During 9th to 11th five year plans, horticulture took long strides placing India on the global map as the second largest producer of fruits and vegetables in the world. Horticultural technologies developed across the country and adopted by farmers exhibited its resilience and surpassed agricultural production during 2012-13 with 268.85 million tonnes. The major crops contributing to it are fruits and vegetables (approx 243.47 million tonnes from 16.187 million hectares area). Though low in volume spices contribute in a great proportion to export earnings of the country. While agricultural growth is essential for food security of the surging population of India, horticulture plays a vital role in ensuring nutritional security, particularly through fruits, vegetables and nuts.

Postharvest management is as important as pre-harvest care, because after harvest the produce becomes more perishable due to severing of its protection from parent plant. According to many studies, farmers have been losing between 30% and 40% of the value of their fruits and vegetables before they reach the final consumer. These losses are observed at harvesting, during packing, transportation, in wholesale and retail markets, and during delays at different stages of handling (Kitinoja *et al*, 2010). Less than 5% of funding for horticultural research and extension (R&E) has been allocated to postharvest issues over the past 20 years (Kader and Rolle, 2004; Weinberger and Lumpkin, 2007) as the historical focus has been on increasing production. In the 1990s the focus moved to marketing and more recently to value chain development. In horticultural commodities the stages at which post harvest losses occur can be divided into five as production/harvest, post harvest handling and storage, processing, distribution and consumption. Post harvest losses represent a waste of resources used in production such as land, water, energy and inputs.

By the year 2050, Indian population is expected to rise to 1740 million, putting intense pressure on our natural resources for producing food. With a rise in the household income, diversifying food habits and lifestyle pattern, it is expected that the demand for high value agricultural produce, particularly fruits, vegetables, meat, eggs, milk, fish and value-added food products is going to increase several folds. The technological intervention in production and protection practices of horticultural crops has resulted in unprecedented growth in production and productivity of several crops. Paradoxically, the postharvest losses are still quite high due to various factors and large number of stake holders at harvesting and post harvest stages. Commodity wise challenges in post harvest management of important horticultural crops are elaborated below.

Fruits

India is the second largest producer of fruits in the world after China (NHB,2013). The country occupies first position in fruits like banana, mango, guava and papaya in the world. It also occupies a significant position of 4th in oranges, 5th in apple, 6th in pineapple, and 10th in grapes across the world.

Banana

India is the largest producer of banana in the world with a production of 26.50 million tonnes from an area of 7.76 lakh hectares. Almost 99.8% of that was consumed domestically and only 0.05 million tonnes were exported realizing a value of Rs.13.04 million during 2013. Most of the plantations of banana in India being on small holdings, mechanization of production and post harvest operations have become an un-surmountable challenge. Producing blemish free fruits of banana is essential to realize good market value. On-farm pack house is necessary to dehand, wash, treat with fungicide and pack the fruits in plastic crates and CFB boxes for transport. Though the protocols have been standardized at National Research Centre for Banana, Trichy and being practiced in large farms for Cavendish banana, it is yet to be adopted on large scale by small farmers. The scientific and legally permissible method of ripening is use of ethylene gas which is being adopted by service providers and retail corporate houses. However, non-Cavendish varieties are still being transported as bunches without dehanding or postharvest treatment and ripened in traditional way and / or using calcium carbide. Hard lumps after ripening in Silk group varieties (Rasthali) is still an unsolved problem, and a safe bio-control or non-chemical method for control of postharvest diseases like crown rot and anthracnose still remains a challenge.

Mango

India produced 18 million tonnes of mangoes during 2012-13 and exported about 55,585 tonnes. Mango growers in India are yet to adopt mechanized systems for crop management and post harvest operations. An overall total post harvest losses of 12.74% is reported in mango, the highest being in farm operations like harvesting (4.11%), sorting & grading (2.80%) and transportation (2.53%).

Mango being a climacteric tropical fruit is sensitive to chilling injury, besides being highly vulnerable to stem end rot and anthracnose diseases after harvest and during ripening and senescence. As both these postharvest diseases originate from field, proper pre-harvest care and sanitation are essential to maintain the post harvest quality. The integrated pre- and post harvest management protocol for export and domestic trade of mango has been standardized at CISH, Lucknow and IIHR, Bangalore. Indian mango varieties are the favorites of world food connoisseurs. India exported 63,441 tonnes of mangoes in 2011-12 , but the exports have been limited to Bangladesh and other Asian countries. The major markets in UK, USA and Japanare still eluding Indian exporters. Though these countries have opened up their doors to Indian mangoes, India is unable to exploit the potential, mainly because of lack of treatment facilities stipulated by the importers. Presence of fruit fly, spongy tissue and anthracnose are the limiting factors for export of mangoes from India. The crucial element in export of mango is proper maintenance of the cool chain. Any delay or malfunction of refrigeration system in reefer container on the dock or during sea-shipment will render the consignment unfit for marketing at destination. Indian mango exports to US have not yet taken off because of absence of Vapour Heat Treatment (VHT) and irradiation facilities in important mango growing regions of the country. Among the processed products, mango pulp is one of the important revenue earners both in domestic and export trade. Asceptic packaging technology has revolutionized mango pulp and beverage industry across the country.

Guava

Guava has gained an important place in the fruit basket of India. The guava production in the country was 3.19 million tonnes from 2.35 lakh ha during 2012-13. India exported 1180 metric tonnes of guava mainly to middle east, Europe and USA during 2013. Africa countries like Sudan and Tanzania are emerging as new markets. One of the major challenges with regard to the cultivars is that the guava industry in India is stuck up with mainly two varieties, Allahabad Safeda and Lucknow-49. Pink fleshed and soft seeded guava has tremendous scope both for fresh and processing industry. Owing to its delicate peel and high amount of polyphenols, it is highly perishable. Guava, is received in raw stage at wholesale level. It is ripened at this level either in box or baskets. Having a very shallow climacteric peak, the harvest maturity is trivial parameter which decides its quality. The delicate skin makes it more vulnerable to bruises, and browning losing its appeal within a short time. An overall post harvest losses of 18.05 per cent is reported in guava. About 13.92% of this loss was during the farm operations and among that harvesting losses were 4.36%.

The harvesting and pack house operations are not well developed in guava to increase marketability and reduce spoilage. Development of modified atmospheric packaging to maintain the gloss and appearance can play a crucial role in post harvest management and trade of guava.

Papaya

About 5.38 million tonnes of papaya is grown in an area of 1.32 lakh ha in India. Most of the production is consumed domestically and about 16, 491 tonnes were exported during 2013. The fruit though is a climacteric fruit, has a good shelf life due to its thick skin. However, being a low acid fruit, after ripening it is prone to fungal spoilage and fruit rots. Development of postharvest treatments to control spoilage is necessary besides controlled ripening. Ripening of fruits particularly during winters is a problem in papaya fruits. With the changed unit family structure, small sized fruits are ideal for household consumption, and also for better post harvest handling. Large sized are preferred in cut fruit sales.

Grapes

India is one of the important exporters of grapes to European Union. India produced 2.84 million tonnes of grapes from 1.17 lakh ha during 2012-13 of which 1.7 lakh tonnes were exported. The main cause of post harvest losses in grapes at farm level is due to water berries while berry shattering, and loose berries are reasons at retailers' level. During storage or long distance transportation, spoilages due to molds and shriveling due to moisture loss contribute to postharvest losses. Quantitative post harvest losses in grapes is reported to be 8.30 per cent, of which, 3.21% was during sorting and grading, 1.93% during transportation and 5.54% at farm level storage. Shriveling and berry drop during marketing is one of the serious problems being faced by traders. MA packaging using perforated polymeric films takes care of this to a great extent. Control of grey mold caused by *Botrytis cinerea* is a challenge in storage of grapes. A systemic fungicide though provides a control, its persistence in berries posses a residue problem. Black rot caused by *Aspergillus niger* and *Rhizopus* rot are serious post harvest rots of grapes. Sulphur dioxide impregnated pads are mostly used in cartons to control these rots. Packaging technology has made marketing of grapes more farmer friendly as the packhouse operations are minimum and CFB boxes with 3-5 ply rating are highly suitable for damage free transportation of grapes.

Vegetables

India is the second largest producer of vegetables in the world after China with a production of 162.18 million tonnes from an area of 9.2 million ha. Most of the vegetables are more perishable than fruits due to high moisture content. Post harvest losses in vegetables are a major problem in the supply chain from production to the consumers table.Postharvest losses in vegetables vary greatly among commodities and production areas and seasons.In India, the losses of fresh vegetables are estimated to range from 2.00 to 23 per cent, depending on the commodity, with an overall average of about 12 per cent between production and consumption. Gunny bags are still used for packaging of most of the vegetables except tomato in some places.

Potato

Potato is the largest contributor to vegetable production in India with 45.34 million tonnes from an area of 1.99 million hectares. Potatoes are produced under tropical and sub-tropical conditions and major reasons for losses and quality deterioration are physiological in nature as a result of exposure to extreme temperatures and sunlight. By adopting proper dehaulming, digging without injury during dry weather, and curing the tubers at 25ºC, prevents losses due to spoilages and rot. Effective control of sprouting is a fundamental requirement of potato storage. In pre-packaged marketing, demands are such that any treatment of potato must ensure a virtual absence of sprouts.This can be accomplished by very low temperature storage (0-4ºC), use of established chemicals like CIPC or maleic hydrazide. Effective sprout growth suppression with ethylene, the natural plant hormone, at 10 ppm concentration at a storage temperature of 3.5°C (typical for prepacking) has been demonstrated on an experimental scale. Dry rot, soft rot, pink rot, vascular discolouration, ring rot and freezing injury are some of the storage problems. Conversion of starch to sugars is experienced in cold storage of potato. Post harvest losses at farm level is reported to be 6.73% and 2.26% storage losses aggregating to 8.99% overall losses. The losses which could be attributed to cool storage in particular comprised of sprouting, shrinkage, insects/rodents damage and rotting. The other types of losses are passed on from the field. Therefore, decay/spoilages, starch degradation and sprouting in the storage still remain to be major challenges in postharvest management of potato.

Onion

India is the second largest producer of onion in the world after China, with a production of 16.80 million tonnes from an area of 10.51 lakh hectares. About 7.51% overall post harvest losses are reported in onion. Out of this the total losses in farm operations was 5.17% followed by 2.34% storage losses. Unmarketable bulbs due to decay and transportation damage, driage (physiological weight loss) are major causes for loss of onions besides sprouting. The losses in onions are more in kharif harvest than rabi, owing to high relative humidity in air and rotting of bulbs in field due to rains during harvest season. High humidity also promotes sprouting, thereby reducing its quality and market value. As onion is also one of the most important export commodities from India to the neighboring countries, the fluctuation in the prices are high depending on supply / demand balance. Due to restriction on the use of MH (Malic Hydrazide) in onion, sprouting inhibition is challenge.

Tomato

After potato, tomato is the second largest grown vegetable in India with 188.55 million tonnes (NHB,2013). An aggregate post harvest loss of 12.98% is reported in tomato which comprised of 9.94% field level losses and 3.04% of storage level losses. One of the major bottlenecks in post harvest management is improper packaging of produce. While in some parts wooden boxes are used for packaging tomatoes for distant markets, some use plastic bags (used fertilizer bags) and gunny bags. Invariable use of plastic crates during transportation is recommended to reduce the losses and maintenance of quality. Fluctuating prices in tomatoes from Rs.2.00 to Rs.50.00 makes any technological intervention unprofitable in its handling. A demand driven production system supported with processing facilities only can stabilize the prices in tomato.

Brinjal

After onion, egg plant is the largest grown vegetable in India. Weight loss is the major post harvest problem found in brinjal due to unscientific packaging. Besides, insect damage of fruits in the field, damage due to impact in transportation is major a cause for postharvest quality deterioration and loss.

Cabbage & Cauliflower

Losses in Cabbage and Cauliflower can be reduced by adopting proper package. Bulk of both these commodities are stacked naked into the trucks or small quantities are packed in gunny bag or used plastic fertilizer bags and transported to the nearest market. During several stages of loading and unloading, it is subjected to mis-handling resulting in quantitative and qualitative losses. An aggregate overall post harvest loss of 6.88% is reported in cauliflower. This included 4.85% at farm level and 2.03% storage losses.

Flowers and Foliages

India produced 7673 million cut flowers and 1.729 million tonnes of loose flowers from an area of 2.32 lakh hectares during 2012-13. Postharvest infrastructure and research is a weak link in several Asian countries including India and China. The postharvest losses in flowers and foliages are reported to be in the range of 20-30% across several Asian countries. In majority of countries the flowers and foliages are used domestically with very few export oriented units (EOU). While the EOU of floriculture have the basic infrastructure for postharvest management, the domestic trade is dominated by small players. China's domestic trade is largely in landscape trees and potted plants and among the cut flower sales rose ranks first. Standards and grades are followed or practiced only in China and Korea among Asian countries, while in the rest it is not present in domestic trade.

In India, in recent times, the area under cut flower production has increased significantly. Although flower production is carried out all over the country, West Bengal, Tamil Nadu, Andhra Pradesh, Karnataka and Maharashtra are the major states for production. The major crops used for loose flowers are marigold, chrysanthemum, jasmine, tuberose, crossandra, aster etc. whereas the major cut flower crops include rose, gladiolus, carnation, gerbera and orchids. Although the flower producers have access to important commercial varieties in all major crops from leading breeders across the world, and many Indian tissue culture companies, the post-harvest management is the weakest link in Indian floriculture industry. It is characterized by the absence of any established standards/grades for produce. The growers generally follow the demands of the market. Packaging of floriculture produce is often unscientific and uses paper cartons, bamboo baskets, jute bags etc. Transportation of produce is by road (public/ private vehicles), rail and air, often in gunny bags, bamboo baskets and few in cardboard boxes.

Post-harvest losses in floriculture products in India is estimated to be around 25 percent due to poor harvesting, packaging and handling practices besides lack of cold chain facilities. Facilities for grading, preliminary treatment to extend shelf life, and appropriate packaging are lacking**.** Simple tasks, such as the removal of excess foliage from flower stems and hydration of flowers after harvesting to prevent moisture loss and quality deterioration, are often overlooked. Use of refrigerated or temperature controlled vehicles for transport of flowers is absent in India.

The challenges in floriculture are to breed varieties having longer vase life, commodity specific packaging to reduce the losses and maintain the quality and storage studies for retaining the freshness necessary for overseas export. Though, value addition, particularly for loose flowers, is very common in view of the increased use of flowers in the country for decoration purposes, challenges are in research for identifying diversified use of flowers and floral products in allied industries like cosmetic, wellness and food.

Although India still has a negligible share (<1 percent) of the global markets, the export of floriculture products has grown exponentially during the last decade. Though dry flowers and plants constitute the major export product, the cut flower exports (90 percent, rose) have also increased significantly.

Plantation Crops

Cashew Nut

India has the largest area under cashew and is confined mainly to the peninsular areas. It is grown in Kerala, Karnataka, Goa and Maharashtra along the west coast and Tamil Nadu, Andhra Pradesh, Orissa and West Bengal along the east coast. Cashew occupied an area of 0.991 million hectares in the country in 2012-13, with a production of 0.753 million tonnes. The highest productivity is observed in Kerala and Maharashtra with over one ton per ha. India is also one of the largest cashew consuming countries in the world.

Currently cashew is produced on under utilized or waste lands with poor cultural practices. There are 3650 cashew processing industries in the country (both organized and unorganized sector together), with an installed capacity for processing of 15 lakh tonnes, for which the contribution from the indigenous production is only 38%. India earned Rs.2464 crores through export of processed cashew kernels and cashew nut shell liquid during 2006-07. With a proper vision the industry can be transformed into a modern and high value-added industry by restructuring of factories, imparting skill development, mechanization and value addition.

Arecanut

The country produced 0.08 million tonnes of arecanut from 0.446 million hectares during 2012-13. The major producers are states of Karnataka, Kerala, Assam, West Bengal, Tamil Nadu and Meghalaya. Its primary use is as a masticator while it has several medicinal or therapeutic properties. Not only our neighboring SAARC countries but also Middle East and other Muslim countries have become assured destinations for the value- added arecanut products from India. Demand for these products has been fast increasing globally especially from among the people of Indian / Asian origin. Export of arecanut products from India has almost tripled in a span of 20 years since 1991. India's export currently reaches more than 40 countries in the world. During 2009-10 India exported nearly 1750 tons of arecanut in the forms of splits nuts (11%), whole nuts (10%), grounded nuts (9 %) and value added forms like scented supari (70 %).

There is a need to look at arecanut beyond masticator use and generate innovations, technology, and programs to promote healthy alternative uses of arecanut. The five measures (*Pancha Sutra)* to face the challenges in promotion and marketing of arecanut includes i) more research to prove its nutraceutical and therapeutic values, its utilization in other industrial applications, eco-friendly uses of other parts of arecanut palm (like sheath and husk) and rapid mechanization of arecanut processing or de-husking.

Coconut

India produced 15.61 million tonnes of coconut from an area of 2.14 million hectares. Coconut is used in several forms like tender nut, mature nut meat, copra, oil, etc. The is a need to reduce the dependence of coconut on copra & coconut oil and popularize more value added products including packaged tender coconut water, desiccated coconut, coconut chips, coconut milk / milk powder, shell charcoal , activated carbon, , etc both in the domestic and international markets. Diversification of coconut byproducts & residual products has to be taken up. More emphasis needs to be given on fresh packaged tender nut water, minimal processed tender coconut, snow ball, fruit based coconut water beverages, mature coconut water, frozen coconut water, coconut vinegar, neera, desiccated coconut, coconut chips, coconut milk, skimmed coconut milk, spray dried coconut milk, coconut cream, etc., and coconut palm by-products from coir, stem, leaves, shells, etc., needs to be developed and commercialized on large scale.

Cocoa

Compared to tea and coffee cocoa is relatively a new entrant into Indian agriculture. Cocoa is mostly grown as companion crop in coconut and arecanut gardens. The commercial cultivation of cocoa however commenced from 1960's only. Cultivation of cocoa is restricted to Kerala, Karnataka, Andhra Pradesh and Tamil Nadu. The country harvested 13,420 tonnes of cocoa beans from 66,470 hectares during 2012-13.

Various Cocoa products are confectionery in nature and consumable. The cocoa industry in India is an important part of 15-billion-rupee chocolate industry. Besides chocolate industry, the confectionary and bakeries also consume huge quantities of cocoa. The quality specifications of cocoa is very important which depends on proper fermentation of beans after harvesting and opening of pods followed by sun drying . In Kerala and Coastal Karnataka, buyers need to do fermentation and sun drying elsewhere as the average land holding is small resulting in inadequate quantities coupled with continuous rain during most part of the year hindering farm-gate processing. However, in Andhra and Tamil Nadu the fermentation and sun drying are done in the farm itself. The post harvest challenge in cocoa industry surrounds around improving the fermentation process and diversification in the cocoa based product preparations.

Spices

During the crop year 2010-11 the country produced about 5.350 million tons of spices from 2.940 million hectares of area. About 10% of this is exported annually. Value added spices like encapsulated spices; oils and oleoresin are assuming significance in view of convenience. With the reported use of spices oils and oleoresins in soft drinks, food and medicines demand for Indian spice oils and oleoresins is bound to shoot up.

The biggest handicaps that Indian spices face in the international market are the high cost of the product and high level of microbial contaminants including mycotoxin in the finished product. We need to make concerted efforts for producing clean spices at competitive prices. India can withstand the competition only by increasing productivity and reducing cost of cultivation leading to low cost per unit of production. Considerable efforts will have to be made to improve the present post harvest processing and storage systems and in educating the farmers and traders in handling and processing the produce hygienically and promotion of spices in consumer packs. As most of the spices are used in powder form, cold grinding to prevent the loss of aroma during processing is essential. Similarly, during postharvest handling and primary processing of spices like drying, curing and packaging, scientific studies needs to be conducted to assess the changes/loss in quality during these unit operations.

Higher productivity, clean spices through improved post harvest techniques and reasonable threshold price affordable to food industry are the keys to future spice trade. Considerable efforts will have to go to improve the present post harvest processing and storage systems and in educating the farmers and traders in handling/process the produce hygienically. 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.

Other technological challenges includes, value addition through microencapsulation, extrusion and other techniques. Characterization of mode of therapeutic action of spices and their fully or partially purified extracts *in vivo* needs to be studied. Application of spices extracts or their purified bioactive principles in user-friendly mode for drug delivery, pesticidal and antimicrobial applications needs to be understood. Phytochemicals from spices are high value low volume commodities. Through chemical modification, synthesis and appropriate packaging at defined dosages in conditions supporting optimum bioavailability minimum toxicity has great scope in health and food industry.

Medicinal and Aromatic Crops

In Ayurvedic and Unani systems of medicine in India, in Chinese traditional medicine, as well as in most of the traditional systems of medicine in Asian countries, medicinal plants and their derivatives have played a significant role. Even today, medicinal plants play an important role in both developed and developing countries. The wellness industry in India is growing by leaps and bound under the banner of health tourism, specially for de-stressing therapies and management of incurable diseases like arthritis, migraine and other non-communicable diseases. Hence cultivation and collection of medicinal and aromatic crops is gaining importance and providing livelihood for many. Moreover, since a large portion of drugs produced by pharmaceutical industry are derived from medicinal plants, the demand for these raw materials is steadily rising.

Though authentic figures on production of medicinal crops is not available 0.918 million tonnes of aromatic crops was produced during 2002-13 in India. The largest global markets for medicinal and aromatic plants (MAPs) are China, France, Germany, Italy, Japan, Spain, the UK and the USA. Japan has the highest per capita consumption of botanical medicines in the world. MAPs are used in the production of pharmaceuticals, extracts, cosmetics, and colouring agents and these account for most of the €3 million of total imports of medicinal plants and their products into Europe. This business includes the traditional demand for raw materials for prescribed pharmaceutical medicines, and a large market for specific vegetable alkaloids like opium, ergot, and quinine (especially into the UK). Though the future scope looks attractive for MAPs, due to least attention it received in past, there are several challenges in their cultivation, postharvest management, marketing and processing.

In recent past, the post-harvest processing of MAPs and its value addition started receiving attention of biochemists, phyto-chemists and chemical engineers for designing effective and efficient equipments for cold and hot extraction of oils, fractions and crude extracts for domestic use and export as well as keeping in view the emergence of 'back to nature', 'ethnic food' and 'yogic food' slogans. Use of spice based oils, oleoresins, ointments and flavourings from natural sources like MAPs started increasing.

One of the major technological challenges in MAP is very low level of knowledge about active ingredients or biomolecules present, coupled with lack of methodologies for its extraction without damaging its activity. Companies involved in commercial extraction of metabolites of MAP are very limited and most of them depend on middle men in their procurements. The scientific methods of drying, packaging and storage of raw material with its consequence on quality is limited. Scientific methods of extraction, separation, validation of benefits through systematic studies and its processing and packaging needs attention.

Summary

The major challenges in postharvest management of horticultural crops are to establish a scientifically strong pre-harvest protocol with postharvest quality and market requirements in view and subsequent postharvest unit operations to reduce the losses and maintain the quality. Establishment of packhouses for washing, sorting, grading, preparation for market, and packaging are essential. Standardization of commodity specific packhouse operations needs more research. Cold chain management based on length of the supply chain and mode of transport plays a crucial role in identifying the suitable method of storage and distribution. Backstopping by propping with suitable processing industries and products helps in stabilization of prices and inflation / deflation. Every commodity requires a different approach which is best suited to the crop and market situation.

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Eradication of Poverty through Floriculture in the Era of Changing Needs of the Nation

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Abstract

India with world's second largest population is in the clutches of its biggest evil and i.e. Poverty. The poverty being the biggest enemy of health is considered as a weapon of mass destructionin un-developed and developing world like India. 60% of population depends on agriculture but still farmers are committing suicide in India. Therefore, in order to have a stable and developing economy Indian government must focus on elevating the levels of these people as well as providing them all facilities and ways to prosper. It is time now to improvise Indian Agricultural practices towards a better economy and floriculture is a better option for that. Flower is a symbol of love, beauty, passion, and peace, but, it could become a synonym for income generation too. Although flower is seem to be delicate but it can prove to be a master weapon to wipeout poverty. The need for floriculture is more in urban slums where people suffer due to lack of income and end up doing undignified jobs. The floriculture industry consists in growing annual, biennial and perennial plants either under glass or outdoors, and in the disposal of the same in wholesale or retail market. In general, business of traditional as well as non-traditional flowers and dry flower industry is called floriculture industry. Floriculture has emerged as an economically viable diversification option in the Indian agribusiness sector in recent times. The area under flower crops has increased from 30,000 hectares in 1993 to 2.53 lakh hectares in 2012, which constitutes around 17% of total global acreage. India is growing at a faster rate in production of flowers by using new technologies to mark its footprint at international market also. The export of total floricultural products has increased from Rs. 14.5 crores in 1991-92 to over 423.4 crores in 2013. How floriculture proved as a weapon to wipeout poverty from our nation? It generates employment, higher profit per unit area, good warm climate and growing conditions thus wider choice of crops species, high domestic demand and huge export potential, large scope of value addition, largest pool of technically qualified people and huge skilled manpower at cheaper rate are available in our country. This can enhance floriculture business to overcome poverty by empowering our farmers and farm labor. Paying attention to the input needs, better resource management and making various policies entrepreneur friendly would lead to a balanced growth of the industry, which help the urban poor to take up floriculture as a sustainable livelihood income generating activity to mitigate poverty.

Introduction

India with world's second largest population is in the clutches of its biggest evil and i.e. Poverty. Sixty per cent of population depends on agriculture but still farmers are committing suicide in India. The poverty being the biggest enemy of health is considered as a weapon of mass destructionin un-developed and developing world like India. What is poverty? Each letter of the word 'poverty' is indicating the meaning.

Poverty

P: Poor nutrition level
O: Overall income of family is very low
V: Vast damage caused in illness due to ignorance
E: Emerging rate of infant mortality
R: Rural truth
T: Truth that is ignored
Y: Yet to be eradicated

The main causes of poverty in India are; low rate of economic development, high growth rate of population, unemployment, backwardness of Indian agriculture**,** lack of education, inadequate implementation of anti-poverty programmes and political and social factors.Since the time India gain freedom, Indian government has taken many major steps to fight with poverty and expel it.In these 67 years, India has flourished in various sectors like Energy generation, Petroleum, IT, Medicine, Engineering, Management and Agriculture.However, it is the truth that more than 60% of Indian population is involved in agriculture, therefore, in order to have a stable and developing economy. The Indian government must focus on elevating the levels of these people as well as providing them all facilities and ways to prosper.It is time now to improvise Indian Agricultural practices towards a better economy, and floriculture is a better option for that.As the sun rises in the land of India, the day begins with the use of flowers. Flower is a symbol of love, beauty, passion, and peace, but, it could become a synonym for income generation too. India is growing at a faster rate in production of flowers by using new technologies to mark its footprint at international market. India has made remarkable progress in floriculture from nineties till today by making world class products. Although flower is seem to be delicate but it can prove to be a master weapon to wipeout poverty. Flowers express many emotions but more than that it understands them too.

Empowerment of Poor People through SHGs

The improvement of socio economies status of people is based on their income level, education, cost of living, health and other parameters. Formation of Self Help Groups (SHGs) and accounting for Small and Medium Floriculture Enterprises (SMFE) from urban people is a solution to empower them and to overcome poverty in our country. As a part of capacity building of SHGs, the knowledge regarding raising of seedlings and grafted plants of elite flower and medicinal plants, floral products making from fresh and dry flowers, extraction of essential oil and pigments from flowers and plant parts, etc. should be given through training and demonstration. Instead of selling raw flowers, value added products if prepared will fetch better price and profit, which leads to higher income and increases standard of living of rural people.

Self Help Group(SHGs): Self Help Group is a small, economically homogenous and affinity group of rural poor voluntarily formed to save and mutually agrees to contribute to a common fund to be lent to its members as per group decision for their socio-economic development. Self Help Groups (SHGs) have been successful in empowering rural women through entrepreneurial activities. SHGs have major impact on social and economical life of rural women. They improve the quality of status of people as participants, decision makers and beneficiaries in the democratic, economic and socio-cultural life. The SHG is cluster based approach for establishing enterprises at village level and assisted in solving the problem of unemployment. The constraints, such as personal, infrastructural, technological, cognitive and marketing are faced by the member of Self Help Group. Awareness regarding credit facilities, financial incentives and other Government- sponsored programmes has been created through SHG. Moreover, the savings, credit and income of people have been increased and controlled by SHG. Thus empowerment of poor through Self Help Groups would lead to benefit not only to the individual but also the family and community as a whole through collective action for development.

Agriculture:The Backbone of Indian Economy

Agriculture is the mainstay of the Indian economy and is the principle means of livelihood for over 60 per cent of the population. GDP of our country was not more than 17.1 per cent during 2008-09 and which was dropped further to just around 16 per cent in 2009-10. However, challenges before agriculture has been increasing such as environmental and technological changes, hike in input price and fluctuation in output price these are the fundamental problems. Therefore, there is need to apply intensive technique and diversification through horticulture production. The growing importance of commercial horticulture is important segment in the national income. Horticulture includes mainly vegetables, fruits and flower crops.

Floriculture: As an Industry the Fast Growing Domain

The floriculture industry consists in growing annual, biennial and perennial plants either under glass or outdoors for production of flowers and floral products, and in the disposal of the same in wholesale or retail market. Flowers and plants have always been an integral part of human living. Besides their aesthetic importance, they are also useful in improving the quality of life.Ornamental plants play a very important role in environmental planning of urban and rural areas for abatement of pollution, social and rural forestry, wasteland development, a forestation and landscaping of outdoor and indoor spaces. Production and consumption of flowers is increasing world over including India. The development of flower cultivation brings larger income per unit area to grower than the cultivation of ordinary crops. Floriculture has emerged as an economically viable diversification option in the Indian agribusiness sector in recent times. A growing market as a result of improvement in the general level of well being in the country and increased affluence, particularly among the middle class, has led to transformation of the activity of flower growing into a burgeoning industry.Availability of diverse agro-climatic conditions facilitates the production of all major flowers throughout the year in some or the other part of the country.

The area under flower crops has increased from 30,000 hectares in 1993 to 2.53 lakh hectares in 2012, which constitutes around 17% of total global acreage. India is growing at a faster rate in production of flowers by using new technologies to mark its footprint at international market also. West Bengal is the leading state for production of cut flowers(45%), but, Karnataka is producing maximum loose flowers(19%) with second position (13%) for cut flowers production(Table 1).

In general, business of traditional as well as non-traditional flowers and dry flower industry is called floriculture industry. It includes production, processing and marketing of all types of flowers. There are two types of production i.e. open field cultivation and green house (controlled) cultivation, while processing is concern to dry flower processing units.

Marketing includes local markets, regulated internal markets and international markets. Component of marketing channels are producer, commission agents, wholesalers, retailers

Table 1: Share of States in producing Cut flowers and Loose flowers during 2012-13

Sr.	Name of States	% share of cut flowers production	% share of Loose flowers production
1.	Karnataka	13 %	19 %
2.	West Bengal	45 %	8 %
3.	Maharashtra	13 %	8 %
4.	Gujarat	12 %	8 %
5.	Uttar Pradesh	9 %	-
6.	Uttaranchal	3 %	-
7.	Delhi	2 %	-
8.	Andhra Pradesh	-	14 %
9.	Punjab	-	9 %
10.	Tamil Nadu	-	8 %
11.	Haryana	-	7 %
12.	Others	3 %	19 %

Source : Floriculture Today, January, 2014

and consumers. With the changing trends and a constant urge for new innovative products in domestic and foreign flower markets, therefore, the flower growers have to respond immediately. Cultivation and consumption of flowers have been part of tradition in world over. The expansions in area and production of flowers in non-traditional regions have been one of the noticeable features. The Indian farmers are cultivating flowers mostly as loose flowers for traditional purposes and sale them in local market. Very few farmers/ greenhouse holders are producing cut flowers for local, national and international market too. There is a vast fluctuation in average market price for both loose and cut flowers depending on religious or social functions period and season of growing (Table 2).

Table 2: Average market price for major Cut flowers/ Loose flowers in India

Sr. No.	Name of Cut Flowers	Price Rs./- per Dozen/each stem	Sr. No.	Name of Loose Flowers	Price Rs./- per kg.
1.	Gladiolus	20-75 / doz.	1.	Marigold	15-60
2.	Carnation	30-75 / doz.	2.	Jasmine	30-150
3.	Gerbera	35-75 / doz.	3.	Crossandra	20-120
4.	Orchids	10-45/each stem	4.	Chrysanthemum	15-50
5.	Liliums	10-45/each stem	5.	Tuberose	20-40
6.	Anthurium	15-45/each stem	6.	Rose	20-80

Source : Floriculture Today, August, 2013

Floriculture is also an important agri-business with potential for export trade.The floriculture market has concentrated in Western Europe, North America and Japan. The new markets emerging are in Europe, Poland, Hungary, Slovakia and Ireland. The mostly preferred cut flowers in the international market are roses, tulip, chrysanthemum, gerbera, orchids and gypsophilla. The export of total floricultural products from India has been increased from Rs. 14.5 crores in 1991-92 to over 423.4 crores in 2012-13. The USA is leading country to import floricultural products followed by The Netherlands from India (Table 3).

Table 3: Export of Floricultural products from India during last four years to major countries(Rs. Crores).

Sr.	Name of country	2009-10	2010-11	2011-12	2012-13
1.	USA	53.06	56.87	71.29	83.81
2.	The Netherlands	42.18	41.62	54.13	59.70
3.	UK	37.88	37.62	38.56	45.68
4.	Germany	40.65	42.81	57.53	56.75
5.	Japan	15.59	11.52	14.72	15.67
6.	Others	105.10	96.01	129.09	161.79
	Total	294.46	296.0	365.32	423.40

Source: Training Manual on Advance Flower Nursery and Value Addition. ceed@google.com

Gujarat State Scenario of Floriculture

Clearly the future growth is laden with new opportunities and potential for transforming agriculture in Gujarat. There is a huge scope for floriculture in Gujarat state due to availability of diverse agro-climatic conditions facilitates the production of major flowers including rose, jasmine, tuberose, spider lily, gaillardia, marigold, goldenrod, chrysanthemum, etc in open field conditions. Likewise under protected conditions the flower crops like Dutch rose, gerbera, carnation, etc are grown for profitable agri. business. During 2012-13 the total area under flower crops in the state was 17280 hector with a production of 1, 49,270 MT flowers. Recently (2012-13) Gujarat State Horticulture Mission incurred an expenditure of Rs. 7738.69 lakh for area expansion of protected cultivation. In Gujarat the responsive farming community and strategic geographical locations has widen the scope of floriculture development and South Gujarat is undergoing rainbow revolution being a hub for floriculture industry. The future growth of floriculture of Gujarat would also be positively influenced by the ready availability of required technical experts for hi-tech Greenhouse in respects of cut flowers.

The Government of Gujarat has adopted strategies that are geared to overcome constraints faced in cultivation of horticultural crops including flower crops. Some of them are: supply of good quality planting material (grafts, seedlings and seeds) for floricultural crops; introduction of new crops;increasing productivity by using sophisticated technology such as micro-irrigation systems;promoting contract farming, export oriented production practices; strengthening of marketing societies; provide training to farmers for post-harvest packaging and minimizing quality losses during transport, etc.

How Floriculture Proved as a Weapon to Wipeout Poverty?

In India flower growing is mainly carried out on small holding under open field conditions with simple techniques. Thus, flower growing can be easily adopted by the farmers having small holdings and the poor people could be engaged in this work as labors. Due to huge skilled manpower the wages are cheaper in our country, which results in low cost of production. The floriculture crops are giving higher profit per unit area as compared to other crops. The members of our largest pool of technically qualified people are absorbed by generating large employment in this industry. There is a wider choice of crops and species in floriculture, which also ameliorate environment and improve the quality of life. Floriculture industry is considered as a labor intensive type, because cultivation of quality flowers required lots of care and huge man power, and wage payment forming roughly one-third of the costs of production. It is estimated that floriculture has a potential to generate employment for about 20 workers/ha. It indicates, that even a modest floriculture programme can generate millions of jobs, predominately for young women, quite apart from significantly, contributing to national income. Large numbers of farm labours are engaged in cultivation, harvesting and post harvesting activities including packaging. The women in urban areas can cultivate cut flowers such as roses, jasmine, marigold, gladiolus, gerbera, anthurium, orchids, bird of paradise, golden rod, carnation, etc. to generate income from a small household area.

In comparison of various components for variable and fixed cost of flower production, about 45-50 per cent of cost is required for labor charges, which includes male and female members of the family as well as hired labors (Table 4).

Table 4: Economics for Cost and return of Rose, Marigold and Tuberose cultivation

Sr.	Components		Rs./-	% to total	Rs./-	% to total	Rs./-	% to total
			Rose		Marigold		Tuberose	
1.	Seed & planting materials		5000	4.30	763	2.16	2949	2.84
2.	Labour includes	Male	26,084	22.43	7242	20.48	14891	14.36
	Family & hired.	Female	30,736	26.43	7957	22.5	29192	28.15
3.	Bullock labour		439	0.38	916	2.59	399	0.38
4.	Farmyard manure		12,470	10.72	3,119	8.82	8,689	8.38
5.	Fertilizer cost		11,527	9.91	2,035	5.76	7,408	7.14
6.	Pesticide cost		4,,897	4.21	382	1.02	1,617	1.56
7.	Electricity charges		2,500	2.15	1,200	3.39	2,500	2.41
8.	Market cost		13,195	11.34	7,030	19.88	24,429	23.56
	Total variable cost (VC)		1,06,848	91.86	30,644	86.67	92,074	88.79
1.	Depreciation charges		833	0.72	191	0.54	499	0.48
2.	Land revenue		13	0.01	13	0.04	13	0.01
3.	Rental value		3,000	2.58	3,094	8.75	3,000	2.89
4.	Interest on working capital 12% of VC for 12 months excluding market cost		5,619	4.83	1,416	4.00	8,117	7.83
	Total fixed cost(FC)		9465	8.14	4,714	13.33	11,629	11.21
	Total (VC+FC)		1,16,313	100.0	35,358	100.0	1,03,703	100.0
	Gross income		3,29,877		54,078		1,87,914	
	Net income over(VC+FC)		2,13,564		18,720		84,211	

Source: Research Report: IX/ADTR/105, Floriculture in Karnataka, 2012.

Main Aspects of Floriculture industry

- **Fresh Flowers**

Cut flowers: The flowers are harvested with long stems i.e. Cut roses, gladiolus, carnation, asters, chrysanthemum, etc. The stem is useful to prolong the life of the flower due to presence of food in form of carbohydrate, which is utilized in metabolic activities as well as the stem makes flower easy to handle during transportation and to arrange in vase for decoration. This type of value addition increases the monitory value of the produce and the cultivators get higher price of cut flowers as compared to loose flowers. Majority high valued cut flowers are grown in protected conditions to produced quality products for export purposes.

Loose flowers: The flowers like Desi rose, marigold, gaillardia, seasonal chrysanthemum, jasmine, etc. are harvested stem less and are used traditionally for worshiping and preparation of garlands, *veni* and other decorative purposes.They are sold on weight bases and their selling price is comparatively lower than cut flowers.In India majority of our farmers are producing loose flowers and which sold in local market, thus, got less return. But, some are used for extraction of essential oil fetched high price i.e. jasmine, desi roses, tuberose, etc.

- **Ornamental Plants**

Plants are propagated and sold for planting in garden or commercial flower production is known as nursery business. This business is considered as lucrative and large numbers of nurseries are engaged in our country. Plants prepared in these nurseries are sold locally as well as exported mostly in gulf countries. The nursery activities required huge men power which can provide sizable employment for skilled, semi-skilled as well as unskilled labors. The plants produced in nursery may be flowering or foliage decorative are sold for landscape purposes. Again for creating landscape and for its maintenance trained peoples (gardeners) are required.

- **Flower Seeds**

Seasonal flowers or flowering annuals has much demand in market for beautification of landscape. These plants are propagated by seeds, and for giving best effect of flowering annuals pure quality seeds are required. Improvement, development and production of quality seeds in large quantity is tuft task and required more skilled labors. There has been limited availability of seeds and most favorable climate prevailed in our country, thus, there is wide scope for this business. Presently Punjab is a leading state to produce and export of flower seeds, but this business could be spread in other states also.

- **Floral Extracts**

India is known for long as land of '*Attar'* and other perfumes. The demand for floral extracts is increasing day by day. The flower crops like rose, tuberose, jasmine are the major flowers used in floral extract. Production of flowers for this and the process for extract of essential oils or pigments could become a business for enhancement of employment and rise in labor demand to overcome poverty in our country.

- **Dry Flowers and Plants**

Plant parts, leaves, or whole flowers may be dehydrated by various methods to use them as dried flowers. These products are becoming popular due to their non perishable nature. There is a hug demand in developed country, hence, which constitutes nearly 60% of our total floriculture export at present.Wide range of flowers and plant parts are naturally available in our country can be dried and preserved. This becomes house hold business at home scale with minimum capital investment. Today dry flower industry is concentrated in West Bengal and Tamil Nadu (Tuticorine) only due to availability of cheap labors and natural raw materials could be extended in other states also.

Empowerment through Value Addition in Floriculture

Value added floriculture is a process of increasing the economic value and consumer appeal of any floral commodity through changes in genetics, processing and packaging. Diversification with this profitability of a commodity is increased especially small scale floriculture industry. Unstable prices for raw commodities, federal farm policies and changing consumer preferences can be satisfied by value addition to earn more money by cutting out the middleman. Value addition gives high premium to the grower as well as provides quality products for the domestic and export market. Value addition in flower crops can directly or indirectly influence floral market to a great extent. This plays a vital role in economic development of people especially in case of rural women can involve to produce value added floriculture products.The poor people in rural areas where floriculture is already practiced have an opportunity to increase their incomes by taking to modernization in floriculture. It includes preparation of garlands; bouquets, *veni*, button-hole, flower baskets, floats, floral wreaths, corsages etc can add value up to 5-10 times from flowers and green foliages (Table 5). It also includes making of dry flowers and extraction of essential oil or pigments.These new models of value addition in flower have high export potential and can play a significant role in generation a new flower market strategy. Even making of value added products is an artistic and creative work much more closely related with women.

Entrepreneurial Opportunities for People in Floriculture

So far none or very little effort has been done on entrepreneurship development among poor farmers. Such developments require concerted efforts. These are useful in empowering the farmers and enabling them to break the barriers that keep them from main advantages of commercial agriculture especially floriculture. There is a tremendous opportunity in floriculture trade at entrepreneurial level for people resides growing and selling cut flowers, one can set up small enterprises where value-addition in the form of bouquets and flower arrangements on contractual basis can be taken up. Trade in dried flowers is also on the rise. The people can easily tap this opportunity. Considering the potential of floriculture in generating higher levels of income, employment opportunities, greater involvement of farmers and increase in exports, it has been identified as extreme focus area by the Government of India. And several development schemes have been introduced. There is, however, a need to focus attention on farmers, so that the benefits of the schemes also reach them. If possible, it may be, made mandatory that at least 30 per cent of the beneficiary farmers be women.

Table 5 : Cost and comparisons of selling price of flowers and floral products

Sr. No.	Floral products		Price of flowers used (Rs)	Labor charges and supporting material price (Rs)	Selling price of the product (Rs)
1.	Garlands	- Simple	10-15	20-25	50-75
		- Medium	25-30	25-35	100-150
		- Super	50-75	50-70	500-700
2.	Veni		15-25	20-25	80-90
3.	Button hole		5-7	10-15	25-30
4.	Bouquet	- Simple	10-15	5-10	20-35
		- Super	30-50	20-25	100-150
5.	Decoration of bridal car		200-250	100-150	500-1000
6.	Wedding decoration		1500-2000	1000-1200	5000-7000

Source: Estimated values by related personal interviewed, 2013.

Cost-effective Greenhouse Entrepreneur : The small-scale greenhouse technology has tremendous opportunities, especially for farm women as it can be practised on small land area of 500 m^2. Traditional farming on these small holdings is also economically unviable. While growing cut flowers under protected greenhouse on the small land holding is economically profitable than and can alleviate women as also small and marginal farmers from poverty. An acre of land under traditional open field floriculture yields an income of Rs.10,000-20,000 annually, compared to greenhouse cultivation Rs. 45-50,000 annually from a mere 500m^2 of land (Table 6).

Main Issues for boosting the Floriculture Export

In India, majority area under flower crops is for cultivation of loose flowers for traditional uses like worshiping and floral decoration. But, there is large scope for production of cut flowers for export purpose. By producing quality cut flowers, essential oils, pigments and dehydrated flowers could be exported to developed countries. This can provide more opportunities for high income to enhance floriculture business. The Government is also giving sufficient financial support and guidance for this purpose. Even though some major issues are listed below for boosting the floriculture export:

Table 6: Standardization of agro-techniques for cultivation of horticulture crops under cost effective greenhouse.

Sr. No.	Name of flower crops	Density(plants/m^2)	No of flowers /100m^2/year	Net Profit Rs/ 100m^2 /year
	Rose	7	20,000	10,000
	Gerbera	9	21,600	47,000
	Carnation	25	31,300	30,000
	Tuberose	34 bulbs	14,300	14,300

- Need for setting up of an export promotion council for export of floricultural products
- Increase in production of value added products like dry flowers, seeds, potted plants, micro-propagated plants etc.,
- Organization of appropriate training for personnel involved in production and export of floricultural products,
- To make the producers and exporters aware about effective quality control measures,
- Establishment of appropriate marketing and distribution channels,
- Setting up of more export processing zones for floriculture products etc.

Case Studies for Income generation through Floriculture

Jasmine cultivation: Cultivation of jasmine (*Jasminum sambac*) started in Shankarapura town in Udupi district, Karnataka state about 100 years ago. It was promoted by a Christian priest to help poor women in the area to earn income. It is found extensively in Bhatkal, Udupi, Dakshina Kannada and Uttara Kannada, and has been found more economically viable among all the three varieties. The flower is in high demand in places such as Mumbai, besides the coastal region. Every home in this region has 0.5 to 1 acre (2,000 to 4,000 m^2) of land in front of the house for Jasmine growing'. Local traders collect jasmine flowers from the farmers directly. Prices are decided at the auction centre in Shankarpura daily. According to local women, who works at the Jasmine Land Flower Stall in Udupi, the price of one “atte” (800 flowers make one chendu and four chendus make one “atte”) of jasmine was hovering between Rs. 300 and Rs. 400 till October. Since then, the price of one “atte” of jasmine has been hovering around Rs. 700. It touched Rs. 1,000 an “atte” during October end. When poor women in Shankarapura town have successfully used floriculture as an income generating activity, poor women in other cities across India can adopt jasmine cultivation as an activity to earn income and eradicate poverty. Moreover, this activity takes place early morning and the women are free to undertake other work during the day.

Dry Flowers Production: In the Vilpatti village of Dindigul district of Tamilnadu, 45 women below poverty line from three self-help groups were assisted by an NGO and aided under SGSY received training in dry flower arrangement from an art gallery in November 2000. Under the cluster approach these three groups formed a confederation named BIRIJA and is engaged in the collecting, processing and selling dry flowers. BIRIJA has a marketing tie-up with an art gallery to conduct exhibitions and sell their finished products. Within six months of the commencement of this venture, monthly sales touched to Rs. 70,000. The members received an average net income of Rs.1500 per month. Apart from improving their living conditions, the members have gained confidence and are actively involved in social work, participating in the movement against illicit arrack and in gram sabha meetings. (Source: Ministry of Rural Development, Government of India)

Summary

India has a long floriculture history and flower growing is an age old enterprise. What it has lacked is its commercialization. The growing demands of flowers in the domestic as well as the export market will require a concerted effort on the part of the government as well as the private entrepreneurs to develop floriculture on scientific lines. It is a highly profitable business because of higher productivity per unit of land. Incomparison to other crops it gives higher profit.With such initiatives and subsidies by central and state government, Floriculture couldwell be the next big boom after Information Technology.Paying attention to the input needs, better resource management and making various policies entrepreneur friendly would lead to a balanced growth of the industry. This will help the urban poor people to take up floriculture as a sustainable livelihood income generating activity to mitigate poverty. The need for floriculture is more in urban slums where people suffer due to lack of income and end up doing undignified jobs.

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Climate Smart Floriculture-Landscape Services

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Floriculture is fast emerging as a major venture in the world scene. Improvement in the standard of living has a direct impact on demand of modern flowers. The flowers have been used in social ceremonies and also for religious purpose. In India, the floriculture industry got an appreciable boost during the last two decades due to active patronage from the Govt. of India. Floriculture is becoming a booming industry in the world today. This sector, according to international trade classification, encompasses (a) bulbs, corms, rhizomes, tubers and tuberous roots, (b) other live plants (including trees, shrubs, bushes, climbers, roots, cutting, seed and seedlings), (c) cut flowers, loose flower and dried flowers, and (d) foliage, shrubs, bushes, mosses, lichens and grasses. With a humble beginning of growing flowers for individual need it is now a full-fledged industry in India. The global trade is estimated to be worth more than $100bn per year (African business magazine.com). The country has exported 27,121.88 MT of floriculture products to the world for the worth of Rs. 423.46 crores in 2012-13. The developing countries are the major producer while developed countries are the major consumer of flowers. However, scenario is changing in India. With growing tourism, flourishing hotels, increase in per capita income and adoption of luxurious lifestyles the domestic flower market is expanding at a fast pace. Further, higher return per unit of land compared to traditional crops is further driving farmers into floriculture trade. Keeping in view the promising trade prospective, Govt. of India has initiated developmental programmes mainly through the schemes of Ministry of Agriculture like National Horticulture Mission and Horticulture Mission for North East & Himalayan States.

Climate change is playing an important role in modern era and affecting all living beings worldwide. It is one of the most important global environment challenges affecting humanity, food production, natural ecosystems, freshwater supply, health, etc. According to the latest scientific assessment, the average global temperature has increased by $0.8^{O}C$ in the past 100 years. The IPCC (Inter-governmental Panel on Climate Change) projects that global mean temperature may increase between 1.4 and 5.8 degrees Celsius (^{O}C) by 2100. Climate change will lead to warming and that ultimately brought changes in rainfall patterns, increased frequency of extreme events of drought, frost and flooding. The chemical composition of the atmosphere for nitrogen is 78%; about 21% is oxygen, which all animals need to survive; and only a small percentage (0.036%) is made up of carbon dioxide which plants require for photosynthesis. It is established that about 30% of the incoming energy from the sun is reflected back to the space while rest reaches the earth, warming the air, ocean and land maintaining an average surface temperature of about $15^{O}C$. The continued effect of these activities results in increasing emission of CO_2 and other green house gases (GHG) leading to global warming as a green house effect due to entrapment of back radiation from earth by these gases. The current level of CO_2 in the atmosphere, the main GHG, is 35.4% more than the preindustrial level and is growing. The level of green house gases are now far above any level in the past 650,000 years as indicated by the study of the ice core permafrost. The concentration of all GHG reported to have increased by as much as 70% between 1970 and 2004.

Impact of Climate Change on Floriculture

Plants are major components of the ecosystem that are greatly affected by climatic and geographical factors and it is well established that climate change has a direct impact on agriculture as a whole that is mainly affecting the crop production. The global climate change will have important effects on biological processes of every crop over next decades. Phenology includes the timing of flower blooms, crop stages and insect activity. The growth and development of most plants is highly regulated by the march if climatic changes. As far as floriculture sector is concerned, issues like low production and low quality of floricultural crops are are affected due to the climate change. It is predicted that with rise of global temperature (4.4ºC) by 2080 over the cultivated areas, it will result in reduction of India's agricultural output by 30-40% that will be quite alarming. This alarming problem of climate change will further aggravate unless proper remedial measures are taken. Further, occurrence of new diseases, pests together with severity of the existing ones is also foreseen. Some of the well established commercial varieties of flowers will perform poorly in an unpredictable manner.

- It is predicted that the impact of climate change on flowering plants and crops will be more pronounced and will affect both the quality and production. Change in the timing, duration and abundance of flowering have potential to disrupt ecological relationship among plats, pollinators, herbivores and flower parasites and pathogens. This pattern may occur because early flowering species respond to climate or other variables that are changing more rapidly than those to which late flowering species respond. Jasmine is affected by change in climate as low temperatures shut down flowering in Jasmine. Temperature less than (19ºC) and lead to reduction in flower size.
- The winter regime and chilling duration will reduce in temperate regions affecting the temperate flower crops like Rhododendron, Orchid, Tulips, Alstroemeria, Magnolia, Saussurea, Impatiens, Narcissus etc. Some of them will fail to bloom or flower with less abundance while others will be threatened
- Climate change will affect the production schedule which is mainly due to rise in temperature. Due to rise in temperature, photoperiods may not show much variation, as a result photosensitive crop will mature faster
- Pollinators and Pollination will be affected adversely because of higher temperature which ultimately affects the yield. Floral abortions and flower drop will be occurred frequently at higher temperatures.
- The requirement of annual irrigation will increase with rise in temperature.
- The rise in temperature will achieve heat unit requirement in much less time.
- Indigenous species in the natural habitat will be under threat for not getting favourable agro-climatic conditions for their proliferation.
- Western Ghats and surrounding regions may be deprived of normal precipitation due to abnormal monsoon. Plant species requiring high humidity and water may find them under difficult conditions for survival.
- Plains of India will also have similar kind of problems and will be affected either by drought or excessive rains, floods and seasonal variations.

- Commercial production of flowers particularly grown under open field conditions. Several processes will be severely affected leading to poor flowering, improper floral development and colour besides reduction in flower size and short blooming period.

Landscape Approaches at the Nexus of Climate Change Mitigation and Adaptation

Climate change will significantly affect all types of land use and ecosystem services, as well as the quality of life for societies. The primary goal of landscape ecology is to understand the interaction of landscape patterns and processes, and to make this knowledge available in the societal learning process of developing landscapes in a sustainable way. One of the strengths of landscape ecology is to deal with changes in pattern/process relationships that affect multiple ecosystem services. Therefore, it provides a framework to understand how to manage and adapt landscapes to maintain multiple ecosystem services. Landscape approaches to enhancing multi-functionality have been identified as a promising pathway to synergies between mitigation and adaptation besides helping achieve other livelihood needs through ecosystem services and functions provision.

Turf Grasses

A lawn is an area of aesthetic and recreation planted with turf grasses. It may also be defined as green carpet for a landscape. It is considered as an integral part of any home landscape which provides aesthetic value. It improves the appearance of the home, enhances its beauty, increases services and usefulness. Turf grasses widely used in lawn development-are narrow-leaved grass species that form a uniform, long-lived ground cover, tolerate traffic and low mowing heights.

Positive Role of Turf Grasses in Climatic Change Conditions

Entrapment and Biodegradation of Organic Chemicals and Conversion of Carbon Dioxide Emissions: The extensive fibrous root system of turf grasses contributes considerably to soil up gradationthrough organic matter derived from atmospheric carbon dioxide through photosynthesis. A diverse large population of soil micro-flora and fauna support this process. These organisms offer one of the most active biological systems for the degradation of trapped organic chemicals and pesticides. Therefore, this turf-ecosystem is important for protection of ground water quality.

Enhancement of Heat Dissipation and Temperature Moderation: The overall temperature of urban areas is warmer than nearby rural areas. Turf grasses through the cooling process of evapo-transpiration serve an important function in dissipating the high levels of heat generated in urban areas. For example, a football field has the cooling capacity of a 70 ton air conditioner. The cooling effect of irrigated turfs and landscapes can result in energy savings by reducing the energy input and allied costs required for the mechanical cooling of interiors of adjacent homes and buildings.

Runoff Reduction and Flood Control: The dense plant canopy of mowed turf grasses is very effective in the entrapment of water and airborne particulate materials as well as in absorbing gaseous pollutants. The high degree of water runoff which occurs from impervious surfaces in urban and peri-urban areas carries many pollutants in the runoff. Turf grasses offer one of the best known systems for catchment of the runoff water plus the pollutants, especially when proper landscape designs are used.

Ornamental Trees

Planting of ornamental trees is an old age practice. It provides aesthetic beauty with additional benefits like shade, arrest degradation and maintain soil fertility, diversify income sources, enhance use efficiency of soil nutrients, water and radiation. Trees bring favourable changes in the microclimatic conditions by influencing radiation flux, air temperature, wind speed etc. which will have a significant impact on modifying the rate and duration of photosynthesis and subsequent plant growth, transpiration, and soil water use

The general effects of climate change on tree species include changes in:

- Regeneration success
- Forest health (e.g., reduced vigour, maladaptation, and increased mortality)
- Productivity (positive in some places; negative in other places)amount of growing stock (as a result of increased frequency, intensity, duration, and location of disturbances)
- Species ranges, species composition, age class distribution, and forest structure at any given location, over time.
- Trees remain quiescent until suitable temperatures for growth are experienced.
- The start of intense blooming days (IBD) of many tropical flowering trees is affected by the number of days at or below 50°F.
- The duration of IBD is affected by the numbers of days at or below 50°F.
- A significant change in climate is expected to alter the flowering start dates, IBD dates, and duration of IBD for many ornamental flowering trees in the subtropics.

Reduction of Nitrogen Gas by Trees

Acacia auriculiformis, Albizzia lebbeck, Bauhinia purpurea, Bauhinia variegata, Butea monosperma, Cassia fistula, Cassis siamea, Dalbergia sissoo, Peltophorum ferrugineum, Samanea saman, Saraca indica, Sesbania grandiflora, Casuarina equisetifolia etc.

Positive Impact

Global climate change is expected to affect floricultural crops through its direct and indirect effects. Scientific evidence suggests a positive effect of increase in atmosphere CO_2 on C_3 photosynthetic pathway promoting the growth and productivity of C_3 plants (like Carnation, Chrysanthemum, Day lilies, Ferns, Geranium, Kentucky blue grass, Lavender, Marigold, Morning glory, Potted azalea, Roses and Tulips). Increased CO_2 will reduce evapo-transpiration and thus increase the water- use efficiency. The C_3 plants are likely to gain from the increasing level of CO_2 in the atmosphere. Elevated carbon dioxide has positive effect by increasing the productivity ranging from 24-51%. CO_2 enrichment in greenhouses (800-2000 ppm depending on the crop) to increase the production of flower crops is popular. It would be possible to spend less on energy to generate CO_2 for carbon fertilization.

Negative Impact

The above positive effects will be counteracted by increase in temperature, reduced humidity levels, reduced water levels, increased salt levels in water and soil. Rise in temperature will reduce crop duration, increase respiration rate, alter photosynthate partitioning to economic product, alter phenology, particularly flowering and reduce chilling unit accumulation, hasten senescence and flower maturity. However, the overall impact of climate change and global warming will depend on interaction effect of elevated carbon dioxide and temperature rise.

The higher ambient temperature has a direct impact on:

- Volatile fragrances the flowers emit
- Deterioration of pigments leading to dull shades
- Reduced production and productivity under open and protected environment
- Shift in insect pest and disease outbreaks
- Absence of winter chilling that reduce flowering
- Reduced post harvest life
- Poor pollination and seed set due to changes in insect behavior
- Similarly higher rainfall would increase anaerobic stress at the root zone leading to yellowing, poor growth and even mortality.

Effect on Floral Biodiversity

The scientists, who published their research study in the Proceedings of National Academy of Sciences, described that one in every five species of wild flower could die out over the next century if the levels of carbon dioxide in the atmosphere double in line with predictions. The research found that higher levels of gas reduced numbers of wild flowers by 20 % and cut overall plant diversity by 8%.

Early Blooming in Flowers

Climate change seems to have affecting flowering patterns in the whole world. A change in timing of plant flowering can disrupt the creatures that pollinate them. In the Himalayas, the Rhododendron usually bloom in March. But in 2009, they came in full bloom, almost 45 days ahead of schedule. With weeks of abnormally warm weather, candytuft, baby breath's, snowdrops, witch-hazels, grape-holly, Dawn fragrant viburnum, camellias, winter honeysuckle all came in flowering couple of weeks before in USA.

Effect on Flower Fragrance

Global climate change is not only pushing flowers into extinction, but also have casted its spell on quality and quantity of flowers. Flower due to global warming are losing their fragrance. The scent in flowers last longer in colder climate as plants can retain their essential oils for a longer period of time.

Effect on Flower Export

In Tamilnadu heavy snowfall and unseasonal climatic change have greatly affected the flower cultivation and leading to shortfall in flower exports from South India in last year. Buds gets decayed largely and flowers fall down due to the hectic climate prevailed in many places of the south Indian state. Similarly in Pune district, absence of the required chilled weather during winter and severe heat during summer has adversely hit production of roses.

Impact on Information and Extension

The major innovations in response to climate variability will take the form of improved information through global monitoring and forecasting. The improved interpolations could lead to improved short-term forecasts, which could be disseminated via SMS using rapidly spreading cell phone networks.

Improved Varieties of Flower Crops for Changing Climate

Breeding or development of new cultivars of floricultural crops tolerant to high temperature, resistant to pests and diseases, short duration and producing good yield under stress conditions, will be the main strategies to meet this challenge. The Division of Floriculture and Landscaping has some promising varieties and technologies are:

Chrysanthemum

Chrysanthemum is a short day plant. So flowering round the year in open field condition is not possible.

Pusa Anmol

Highly floriferous bushy variety with yellowish pink flowers. Produces three flower flushes in a year (October-November, February-March and June-July) as against one in a majority of the cultivars. The variety Pusa Anmol flowers in 85-100 days after transplanting. Ideal for loose flowers and whole plant cut flower. Blooms remain fresh for 20-22 days in field conditions as well as in vase. It can be cultivated in hills and plains to get off-season blooms. This variety being a photo and thermo insensitive is ideally suited for off season production in open cultivation without any additional expenditure on additional lighting and black out.

Orchids

It is likely that orchids, more than any other plant family, will be in the front-line of species to suffer large-scale extinction events as a result of climate change. Flowers do not open up fully in tropical orchids wherever temperatures below 15^{o}C. High temperature leads to flower bud drop and unmarketable spikes in tropical orchids when temperature remains > 35^{o}. Long term studies *of Ophrys sphegodes* in the UK found that the species flowers 6 days earlier for each 1 C increase in spring temperatures. A study led by scientists from the Royal Botanic Gardens, Kew's Jodrell Laboratory, which focuses on epigenetics in European common marsh orchids, has revealed that some plants may be able to adapt more quickly to environmental change than previously thought. *Platathera leucophaea* is a North American threatened orchid that is vulnerable to drought. Its largest populations are centered in Illinois, but numbers have dropped steeply in the last few years, as the climate has been warmer and drier.

Narcissus

The rise in temperature caused advancement in the flowering dates of *N. bulbocodium* across the Portuguese territory, estimated in 1.5 days per decade. The early onset of flowering can have consequences not only for the individual plants and population affected, but also to the maintenance of diversity at the community level.

Adaptation Strategies

There is need to develop sound adaptation strategies in order to address the adverse impacts of climate change. It will include the impact of climate change on productivity and quality of floricultural crops. The major emphasis should be on areas like development of production systems for improved water use efficiency and to adapt to the hot and dry conditions. Some of the strategies are :

- Changing sowing or planting dates in order to combat the likely increase in temperature and water stress periods during the crop growing season.
- Modifying fertilizer application to enhance nutrient availability and use of soil amendments to improve soil fertility and enhance nutrient uptake.
- Providing irrigation during critical stages of the crop growth and conservation of soil moisture reserves are the most important interventions.
- The crop management practices like mulching with crop residues and plastic mulches help in conserving soil moisture.
- Challenges posed by climate change could be tackled by Modified crop management practices. Several institutions have evolved hybrids and varieties, which are tolerant to heat and drought stress conditions.
- Research should be intensified to develop new varieties suitable to different agro ecological regions under changing climatic conditions. The choice of a variety is complicated by the risk that the best variety for the current climate may be poorly suited for future climates. Thus, while adaptations such as planting new varieties and shifting to new areas may reduce impacts in long term, short term losses may largely be unavoidable.
- The physiological and morphological differences between varieties (genotypes) enable production over a relatively large range of climates and depending upon the suitability to different growing areas the cultivars may be adopted.
- In situations, where there is strong consumer preference for select cultivars and also the suitable varieties are not available to adapt to the changing climate of a particular growing region, the option of using rootstocks in case of rose for better performances of the scion cultivars could be explored.

Future Strategies

The crop based adaptation strategies need to be developed depending on the vulnerability of individual crop and agro-ecological region. It will in integrate all available options to sustain the productivity. There is need to develop strategies and tools to understand the impact of climate change and evolve possible adaptation measures in floricultural crops. To combat with the bad effects of changing climate we need to formulate a sound action plan. Various areas also need timely and proper consideration like identification of gaps in vital information, prioritization of researchable issues from point of view of farmers, policy planners, scientists, trade and industry. Therefore it is need of the hour that we should know the likely changes that can happen in next 50 to 1000 years and their effects. These changes will affect majorly growth, development and quality of flower crops. At this point of time there arises the need of technologies that will help to mitigate the problem and also a string and innovative research should be done to overcome the challenges of climate change. Thus finally, policy issues, adaptation strategies and mitigation technologies could be worked out and challenges could be converted into opportunity. Priority of education, research and development and policy implications for enhancing adaptive capacity of Indian floriculture to climate change.

In view of these problems, Floriculturists will have to play a significant role in the climate change scenario and proper strategies have to be envisaged for saving floriculture from future turmoil.

- Identifying plants at risk and conservation planning. It is necessary that selection of plant species/cultivars is to be considered keeping in view the effects of climate change.
- Maintaining and restoring natural ecosystems is a key activity to mitigate the effects of climate change.
- Monitoring and measuring impacts of climate change
- The most effective way to address climate change is to adopt a sustainable development pathway, besides using renewable energy, forest and water conservation, reforestation etc.
- Awareness and educational programmes for the growers, modification of present floricultural practices and greater use of green house technology are some of the solutions to minimize the effect of climate change. Hi-tech floriculture is to be adopted in an intensive way.
- It is necessary that selection of plant species/cultivars is to be considered keeping in view the effects of climate change.
- The performance of different seasonal may not be satisfactory due to shorter and warmer winter.
- Judicious water utilization in the form of drip, mist and sprinkler will be a key factor to deal with the drought conditions.
- Awareness and educational programmes for growers, modification of present floricultural practices and more use of greenhouse technology are some of the solutions to minimize the effect of climate change. Hi-tech floriculture is to be adopted in an intensive way.
- Development of new cultivars of floricultural crops tolerant to high temperature, resistant to pests and diseases, short duration and producing good yield under stress conditions, will be the main strategies to meet this challenge.

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Interior Greenscaping for Climate Smart Living

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Plants have captivated man from time immemorial. Some of the earliest known records of indoor plants come from the artwork of ancient Egypt which depicts house plants in urns and troughs. Indoor plants help create a pleasant environment at home or office. Small plants add color and scenery to windows or tables, while larger ones soften and blend with groups of furniture. Indoor plants create a cool, spacious feeling, even in hot summers. Interior greenscaping also known as plantscaping is the practice of designing, arranging and growing indoor plants in enclosed environments. In apartments plants add warmth, personality and year round beauty. Shopping malls and hotels and take full advantage of the colorful, relaxed atmosphere created by green and flowering plants. Banks and other commercial buildings rely on interior plants to "humanize" the work environment and increase productivity. Plants also have multiple ecological benefits which include regulating temperature and moisture, filtering dust, adsorbing poisonous gases and pollutants and reducing noise. Further, plants contribute positively to our physical and mental health by reducing stress and keeping us cheerful. As jobs become more and more demanding, the frequency of stress related disorders has also increased. Studies conducted in this regard indicate that indoor plants improve employee morale, reduce absenteeism and increase worker efficiency. These benefits are becoming increasingly important, in an era of growing urban populations, rising carbon dioxide levels and climate change. A considerable amount of new research on the benefits of interior plants has been conducted over the last twenty years. This paper aims to present those findings which demonstrate the ability of indoor plants to remove indoor air pollutants, enrich indoor air quality, improve work productivity and enhance creative performance.

Indoor Air Pollution (IAP)

Indoor pollution refers to any undesirable change in the physical, chemical and biological characteristics of air in the indoor environment within a home, building or an institution or commercial facility. Way back in 1992, The World Bank had designated indoor air pollution in developing countries as one of the four most critical global environmental problems. As per a recent study by the World Health Organisation (WHO) approximately 7 million people died of air pollution around the world in 2012. Indoor air pollution was responsible for 4.3 out of the 7 million deaths with most of the fatalities being in poor and developing countries. Among these deaths: 12% were due to pneumonia, 34% from stroke, 26% from heart disease, 22% from Chronic Obstructive Pulmonary Disease and 6% from lung cancer and the root cause being air pollutants.

Around the world, 3 billion people in poor and developing countries still cook and heat their homes using solid fuels (i.e. wood, crop wastes, charcoal, coal and dung) in open fires and leaky stoves. Such inefficient cooking fuels and technologies produce high levels of household air pollution with a range of health damaging pollutants, including small soot particles that penetrate deep into the lungs. In poorly ventilated dwellings, indoor smoke can be 100 times higher than acceptable levels for small particles. Exposure is particularly high among women and young children, who spend most of their time indoors. The risk for women is higher, due to their role in food preparation. Exposure to household air pollution almost doubles the risk for childhood pneumonia. Over half of deaths among children less than 5 years old from Acute Lower Respiratory Infections (ALRI) are due to particulate matter inhaled from indoor air pollution from household solid fuels. Approximately 17% of annual premature lung cancer deaths in adults are attributable to exposure to carcinogens from household air pollution caused by cooking with solid fuels like wood, charcoal or coal. As per the 2001 national census, 82.5% Indian rural households use biomass, a major source of indoor air pollution as a cooking fuel. The third National Family Health Survey (NFHS) in 2005–06 also arrived at similar estimates. About 27.5% of under five infant mortality in India is because of indoor pollution (TERI, 2011).

Indoor air pollution is also a major concern in developed countries, where energy efficiency improvements sometimes make houses relatively airtight, reducing ventilation and raising pollutant levels. Besides, use of synthetic materials in building and furnishing, use of chemical products, pesticides and household care products also contribute to indoor pollution.

Sources of Indoor Air Pollution and their Effects on Human Health

The quality of the indoor environment has become a major health consideration in the developed world, since urban-dwellers generally spend 80–90% of their time indoors (American Lung Association, 2001).

Volatile Organic Compounds (VOCs)

Volatile organic compounds (VOCs) are a major component of indoor air pollution. VOCs consist of a large number of organic substances with diverse physical, chemical and biological properties, which will volatilize at normal room temperatures. The United States Environmental Protection Agency (EPA) has found concentrations of VOCs in indoor air to be 2 to 5 times greater than in outdoor air. Some commonly observed VOCs in indoor environment and their sources are listed in Table 1. Furniture coatings were found to release as many as 150 different VOCs. Although each compound is likely to be present in very low concentrations, the mixture can produce additive and possibly synergistic effects (Weschler and Shields 1997; WHO 1989; 2000). Pesticides applied indoors may last for years in carpets, where they are protected from the normal degradation caused by sunlight and bacteria. There is growing evidence that chronic exposure to VOCs have adverse health effects on human (Rumcher *et al.,* 2004; Suh *et al.,* 2000). The short term adverse effects include conjunctive irritation, nose and throat discomfort, headache and sleeplessness, allergic skin reaction, nausea, fatigue and dizziness. While the long term adverse effects include loss of coordination, leukamia, anaemia, cancer and damage to liver, kidney and central nervous system (Kim *et al.,* 2002; Kerbachi *et al.,* 2006).

Second Hand Smoke (SMS)

Passive smoking is the inhalation of smoke, called Second Hand Smoke (SHS) or Environmental Tobacco Smoke (ETS) by persons other than the intended "active" smoker. Second Hand Smoke (SHS) is classified as a “known human carcinogen” by the International Agency for Research on Cancer, a branch of the World Health Organization. Tobacco smoke is a mixture of gases and particles. It contains more than 7,000 chemical compounds. More than 250 of these chemicals are known to be harmful and at least 69 are known to cause cancer. Long term exposure to SHS may increase the risk of lung cancer, cardiovascular diseases and respiratory diseases.

Table 1: Commonly observed VOCs in indoor environment and their sources

Chemicals	Sources
Acetone	Paint, coating, finishers, paint removers, thinner
Aliphatic hydrocarbons (octane, decane, undecane hexane, isodecane, mixtures etc.)	Paint, adhesive, gasoline, combustion sources, liquid process photocopier, carpet, linoleum
Aromatic hydrocarbons (toluene, xylene, ethylbenzene, benzene)	Combustion sources, paint, adhesive, gasoline, linoleum, wall coating
Halogenated hydrocarbons (methylene chloride, trichloroethane)	Upholstery, carpet cleaner, protector, paint, paint remover, lacquers, solvents, correction fluid, dry cleaned clothes
n-Butyl acetate	Acoustic ceiling tile, linoleum, caulking compound
Dichlorobenzene	Carpet, moth crystals, air freshners
4-Phenylcyclohexene	Carpet, paint
Terpenes (limonene, α-pinene)	Deodorizers, cleaning agents, polishes, fabrics, fabric softener, cigarettes

Source : Tucker, 2001

Bioaerosols

A bioaerosol is an airborne product of a biological contaminant. Biological contaminants in the home may include mold, bacteria, viruses, mites, and pollen. Bioaerosols can cause infectious diseases such as Legionnaires' disease. They can also cause allergic reactions, including hypersensitivity pneumonitis, allergic rhinitis, and some types of asthma. Symptoms caused by biological pollutants include sneezing, eye irritation, coughing, dizziness and respiratory infections.

Factors that can contribute to the growth of biological contaminants are wet or moist building materials (carpeting, ceilings and walls) and poorly maintained humidifiers, dehumidifiers and air conditioners. "Humidifier fever" is a common illness caused by improper maintenance of humidifiers that can produce fever, chills, headaches and persistent coughs. One of the most important sources of airborne bacteria in indoor environments is the presence of human beings. In particular activities like talking, sneezing, coughing, walking, washing and toilet flushing can also generate airborne biological particulate matter. Other possible sources of biological contaminants are pets, dust and organic waste.

Formaldehyde

It is a colourless gas with a pungent odour that comes mainly from particle board, pressed wood, foam insulation, paper bags, waxed papers, facial tissues, stiffeners and wrinkle resisters, water repellents, fire retardants, binders in floor coverings, carpet backing, permanent press clothes, natural gas, kerosene and cigarette. It causes irritation of mucous membranes of the eyes, nose and throat, those allergic contact dermatitis, respiratory problems, eye irritation, headaches, asthma and carcinogenicity to the throat.

Asbestos

It is often used in shingles, fireproofing, heating systems, floor tiles, and ceiling tiles. When asbestos containing material is damaged or disintegrates, microscopic fibers are dispersed into the air. Inhalation of these microscopic asbestos fibers may lead to lung cancer or mesothelioma.

Radon

It is an invisible, radioactive atomic gas that results from the radioactive decay of radium, which may be found in rock formations beneath buildings or in certain building materials themselves. Due to modern houses having poor ventilation, it is confined inside the house. Radon is a heavy gas and tends to accumulate at the floor level. The half life for radon is 3.8 days, indicating that once the source is removed, the hazard will be greatly reduced. After cigarette smoking, radon is the second leading cause of lung cancer.

Combustion Products

In general, combustion or burning is a chemical reaction in which a fuel combines with oxygen. When there is insufficient oxygen, the fuel burns incompletely and produces by products of combustion. Examples of such by products are carbon monoxide, nitrogen dioxide, carbon dioxide and respirable particulates which are generated from automobile exhausts, furnaces, water heaters, space heaters, scented candles, oil lamps, wood stoves, fireplaces and gas stoves.

Carbon monoxide (CO): It is a colourless, odourless gas which reduces the blood's ability to carry oxygen. It may cause tiredness, headaches, nausea, flu-like symptoms, dizziness, impaired vision and confusion. In people with heart disease, it can also cause chest pain. Very high levels of carbon monoxide exposure can cause loss of consciousness and death.

Nitrogen dioxide (NO_2): It can cause irritation of the eyes, nose, throat and lungs, in addition to shortness of breath. People with respiratory illnesses, such as asthma, may be at higher risk of experiencing health effects from nitrogen dioxide exposure.

Carbon dioxide (CO_2): It is a gas that is exhaled by humans during the respiratory process. This gas is measured during Indoor Air Quality studies because it provides a good indication if the ventilation system is bringing in enough fresh air for the amount of people utilizing the space. It is typically measured not as a pollutant, but as an indicator as to whether other pollutants may be in the air. At high levels, it can cause headaches, dizziness and fatigue.

Particulate Matter (PM): It is a complex mixture of solid and liquid particles of organic and inorganic substances suspended in the air. The major components of PM are sulfate, nitrates, ammonia, sodium chloride, black carbon, mineral dust and water. The most health damaging particles are those with a diameter of 10 microns or less, which can penetrate and lodge deep inside the lungs. Scientific studies have linked exposure to high concentrations of some types of PM with a variety of problems, including irregular heartbeat, aggravated asthma, decreased lung function, increased respiratory symptoms, such as irritation of the airways, coughing or difficulty in breathing, non fatal heart attacks and premature death in people with heart or lung disease.

Indoor Air Quality and Global Climate Change

Climate change and indoor climate are inextricably linked. However, this linkage is often overlooked and warrants far more attention. Now a day's people spend most of their time indoors be it at home, school or work. Eventually people would experience climate change from an indoor perspective. According to a report by Institute of Medicine, USA, the outdoor environment permeates indoors. The most common response to climate change is that buildings will shelter the population from climate change impacts. Although tightly sealed buildings can protect occupants from alterations in weather patterns such as heavy rains or high temperatures, decreased ventilation rates will increase concentrations of indoor emitted pollutants. A mixture of climate change related factors such as excessive temperatures, poor ventilation, indoor dampness and emissions from building materials and equipment such as backup power generators can combine to create a wide spectrum of unexpected health problems.

Climate change can seriously affect indoor air quality through several mechanisms

- Increased outdoor pollution that raises pollution levels indoors.
- Higher temperatures resulting from climate change will increase the use of air conditioning, leading to substantial increases in demand for electricity and the need for increased electricity generation. Increased use of air-conditioning could exacerbate emissions of greenhouse gases and if accompanied by reduced ventilation rates, increase the concentration of pollutants emitted from indoor sources. The longer these pollutants remain indoors and increase in concentration, higher is the risk to human health.
- The potential for poisoning from exposure to carbon monoxide emitted from improperly used portable gasoline powered generators may increase, if peak electricity demand is not met during heat waves in the summer season. Generators when used properly with good ventilation are not a problem. However, when used improperly in sealed or poorly ventilated buildings, it may lead to carbon monoxide poisoning.
- The increased frequency and intensity of extreme heat events will create stresses on indoor environments that will not be fully met, causing increased morbidity and mortality from extreme heat indoors.
- Increased pollen production due to rising temperature and carbon dioxide concentrations in some genera can trigger allergies, hay fever and asthma.
- Climate change has the potential to produce significant increases in near-surface ozone concentrations. Ozone is known to react with many VOCs found indoors to create a variety of chemical by products with potentially troubling adverse health consequences that could present a significant unanticipated public health issue. Recent studies indicate that ozone reacts with the constituents of carpets, cleaning products and air fresheners, paints, building materials and a variety of surfaces to produce some irritating and toxic compounds such as formaldehyde and other aldehydes, acid aerosols and ultrafine particles.
- Of particular concern for ozone reactions is the prolific use of cleaning products and air fresheners, which contain selected terpenes (ά-pinene, limonene, and isopropene) that readily react with ozone. Studies suggest that such reactions produce substantial quantities of toxic secondary byproducts.
- Increased relative humidity from climate change will increase the moisture content of materials indoors and thus increase the risk for mold growth.

- Damage caused by flooding and eventually the abundance of water available to pests will likely increase pest-harborage opportunities and increase the capacity of buildings to support pests infestation. An increase in pests could increase exposure to pest allergens, infectious agents and to pesticides.
- Alteration in the ecological balance brought about by climate change can alter the geographical distribution and biological cycle of many disease vectors, allowing the establishment of new breeding sites and bursts of disease carriers, thus posing significant disease risks to humans. For example malaria and dengue.
- Increases in populations of structural pests, crop pests and forest pests are also likely to increase the use of pesticides and pesticide exposure both, indoors and outdoors.

Climate change and indoor climate are strongly connected and have many characteristics in common, most obviously, their effect on human health. Good indoor climate can shield humans against the ill effects of air pollution as well as the severe consequences of climate change.

Plants and Indoor Air Quality

One of the ways plants affect people is through the physical changes that plants cause to their surroundings. For example, plants release oxygen and moisture into the air. Some of these changes in the environment can increase the health and comfort level of humans in enclosed environments. The U.S. National Aeronautics and Space Administration funded early studies on using plants to clean the air in space stations. These studies showed that many common foliage plants reduced levels of some interior pollutants, including formaldehyde and carbon monoxide, from small, sealed test chambers (Wolverton *et al.*, 1984; 1985). The pollution reduction was largely due to bacteria growing on the plant roots (Wolverton *et al.*, 1989; Wood *et al.*, 2002).Further research has shown that plants remove many indoor air pollutants, including ozone, toluene, and benzene (Darlington *et al.*, 2001; Wood *et al.*, 2002; Papinchak *et al.*, 2009). Several indoor species have been screened for their ability to remove benzene, some of which could remove 40 to 88 mg m^{-3} d^{-1} (Orwell *et al.*, 2004), in addition to other VOCs (toluene, TCE, m-xylene and hexane) (Cornejo *et al.*, 1999; Orwell *et al.*, 2006; Wood *et al.*, 2002; Yoo *et al.*, 2006).

Wolverton and Wolverton (1993) evaluated indoor plants for their ability to remove xylene and formaldehyde from sealed chambers at the Wolverton Environmental Services, Mississippi, USA. In this study they evaluated thirty indoor plants and found that *Phoenix roebelenii* was the most effective in removing xylene with 610 µg removed per hour. In case of formaldehyde, *Nephrolepis exaltata* proved the most effective(Table 2 and 3).

Table 2: Xylene removing indoor plants

Plants	Removal rate (µg/hr)
Phoenix roebelenii	610
Diffenbachia camille	341
Dracaena marginata	338
Diffenbachia maculata	325
Homalomena sp.	325
Nephrolepis obliterata	323

Table 3: Formaldehyde removing indoor plants

Plants	Removal rate (µg/hr)
Nephrolepis exaltata	1863
Chrysanthemum morifolium	1450
Phoenix roebelenii	1385
Dracaena deremensis	1361
Nephrolepis obliterata	1328
Hedera hedix	1120

Song *et al*. (2007) conducted an experiment to study the concentrations of volatile organic compounds (VOC) in indoor areas and found that plants like *Aglaonema brevispathum*, *Pachira aquatic* and *Ficus benjamina* reduced the levels of VOC's like methane, toluene, ethyl benzene and formaldehyde.

In a study at University of Georgia, 28 ornamental plant species commonly used as indoor plants were screened for their ability to remove five volatile indoor pollutants (benzene, toluene, octane, TCE, and α-pinene). *Hemigraphis alternata, Hedera helix, Hoya carnosa,* and *Asparagus densiflorus* had the highest removal efficiencies for all pollutants. *Tradescantia pallida* displayed superior removal efficiency for benzene, toluene, TCE, and α-pinene. *Fittonia argyroneura* effectively removed benzene, toluene and TCE. *Ficus benjamina* effectively removed octane and α-pinene. Whereas, *Polyscias fruticosa* effectively removed octane. The variation in removal efficiency among species indicates that for maximum improvement of indoor air quality, multiple species are needed (Yang *et al.,* 2009).

Researchers from the University of Technology, Sydney have carried out laboratory and real-world office studies over the past 15 years on the ability of indoor plants to reduce VOCs, CO_2 and CO. They have so far tested 11 internationally used indoor plant species for VOC removal. Results indicated that indoor plants reduced CO_2 levels by about 10% in air conditioned buildings and by 25% in naturally ventilated buildings (Tarren *et al.,* 2007). They also reduced CO levels by up to 90%. A common pattern of removal in all species and VOCs tested was observed which is as follows :

- Removal rates started slowly, but over four to five days, they rose to more than 10 times the initial rate *i.e.* removal rates were stimulated by exposure to an initial dose.
- Once induced, the potted plant microcosm reliably removed top up doses to the original concentration within about 24 hours
- Reduced the VOC load by over 80% to below 100 ppb
- If the VOC load went up, so did the removal rates.
- Rates were unchanged in light or dark (worked 24/7)
- Residual concentrations were also removed, effectively to zero.
- All species tested worked about equally well, after a week of acclimatisation to the VOC.
- Twenty cm pots were as effective as thirty cm pots (less space consumption)

Zhou *et al.* (2011) tested thirty plant species from *Araceae, Agavaceae* and *Liliaceae* families for their abilities to remove formaldehyde from the air. They identified the following ten plant species for formaldehyde removal from the air: *Scindapsus aureus, Asparagus setaceus*, *Sansevieria trifasciata* cv. Hahnii, *Chlorophytum comosum, Aglaonema commutatum* cv. White Rajah, *Aglaonema commutatum* cv. Red Narrow, *Aglaonema commutatum* cv. Treubii, *Scindaspus pictus* cv. Argyraeus, *Gasteria gracilis and Philodendron sodiroi* cv. Wendimbe.

This study was further extended to ten plants from *Marantaceae* family and ten plants from *Pteridophytes*. Of the twenty potted plants tested, eight species which could be recommended for the removal of formaldehyde from the air were *Neottopteris nidus, Calathea rotundifolia, Pteris cretica cv. Albolineata, Calathea ornata, Platycerium* *bifurcatum, Neottopteris nidus cv. Volulum, Calathea roseo-picta* and *Calathea freddy* (Zhou *et al.,* 2013).

How Indoor Plants Filter the Air

VOC removal rates remain unchanged in light or dark *i.e.* even when the leaf stomata are closed and there is no photosynthetic activity. If the plant is removed and the potting mix returned to the chamber, the removal rates are maintained for a few days. These findings indicate that normal microorganisms in the potting mix were the primary VOC removal agents, which was later on confirmed by subsequent microbiological testing. Bacterial species respond in two ways when presented with a different organic compound in their environment. They can either induce enzymes to digest the material or can reproduce rapidly to produce more cells which can digest the substance. These bacterial species feed on the decomposing organic matter in the potting mixture. The role of the plants here is in nourishing the root zone microbial communities. This 'symbiotic microcosm' relationship is a universal feature of plant and soil interactions. Studies have found that, whatever be the species and potting mixture combination, the VOC removal response has always been the same. Since these findings are completely consistent across all species and VOCs tested, there is a high probability that any interior species will be equally effective in VOC removal, once induced by exposure to the substance.

All green plants photosynthesise, *i.e.* combine water with absorbed CO_2 to manufacture sugars and in doing so release equimolar concentrations of O_2 as a by product. Thus, indoor plants refresh air in two complementary ways. CO is very much more toxic than CO_2. However, plants and some soil bacteria consume and utilise this gaseous substance as part of their growth metabolism. Plants also absorb volatile organic compounds from the air into their leaves and then translocate them to their root zone, where microbes break them down. Microorganisms in the soil can use trace amounts of pollutants as a food source. Some organic chemicals absorbed by plants from the air are destroyed by the plant's own biological processes. Given that air also reaches plant roots, uptake by root tissues is another means by which air can be purified.

These studies showed that the Potted Plant Microcosm (PPM) represents a self-regulating biofilter and phytoremediation unit of indoor air. Thus, indoor plants at home or office can filter out toxins, stale air, pollutants, harmful viruses and mould spores. Virtually every tropical foliage and flowering plant works to remove pollutants from the interior environment and particular plants are better at removing certain toxins. Based on studies conducted by NASA, the below mentioned plants were found to be most effective in air purification.

Table 4: Best air filtering indoor plants according to NASA, USA

Botanical Name	Excellent for removing	Good for removing
Aechmea fasciata	Formaldehyde and Xylene	-
Aglaonema modestum	Benzene and Toluene	-
Aloe vera	Formaldehyde	-
Chamaedorea seifrizii	Benzene and Formaldehyde	-
Chrysanthemum morifolium	Trichloroethylene	Benzene and Formaldehyde
Dendrobium	Acetone, Ammonia, Xylene Chloroform, Ethyl acetate,	-

	Methyl alcohol and Formaldehyde	
Dieffenbachia maculata	-	Formaldehyde
Epipremnum aureum	Carbon monoxide and Benzene	Formaldehyde
Euphorbia pulcherima	Formaldehyde	-
Ficus benjamina	-	Formaldehyde
Guzmania "Cherry"	Formaldehyde and Xylene	-
Liriope muscari "Variegata"	Formaldehyde	-
Musa oriana	Formaldehyde	-
Neoregelia carolinae "Perfecta Tricolor"	-	Xylene
Peperomia obtusifolia	-	Formaldehyde
Phalaenopsis	Formaldehyde and Xylene	-
Rhododendron indicum	-	Formaldehyde
Schefflera arboricola	-	Benzene, Formaldehyde and Toluene
Syngonium podophyllum	-	Formaldehyde
Tradescantia sillamontana	-	Formaldehyde

Indoor Plants and Human Health

Indoor plants contribute positively to our mental and physical health. Some well known effects of plants on human psychology and health are discussed below:

Table 5: Best Indoor Plants for cleaning air

Botanical Name	Benefits	Best Use
Chlorophytum comosum *Chlorophytum elatum*	Purifies air rapidly; removes carbon monoxide and formaldehyde	In living spaces
Dracaena marginata *Dracaena dermensis* *Dracaena massangeana*	Purifies air; Removes formaldehyde, benzene, toluene, xylene and trichloroethylene	In living spaces
Gerbera jamesonii	Releases oxygen at night; purifies air by removing benzene and trichloroethylene	In bedrooms to refresh night time air or living spaces
Hedera helix	Removes benzene, formaldehyde and trichloroethylene from air	In Dorm rooms or home office
Nephrolepis exaltata 'Bostoniensis'	Humidifies air	In living spaces; note that dry winter rooms can quickly kill Boston ferns; mist plants daily for best results
Philodendrom domesticum *Philodendrom oxycardium* *Philodendrom selloum*	Purifies air; removes formaldehyde	In living spaces of new or renovated homes with new floors, walls, carpets, etc.
Sansevieria trifasciata	Purifies air; removes formaldehyde and nitrogen oxide produced by fuel-burning appliances	In living spaces, kitchens, rooms with wood stoves
Spathiphyllum	Removes mold from air	In bathrooms or damp areas

Source: bayeradvanced.com

Freshness and Cheerfulness

Plants keep us more cheerful and fresh. When we breathe, our body takes in oxygen and releases carbon dioxide. Excess carbon dioxide can elevate drowsiness levels. During photosynthesis, plants remove carbon dioxide from the air and release oxygen. Adding oxygenator plants to interior spaces can increase oxygen levels.

Stress Buster

Proximity to live greenery makes us feel more at ease with our surroundings. We experience less stress when there are plants around us. Houseplants can contribute to a feeling of well being and induce calmness and optimism.

Relief from Headache Problems

Pollution and excess of carbon dioxide contributes to headache problems. Indoor plants generate oxygen, increasing its level in air and lower the carbon dioxide level. This reduces the possibilities of headache.

Allergies, Common Cold and Dry Skin

Indoor plants can reduce cold related illnesses by more than 30% by increasing humidity levels and decreasing dust. Exposing children to plant related allergies early in the life works like a custom allergy shot and helps develop the child's immunity. Plants like eucalyptus and marigold, act as natural antiseptic. They open bronchial passages and clears mucus during colds, flu or bronchitis. Further, plants are a natural humidifier and contribute in maintaining moisture content in the indoor atmosphere that relieves from dry and itchy skin.

Improving Health

Viewing plants is linked to positive health outcomes of individuals, such as in pain reduction, less need for analgesics, and a quicker recovery from surgery as revealed from scientific studies. Research carried out at Kansas State University reveals that addition of plants in hospital rooms hastened recovery rates of surgical patients. Compared to patients in rooms without plants, patients in rooms with plants request less pain medication, had lower heart rates and blood pressure, experience less fatigue and anxiety and were discharged from the hospital sooner.

Insomnia

Some plants, like gerbera and daisies, release oxygen at night and can thus improve night's sleep. Placing them closer to the bed ensures optimal oxygen and good sleep.

Concentration and Focusing

A study in England found that students demonstrated 70 per cent greater attentiveness when taught in classrooms with indoor plants. In the same study, attendance was also higher for lectures given in classrooms with plants.

Sick Building Syndrome

There is general agreement amongst scientists that plants improve the indoor environment and are useful in fighting the modern phenomenon of Sick Building Syndrome (SBS). No specific cause of SBS has been identified but poor air quality, excessive background noise and inadequate control of light and humidity are all thought to be important factors. As plants have large surface areas for exchange of gases and water with their surroundings, they can help tackle some of these issues.

Indoor Plants and Work Environment

Numerous studies across the world have highlighted the countless benefits of having indoor plants in the work environment. Some of those benefits are as under.

Increase Productivity

Human assets are the most valuable and expensive assets in any business. Productivity has been shown to be higher when plants are present. In a computer task study, Lohr *et al.*, 1996 measured productivity by tracking reaction time on a task that involved visual concentration, mental processing and manual dexterity. People responded significantly more quickly when plants were in the room than when the plants were absent and there was no increase in error rate associated with the faster response. Reaction time in the presence of plants was 12% faster than in the absence of plants indicating that plants contributed to increased productivity.

Reduce Absenteeism

A 1998 Norwegian cross over study, among 51 offices over two three month periods, evaluating the effects of indoor plants on health and well being of occupants, found significant reductions in incidence of symptoms such as coughing (37%), fatigue (30%), dry, hoarse throat and dry or itching facial skin (23%). The score sum, as a mean of 12 symptoms was 23% lower during the period when the participants had plants in their offices, than when there were no plants (Fjeld 2002).

In a study of personnel working in a hospital radiology department, a 25% decrease in complaints was observed after the introduction of indoor foliage plants and full spectrum lighting. Particularly significant effects were observed for headache, feeling heavy headed, fatigue, dry, hoarse throat and dry/itching skin on hands. The radiology department director also reported that short-term absence due to illness decreased from the usual 15% to 5% during the experimental period and with plants remaining in the room this decreased rate has persisted for 5 years.

Stimulate Creative Thinking

Dr. Roger Ulrich, Director of the Center for Health Systems and Design at Texas A&M University found that problem solving skills, idea generation and creative performance improved substantially in workplace environments that include flowers and plants. In his studies, both men and women demonstrated more innovative thinking in the presence of plants than they did in an environment with art sculpture or no decorative objects.

A detailed environmental survey in a London commercial building showed that the office physical environment has a direct influence on the health, well-being and the productivity of occupants, besides having a positive effect on creativity and the quality and quantity of work carried out (Clements-Croome and Kaluarachchi 1999).

Three independent experimental studies in Denmark and Sweden have shown that improving indoor air quality improves the performance of typical office work such as word processing, proof reading and arithmetical calculations (Wargocki *et al.* 1999, 2000, 2002).

Help Reduce the Decibel Distraction Factor

Strategically placed plants can absorb noise in busy office environments. A study conducted by Costa and Lothian examined the effects of interior plants on acoustics in interior spaces (Freeman, 2003). This study found that plants can reflect, diffract or absorb sounds, depending on the frequency. Plants worked best at reducing high frequencies sounds in rooms with hard surfaces. A small indoor hedge placed around a workspace reduced noise by 5 decibels. The positive contribution of interior plants to sound absorption has been well documented in numerous studies including the work done by Dr. Helen Russell, Oxford, England and David Uzzell, University of Surrey, England. By cutting down on audible elements of a busy work place, plants can reduce employee distractions which may result in increased productivity. Good examples of noise reducing plants are *Spathiphyllum wallisii*, *Philodendron scandens*, *Dracaena marginata* and *Ficus benjamina*.

Boost Staff Comfort Levels

The recommended humidity range for human health and comfort is between 30 and 60 per cent, but many offices fall short of these figures Low interior humidity can lead to increased fatigue, respiratory discomfort and an overall drop in workplace well being. According to a study carried out by Washington State University, plants release moisture in an office environment creating a humidity level which matches the recommended human comfort range. A comfortable office environment is more conducive for productivity.

Help Reduce Stress

A study by Lohr *et al.,* 1996 showed that stress reducing responses also occur when people are in a room with a few containerized interior plants, even when their attention is not drawn to the plants People were asked to participate in a study measuring their responses when performing a computer task. Participants were randomly assigned to perform the task when no plants were in the room or when plants were present and positioned within the participant's peripheral vision. While performing the computer task, participants systolic blood pressure rose, indicating that the task was stressful. In the presence of plants, the rise was not as great, and it returned to pre-task levels more quickly than for those tested without plants. This documented that interior plants, like images of nature, could produce a calming response. Other researchers have also documented that interior plants evoke stress reducing effects that are similar to those evoked by nature (Dijkstra *et al.,* 2008).

Increase Staff Retention

Studies at Oxford Brookes University conclude that employees perceive buildings with interior plants as more expensive looking, more welcoming and more relaxed. Employees with positive perceptions of their work place are less likely to seek employment elsewhere thereby increasing staff retention.

Add Colour

Attractively coloured foliage and flowering plants can impart colour to the office thereby making it lively and vibrant. They also soften harsh building lines and add a whiff of freshness to the office environment.

Effects of Indoor Plants on 'Business Image'

An American study, with 170 respondents, explored what effects indoor plants had 'on a business's image to a visitor' (potential customer/client). There was universal agreement among respondents on a number of issues, including that indoor plants led to the perception that the business was:

- Warm and welcoming
- Stable and balanced
- Well-run
- Comfortable to work with
- Patient and caring
- Concerned for staff welfare
- Prepared to spend money on added beauty
- Not mean
- Providing a healthier and cleaner atmosphere

It can be expected that the same responses will be shared by the firm's staff also.

Summary

City dwellers spend most of their time indoors and so indoor air quality has become a major health consideration in urban areas. Indoor air pollutants associated with combustion of solid fuels in rural households are now recognized as a major source of health risk for women who are the primary cooks and their young children who often accompany them while they cook. Numerous scientific studies across the world have documented the removal of VOCs, carbon dioxide and carbon monoxide by indoor plants. Available evidence indicates that the plants rhizospheric bacterial community is largely responsible for VOC removal. The potted-plant microcosm can be exploited as an adaptive, self-regulating, low cost, sustainable system for bioremediation of VOC pollution in indoor environment.

There are a number of positive feelings associated with indoor plants. They make our surroundings more pleasant and this make us feel calmer, cheerful and fresh. Indoor plants humanize our surroundings and evoke happiness in our lives. Indoor plants are also linked to pain reduction and quicker recovery from surgeries. There are studies associating indoor plants with a reduction in allergies, common cold and dry skin. There is now a wealth of evidence to suggest that indoor plants at work place can reduce stress and absenteeism among employees. Productivity and creativity increased substantially in offices that had indoor plants. They also reduced background noise level, increased the comfort level of office bearers and boosted staff retention. The benefit of indoor plants in the work place far outweighs the costs associated with maintaining them. Climate change can have serious and unpredictable impacts on nature and humans. Climate change and indoor climate are inextricably linked. Good indoor climate can shield humans against the ill effects of climate change. Taking into account the wide spectrum of tangible and intangible effects, interior greenscaping can be explored for climate smart living.

List of house plants which improve indoor air quality

Botanical Name	Common Name	Plant Type	Light requirement
Aechmea fasciata	Silver Vase/Air plant	Herbaceous perennial	Bright indirect sunlight
Aglaonema brevispathum	--	Herbaceous perennial	Bright indirect sunlight
Aglaonema commutatum	Poison Dart Plant	Herbaceous perennial	Bright indirect sunlight
Aglaonema modestum	Chinese Evergreen	Herbaceous perennial	Bright indirect sunlight
Aloe vera	Aloe	Herbaceous perennial	Full sunlight
Asparagus densiflorus	Asparagus Fern	Herbaceous perennial	Bright indirect sunlight

Botanical Name	Common Name	Plant Type	Light requirement
Asparagus setaceus	Asparagus Fern	Vine	Partial shade
Calathea concinna	Concinna Prayer Plant	Herbaceous perennial	Bright indirect sunlight
Calathea roseopicta	Rose Painted Calathea	Herbaceous perennial	Bright indirect sunlight
Calathea rotundifolia	--	Herbaceous perennial	Bright indirect sunlight
Calathea ornata	Prayer Plant	Herbaceous perennial	Bright indirect sunlight
Chamaedorea seifrizii	Bamboo Palm	Palm	Bright indirect sunlight
Chlorophytum comosum	Spider Plant	Herbaceous perennial	Bright indirect sunlight
Chlorophytum elatum	--	Herbaceous perennial	Bright indirect sunlight
Chrysanthemum morifolium	Pot Mum	Herbaceous perennial	Full sunlight
Dendrobium	Orchid	Orchid	Bright indirect sunlight
Dracaena deremensis	Janet Craig Dracaena	Shrub	Bright indirect sunlight
Dracaena marginata	Madagascar Dragon Tree	Shrub	Bright indirect sunlight
Dracaena fragrans	Corn Plant	Shrub	Bright indirect sunlight
Diffenbachia maculata	Dumbcane	Herbaceous perennial	Bright indirect sunlight
Epipremnum aureum	Golden Pothos	Vine	Bright indirect sunlight
Euphorbia pulcherima	Poinsettia	Deciduous shrub	Bright indirect sunlight
Ficus benjamina	Weeping Fig	Broad leaved evergreen	Bright indirect sunlight
Fittonia argyroneura	Silver Fittonia	Herbaceous perennial	Bright indirect sunlight
Gasteria gracilis	--	Cacti-Succulent	Full sunlight
Gerbera jamesonii	Transvaal Daisy	Herbaceous perennial	Bright indirect sunlight
Guzmania "Cherry"	--	Epiphyte	Bright indirect sunlight
Homalomena sp.	--	Broad leaved evergreen	Bright indirect sunlight
Hedera hedix	English Ivy	Vine	Bright indirect sunlight
Hemigraphis alternata	Red Flame Ivy	Herbaceous perennial	Bright indirect sunlight
Hoya carnosa	Wax Plant	Herbaceous perennial	Full sunlight
Liriope muscari	Lily Turf	Herbaceous perennial	Bright indirect sunlight
Musa oriana	Indoor Banana	Herbaceous	Full sunlight
Neoregelia carolinae	Blushing Bromeliad	Epiphyte	Bright indirect sunlight
Neottopteris nidus	Birds Nest Fern	Epiphyte	Bright indirect sunlight
Nephrolepis obliterata	Kimberley Queen Fern	Fern	Bright indirect sunlight
Nephrolepis exaltata	Boston Fern	Fern	Bright indirect sunlight
Pachira aquatic	Water Chestnut	Broad leaved evergreen	Bright indirect sunlight
Peperomia obtusifolia	Baby Rubber Plant	Herbaceous perennial	Bright indirect sunlight
Phalaenopsis	Moth Orchid	Orchid	Bright indirect sunlight
Philodendron sodiroi	--	Vine	Bright indirect sunlight
Philodendrom domesticum	Spade Leaf Philodendron	Vine	Bright indirect sunlight
Philodendrom selloum	Selloum	Vine	Bright indirect sunlight
Philodendron scandens	Heart Leaf Philodendron	Vine	Bright indirect sunlight
Phoenix roebelenii	Pygmy Date Palm	Palm	Full sunlight
Polyscias fruticosa	Ming Aralia	Broad leaved evergreen	Bright indirect sunlight
Pteris cretica	Cretan Brake Fern	Fern	Bright indirect sunlight
Platycerium bifurcatum	Staghorn Fern	Epiphytic Fern	Bright indirect sunlight
Rhododendron indicum	Azalea	Broad leaved evergreen	Bright indirect sunlight
Sansevieria trifasciata	Snake Plant	Herbaceous perennial	Bright indirect sunlight
Schefflera arboricola	Umbrella Plant	Broad leaved evergreen	Bright indirect sunlight
Scindaspus pictus	Silver Vine	Vine	Bright indirect sunlight
Spathiphyllum	Peace Lily	Herbaceous perennial	Bright indirect sunlight
Spathiphyllum wallisii	Dwarf Peace Lily	Herbaceous perennial	Bright indirect sunlight
Syngonium podophyllum	Arrow Head Plant	Vine	Bright indirect sunlight
Tradescantia pallid	Spider Lily	Herbaceous perennial	Full sunlight

Botanical Name	Common Name	Plant Type	Light requirement
Tradescantia sillamontana	White Velvet/Oyster Plant	Herbaceous perennial	Full sunlight

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Greening the Urban Area for Adoption to Climate Change: Urban and Peri Urban Horticulture – An Option

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Urbanization is associated with increasing green house gases besides increasing the environmental temperature which is one of the causes, for climate change. The challenges posed by climate change are many, where in temp will increase, CO_2 concentration in atmosphere will increase leading to vulnerability of mankind to various problems including the food security. This is the cause of concern across the globe attracting focussed attention for adaption and mitigation to climate change. Green space or green plants is the one of the approaches in strategic planning for mitigation and adoption for climate change. Since the green cover sequesters Co_2 from the environment keeping the gaseous balances well as reducing the environmental temperature. Therefore greening of the cities is essential for addressing the challenges posed by climate change. Rapid growing cities have the manifestation of many problems associated with the environment. This is happing due to land use pattern in urban area owing to population growth.The environmental crisis of the urban region has become acute and interlinked in complex ways to urban energy, land use and the political economy of urban development. The environmental crisis of the urban region has become acute and interlinked in complex ways to urban energy, land use and the political economy of urban development. Cities will continue to need resources such as food, fibre, clean water, nature, biodiversity, and recreational space, as well as the people and communities that produce and provide these urban necessities and desires. Action is needed now to steer urban development towards green cities that contribute to environmental security, and clean environment for urban dwellers. At this juncture, cities need to be designed with more green spaces in order to provide clean and green environment.

According to UN reports, India has the highest rate of change of the urban population and will remain above 2% annually for the next three decades. At this rate, an estimated 854 million people will live in Indian cities by 2050. Without careful production of knowledge, and large investments to link that knowledge to action, cities will be overwhelmed with environmental challenges. Plants do offer a great extent of environmental and ecological services along with aesthetic values. Trees and other ornamental plants are crucial to the sequestration of carbon form atmosphere and play an important role in reducing carbon foot print (Brethour *et.al* 2007). The green-space needs to be strategically planned. Cultivating urban green spaces is becoming inevitable for clean and green environment in urban areas. Clear guidance is needed for local authorities and other practitioners on how best to manage public urban green spaces in order to respond to climate change**.**

Research has shown that large trees can absorb significant amounts of carbon dioxide, particulate matter and other pollutants from the atmosphere each year and release oxygen through photosynthesis. As such, trees and other landscape plants serve as an important tool in improving air quality in cities and mitigating potential health effects on human inhabitants. In recent days urban green spaces have gained popularity in to different perspective by introducing ideas like green buildings, greenbelt, green roofs, and energy conserving landscape and using ideal plants for air, sound and water, soil pollution mitigation. Parks and urban green spaces impact people's health by providing them with an inexpensive setting for recreation.

Challenges

Urbanisation does not have only local environmental impacts but also large 'ecological footprints' beyond their immediate vicinity. Intensive and extensive exploitation of natural resources to support urban economy includes excessive extraction of energy resources (including fuel wood), quarrying and excavation of sand, gravel and building materials at large scales, and over extraction of water. These all contribute to degradation of the natural support systems and irreversible loss of critical ecosystem functions, such as the hydrological cycle, carbon cycle and biological diversity, in addition to conflicts with rural uses of such limited resources. Other effects can be felt further afield such as pollution of waterways, long-range air pollution that impact on human health as well as on vegetation and soils at a considerable distance.

The cities suffer from air pollution more than other rural areas. The common pollutants in the air are carbon dioxide (maximum) and other gases of nitrogen, sulphur, fluorine and volatile pesticides. Plants can reduce the level of carbon dioxide in the atmosphere as they take in carbon dioxide during photosynthesis and give out oxygen, thus purifying the air.

Carbon dioxide has a long shelf life so the climate change which will occur over the next 40 years is already determined and, although the opinion about the scale of the problem differs, many experts agree that it is unstoppable.

Urban areas, where the majority of the population live, warm more than rural ones because buildings absorb heat. There are significant temperature differences between city centres and their surrounding countryside and surface temperatures can be up to 6°C greater in high density suburbs compared to low density suburbs. The concentration of buildings and urban areas during urbanisation leads to the formation of a specific climate characterised by higher night time temperatures, restriction of wind which disperses pollutants and increased run-off, i.e. 'urban heat islands'.

Adaption and Mitigation through Urban Peri Urban Horticulture

Horticulture provides food to feed the world, beautify our neighbourhoods, decorate our gardens and give ambience and wellbeing by combining the energy of the sun with soil, seeds, water, and ingenuity. Their enterprises range in size from the subsistence micro gardens of villages to huge commercial enterprises with large holdings of greenhouse and field crops and extensive orchards. Horticulture is also parks, public gardens and reserves, sports fields and golf courses, trees, vegetables and flowers in urban and peri-urban communities, home gardens for food and beauty. Such facilities have aesthetic, sociological and psychological benefits for human kind.

In the cities, environmental benefits and synergies can be achieved when horticulture is planned as a part of the urban landscape including safe recycling of solid waste and wastewater. As such, trees and other landscape plants serve as an important tool in improving air quality in cities and mitigating potential health effects on human inhabitants.

Landscaping concepts have gained popularity into different perspective by introducing ideas like Urban green spaces, green buildings, greenbelt, green roofs and energy conserving landscape and using ideal plants for air, sound and water, soil pollution mitigation.

Urban Green Spaces to Play a Vital Role in Combating Climate Change

The consequences of climate change can be addressed through urban green spaces such are Cooling, Water management, and providing a habitat for biodiversity. Urban green spaces can act as 'park cool islands' by cooling air. Even small spaces can have a cooling effect – parks only 1-2 hectares have been found to be 2°C cooler than surrounding areas. The extent of the cooling effect is greatest when temperatures beyond the park are the highest. As climate change increases and temperatures rise the cooling effect of urban green spaces will become increasingly important. The spread of the benefits can decrease with distance from the park. Research based on Tel Aviv, Israel found that the cooling effect of green space can be felt up to 100metres from the site and the shape of green space can have an impact on cooling. Green spaces that lie higher than surrounding land achieve wider influence, as do those with greater tree cover. For example, green corridors can be used to channel air into a city from surrounding forested slopes. Trees, especially when located close to buildings, can act as natural air conditioners and provide shading through evapo-transpiration, therefore reducing energy consumption required to maintain comfortable temperatures. Evapo-transpiration is the exchange of water between plants, soil and the atmosphere.

Urban green spaces help to alleviate the consequences of climate change through, of absorption of pollutants, including greenhouse gases and thereby improving the air quality of urban habitats.

Fig 1: Urban park/green Space

Findings suggest that all urban green space has an impact and that the shape, quality, size and soil type all matter. In particular, patches of green space in towns and cities can be important for rainwater infiltration and reducing run-off.

It is air temperature rather than surface area which influences human comfort (ASCCUE)but air temperature is difficult to model and influence so ground temperature is often used as an indicator. Urban green spaces can act as 'park cool islands' by cooling air. A London study found temperatures to be, on average, 0.6ºC cooler in the park than on neighbouring streets over a 12 hour period. This compared to a shopping street with no shading which was 3°C warmer than the centre of the park (CURE 2004). Work on Greater Manchester found that the surface area of woodland was 12.8ºC cooler than the town centre.

Modelling work based on Manchester suggested that adding 10 per cent green cover kept maximum surface temperatures in high density residential areas and town centres on the hottest summer days at or below the 1961-1990 level (the baseline projections are based on). However, removing 10 per cent green cover from these areas increased maximum surface temperatures by up to 8.2ºC by the 2080s, assuming the highest emissions scenario (AUSCCUE WP).

According to Upmanis, H (2000), even small spaces can have a cooling effect – parks only 1 or 2 hectares have been found to be 2ºC cooler than surrounding areas . The extent of the cooling effect is greatest when temperatures beyond the park are highest. As climate change increases and temperatures rise the cooling effect of urban green spaces will become increasingly important. As the UK has a mobile oceanic climate, 'urban heat islands' are not so extreme as in the US and Europe where much of the research has been carried out. But in the South East, at least, the frequency of extreme summers and heat waves will increase as climate change sets in.

The spread of the benefits can decrease with distance from the park. Research based on Tel Aviv found that the cooling effect of green space can be felt up to 100m from the site and the shape of green space can have an impact on cooling (CURE 2004). Green spaces that lie higher than surrounding land achieve wider influence, as do those with greater tree cover. For example, green corridors can be used to channel air into a city from surrounding forested slopes Loesner, G. (1978).

Role of Urban Trees to Mitigate Climate Change

Trees, especially when located close to buildings, can act as natural air conditioners and provide shading through evapotranspiration, therefore reducing energy consumption required to maintain comfortable temperatures. Evapotranspiration is the exchange of water between plants, soil and the atmosphere. Research on Merseyside found that places where vegetation cover was 50 per cent were 7ºC cooler than areas where there was 15 per cent vegetation cover (Whitford, *et al* (2001) Research in Camden and Newark showed that planting trees in urban areas is a viable and economically efficient way of reducing urban heat islands (LCCP (2006)). A mix of conifers and deciduous trees would be preferable for year-round benefits. The shade provided by mature trees can keep surfaces cooler by as much as 15.6ºC (Gill *et al.,* 2007), Hard surfaces increase the rate and volume of runoff of rainwater resulting in flash flooding. Green space can help with water management as it provides a permeable surface, reducing surface run-off into drains and therefore lowers the risk of flooding during peak flows. In addition green spaces allow water to filter down and replenish groundwater. Vegetation also intercepts more rain thereby reducing the likelihood of flash flooding (NUFU, 2005). The numerous leaves of plants and trees provide a greater area for water to evaporate from than flat surfaces(Whitford, *et al.*, 2001).

Fig 2 : Tree Coverage in Urban areas

According to Gill *et al.* (2007) Modelling based on Greater Manchester suggested that increasing green cover by 10 per cent in residential areas reduces runoff from these areas by

4.9 per cent in the highest rainfall scenarios predicted in the 2080s. Increasing tree cover by a similar 10 per cent would reduce runoff by 5.7 per cent. However, green space alone will not be able to cope with the estimated increases in rainfall and subsequent runoff so storage provision for runoff also needs to be considered. Sustainable urban drainage systems (SUDS) are designed to slow the movement of rainwater between where it falls and where it is discharged into a watercourse. Techniques such as swales, permeable pavements, gravel or grass, infiltration, detention and retention in ponds could be employed. This water could then be used to irrigate green spaces in order to maintain their cooling effects.

Paved surfaces contribute to a number of ailments in urban areas such as the facilitation of waterway pollution via storm water runoff, increasing peak flow in waterways thus increasing soil erosion, potentially overwhelming of sewage systems and heat island effect. Different types of permeable paving using different materials have been developed. For example, there are permeable interlocking concrete pavers (sometimes called porous pavers, typically used in driveways and walkways), porous asphalt (used in parking lots), porous concrete (used in light traffic roads or pedestrian walkways), concrete grid pavers, plastic reinforced grid pavers, pervious concrete, etc.

Fig 3: Paves surfaces with grass

Functional Uses of Turf Grasses

The amount of carbon storage depends on many variables including plant growth, plant type, soil type, management, and environmental conditions. In grass systems, both fertilization and irrigation have been shown to increase C sequestration levels. This is due to an increase in plant biomass within the soil, which in turn increases the amount of soil converted to carbon through humification. Grasses also provide permanent ground cover leaving the soil underneath relatively undisturbed. This reduces soil erosion and keeps carbon stable within the soil. Turf grasses have the potential to sequester C, but research is lacking in this area.

The Estimated Carbon pool for U.S. urban soils is 77 ± 20 Mg C ha^{-1}. Converting previous agricultural land into perennial grasses sequesters 0.3 Mg C ha^{-1} y^{r-1}, and can increase to 1.1 MgC ha yr with fertilizer and irrigation management. Qian and Follett (2002) modelled SOC sequestration with historic soil testing data from golf courses and reported that golf course soils sequester SOC at a rate of 1.0 Mg ha-1 yr^{-1}. All of these C sequestration rate studies included sampling of less than or equal to 30 cm of the top soil. Current research by Qian and Follett (2010) compared fertilized fine fescue (festuca spp) (irrigated and non irrigated), kentucky bluegrass (Poa Pratensis L.) (irrigated), and creepnig bentgrass (Agrostis palustris Huds.) Irrigated for differences in soil organic carbon (SOC) rates. Irrigated fine fescue added the most SOC at the 0 – 20 cm depth (3.35 Mg C ha^{-1} yr^{-1}). The additions from non irrigated fine fescue, kentucky bluegrass, and creeping bent grass were 1.39, 2.05, and 1.73 Mg C ha-1 yr^{-1}. Irrigation increased the amount of C sequestration. All turf grass species were found to exhibit significant amount of C sequestration over the 4 year researching period.

On a per hectare basis, urban turf grasses have the potential to sequester greater amounts of C than cropland systems and greater than or equal amounts of C as forest systems. Although turf grasses may sequester more C than other land uses, the amount of land covered by urban turfgrasses is small when compared to the amount of land covered by cropland and forestland (in the U.S.).

Even though turfgrasses sequester C, fossil fuel use is directly and indirectly associated with lawn management practices such as mowing, fertilizing, pesticide application, and irrigation. Using conversions for C emissions by Dr. Lal from the Ohio State University, all energy use can be converted into carbon equivalents (CE). Mowing consumes gasoline (0.84 kg CE kg^{-1} gas), fertilizer and pesticides require production, transportation, storage and transfer (0.1 – 12.6 kg CE kg^{-1} fertilizer or pesticide), and irrigation requires pumping (CE depends on the type of irrigation system).

Master's research by Gina Zirkle and Dr. Lal modeled C sequestration for home lawns in the U.S. and compared that to the CE of management practices. CE for lawn management practices were only 10 – 20% of the total C sequestration rate. Therefore, home lawns still sequestered 80 – 90% of the SOC when management practices were subtracted from the total C sequestration potential. However, the amount of energy required to maintain turf may be different in other turfgrass ecosystems (examples include golf courses and sports fields).

Selhorst (2007) found that farm land converted to golf courses in Ohio sequesters C at an initial rate of 2.5 – 3.6 Mg C ha^{-1} yr^{-1}. This high rate is most likely due to the increase in fertilizer and irrigation management, as well as supplying a permanent ground cover for the soil. Management practices were also evaluated and it was found that golf courses sequestered carbon up to 30 years before management practices offset the sequestration potential.

Soil organic carbon (SOC) sequestration and the impact of carbon (C) cycling in urban soils are themes of increasing interest. A model was developed to investigate the potential of C sequestration in home lawns. The model contrasted gross C sequestered versus the hidden C costs (HCC) associated with typical lawn maintenance practices.

Fig 4 & 5 : Golf courses and sport fields

Interior Landscaping to Combat Indoor Air Pollution

Plants enhance indoor environment quality and Improve workplace efficiency. Plants also reduce dust levels and also play a role in noise reduction and energy conservation. Plants filter the air in the indoor environment and also increase humidity in the workplace. World Health Organization published a report which claimed that as many as 30% of new or refurbished buildings caused occupants to suffer symptoms that became known as "Sick Building Syndrome" - a term used to describe situations when people experience acute ailments and discomfort, which seem to be linked to time spent in a particular building. Plants have proven to be important life supporters in that they remove carbon dioxide from the air and release oxygen through the process of photosynthesis.

It is now common to find living plants inside homes, offices, banks, hotels, restaurants, clubs, hospitals and schools**.** They are used for aesthetic improvement to any indoor area or interior landscape, as well as functioning to remove air pollutants from the interior environment. Plants take on many indoor environmental health problems by reducing levels of carbon dioxide, increasing relative humidity, reducing airborne dust levels, and reducing levels of certain common interior pollutants such as formaldehyde, benzene, and nitrogen dioxide. Clean air, increased productivity, stress reduction, and reduced sick days are the documented reasons to include professional plant services in interior landscape.

NASA research showed that many house plants have the ability to remove pollutants such as benzene and formaldehyde from indoor air. Important air-purifying house plants are suitable for interior scaping are Golden pothos (*Epipremnum aureum*), *Dracaena deremensis ‘Striped*’, Peace lily (*Spathiphyllum* sp.), Spider plant (*Chlorophytum comosum* ‘Vittatum’), Chinese evergreen (*Aglaonema crispum* ‘Deborah’). Interior decoration of houses with plants and miniature landscaping is gaining popularity. Some special features of interior Scaping such as Terrarium (glass cases), bottle garden, or aquarium and a beautiful mini landscaping in a dish, or a bowl, play a very important role to develop attractive mini garden inside a house. Suitable plants for terrarium are *Acorus gramineous* ‘Varigatus’, *Begonia-rex*, *Chamaedorea,Cryplanthus acaulis*, *Dracaena snaderiana*, ferns, *Fittonia verschaffettii* var. argyroneura, *Maranta cenconcura*, *Pellionia pulchera*, *Selaginella krassiana*. Trailing plants such as *Hedera helix*, *Pilea mescosa*, *Syngonium podophyllum* or *Zebrina pendula* can be used for tray garden which will hang down to the side of the bowl or dish. A desert scene can be creating in such type of gardens by planting small cacti or succulents amidst small piece of stones and pebbles.

Green Walls with Functional Uses

A green, or living, wall is a vertical element of a building [structure] where vegetation is partially or fully applied to provide significant benefits. Green walls, much like living roofs, have origins in Europe. Living walls have been defined as wall systems “composed of pre-vegetated panels, vertical modules or planted blankets that are fixed vertically to a structured wall” while green facades are a “type of green wall system in which climbing plants or cascading groundcovers are trained to cover specially designed supporting structures” Another differentiation is according to the nature of the systems as either extensive or intensive. Utilising different types of green walls may alleviate issues with wall deterioration and in fact protect walls via a barrier against the elements much like with living roofs.

There are three types of green walls

1. With creepers and climbers directly on the wall (facade);
2. With creepers and climbers on a structure adjacent to the wall (living roof);
3. With plants loosely hanging in front of the building with no structural support (green curtain).

In urban areas space is a serious problem, and plants are essential to function as sink of Co_2, in this context, green walls provide an option, which is the growing of plants on the vertical surfaces, be it on the wall of a home or something that is larger like the facade of a building. A grid system that vertically stacks plants is a vertical garden which combines industrial elements with plant based displays in freestanding walls.

Green Roofs to Beautify and to Mitigate Temperature

Cities can be 2 degrees to 8 degrees warmer than surrounding environments due to the large areas of dark surfaces, consisting mainly of roads, parking lots and dark-colored roofs. The extra heat absorbed through dark surfaces during the day is convicted away by ambient breezes, raising air temperature averages; this phenomenon is referred to as the urban heat island effect. Vegetative cool roofs help mitigate the intensity of the urban heat island effect by reducing heat absorption and transfer to the surrounding air. In addition to reduced building energy consumption from diminished air conditioning requirements, cool roofs have numerous indirect benefits, including cutting greenhouse gas emissions, alleviating the urban heat island effect, reducing smog, as well as various public health benefits.

The process of building construction may involve destruction of green cover. Vegetative roofs, or rooftops with green cover, replace this destroyed vegetated footprint. Vegetative roof systems typically comprise of a lightweight growing medium, plants, and a root repellent layer in addition to the regular components of a roof.

The additional components and thickness of the growing medium provides thermal insulation, while the green cover lowers ambient temperatures through evapotranspiration.

Establishing plant material on rooftops provide numerous ecological and economic benefits including efficient storm water management, energy conservation, mitigation of the urban heat island effect, increased longevity of roof system in many cases, and as importantly – providing a more aesthetically pleasing environment to work and live.

Urban areas are witnessing a rapid increase in impervious surface areas as more and more green covers are destroyed to make way for buildings, pavings, and roadways. Re-introducing a pervious surface that can regulate the storm water runoff is one of the primary benefits of green roofs. Rapid run off from roof surfaces is contributing to instances of flooding, erosion. Green roof systems efficiently regulate this runoff and have been shown to initially retain 60-100% of the storm water they receive –eventually releasing it to the atmosphere.

In 20th century, experts in Germany, Japan and other countries proposed a standard of 40 m^2 urban green spaces in high quality or 140 m^2 suburb forest areas per capita for reaching a balance between carbon dioxide and oxygen, to meet the ecological balance of human well-being. Currently, developed countries have tended to adopt a general standard of green space of 20 m^2 park area per capita. International minimum standard suggested by World Health Organization (WHO) and adopted by the publications of United Nations Food and Agriculture Organization (FAO) is a minimum availability of 9 m^2 green open space per city dweller. There is yet another yardstick, which refers to London but has relevance to any city. Abercrombie prepared a plan in 1943-1944 suggesting that 1.62 ha (four acres) open space per 1000population was a reasonable figure to adopt for London. The plan also explains that all forms of open space need to be considered as a whole, and to be co-ordinated into a closely-linked park system, with parkways along existing and new roads forming the links between the larger parks. There are city-specific local guidelines that may provide us useful guidance.

Climate change is expected to place increasing stress on urban areas. Minimizing its impacts through adaptive measures is therefore unavoidable. Worldwide studies concerning people needs in urban landscapes have underlined the fundamental role carried out by greening in the cities not only for social and aesthetical reasons, but also for environmental aims. Problems like soil erosion, river flooding, and lack of biodiversity are frequent in urban contexts. Both policy and science now emphasize the critical necessity of green areas within urban social-ecological systems.

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Bamboos for Landscape, Resource Conservation and Livelihood Security

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Introduction

Bamboo, a versatile group of woody grasses belonging to the subfamily *Bambusoideae* of the family *Poaceae* containing around 1500 species coming under 87 genera are seen unevenly distributed in the various parts of the humid tropical, subtropical and temperate regions of the world (Ohrnberger, 1999).India, Indonesia, Myanmar, Malaya, China, Japan, Philippines and New Guinea are some of the important natural bamboo areas of the world. India is the second largest reservoir of bamboos, next only to China with about 23 genera and 125 indigenous and 11 exotic species, (Nath *et al.,* 2009). In India, bamboo occurs in all state except in arid part of Rajsthan and Kashmir due to unsuitability of climatic conditions.

Bamboo forests occupies about 14 m ha area in the country which is about 12.8% of the total forest area of the country (FSI 2011). The highest growing stock of bamboo in India is exists in North east (66%) followed by Madhya Pradesh (12%) and Orissa (7%). Average productivity of bamboo in India is 2-3 tonnes hectare^{-1}.Bamboo is used for variety of purpose ranging from fodder, pulp, timber, construction works, charcoal, edible shoots, cottage industries etc. Bamboos have socio-economic and ecological value and their management can provide benefits on a local, national and global level through livelihood, economic and environmental security for many millions of rural people. The role of bamboos in biomass production, resource conservation and livelihood security is described as under:

Bamboos for Landscape

Bamboo is a fast growing species in the world therefore frequently used in green background and broad filler. The growth rate ranges from 30 to 100 cm per day in growing season. The culm can attain a height of 36 m with a diameter of 1-30 cm in 4 to 6 months with a daily increment of 15 to 18 cm. Culms take 2 to 6 years for its maturity. Due to its fast growing nature it can produce huge biomass in short span of time and can maximize the productivity of per unit piece of land and time. Bamboo can yield 20- times more timber than trees on the same area (http://life.gaiam.com/article/how-eco-friendly-bamboo). Production of bamboo is reported to improve with the age of plantation, though the percentage of new to old culms decline with age. The biomass production by different bamboo species is compiled in Table 1 which clearly indicates the huge potential of bamboos in biomass production which can cover the open spaces at shortest possible timings. *Bambusa vugaris* – striata and wamin and *Bambusa ventricosa* are very commonly used in beautifying the areas through open plantations and pot cultures. *Sasa veitchii* is a common species used for pot in shade.

Bamboos for Resource Conservation

Bamboos for Controlling Erosion : On account of extensive shallow root system and accumulation of leaf mulch, bamboos are effective for the control of soil erosion, stream bank protection, reinforcement of embankments and drainage channels, etc. Bamboo grows well on steep hillsides, road embankments, gullies, or on the banks of ponds and streams. Sharp curves in rivers can be protected with a revetment of bamboo culm cuttings and further reinforced with clumps of bamboo planted behind the revetment (White and Childers, 1945) Biological live check dams can stabilize the eroded lands.On slopes bamboo rhizome tends to develop uphill side enhancing further bamboo development on the gully sides and thus stabilizing them.

Bamboos can reduce erosivity of rainfall/runoff and erodibility of soil through dissipation of rainfall energy by canopy, surface litter, obstructing overland flow and root binding. Bamboos protect riverbanks by arresting strong currents during flood periods by their extensive fibrous root system. Bamboos have an interlocking rhizome system and extensive fine fibrous root system which ramifies horizontally and vertically binding the soil particles together (Sujatha *et al*., 2008). A study estimated that a single bamboo plant can bind up to 6 m^3 of soil (Anonymous 1997). The root of *Bambusa tulda*, were found to extend horizontally to a distance of 5.2 m (White and Childers, 1945). For monopodial species, the total length of living rhizome per one hectare of *Phyllostachys heterocycla*, *Phyllostachys viridis* and *Phyllostachys nigra* ranged from 50 to 170 km, 90 to 250 km and 200 to 320 km, respectively (Xiao, 2002; Zhou, 2005). In India, bamboos have been tested for protecting severely eroded gullies of ravine class VI and VII lands1 with promising production potential (Dhruva Narayana, 1993).

Bamboos for Rainwater Retention and Soil Moisture Conservation : Bamboos due to evergreen nature, dense foliage and large culms can intercept more rainfall as compared to any tree species thereby checking the velocity of the rain drops and soil erosion. The high stem flow amount and funnelling ratio of bamboo plants in comparison to deciduous and coniferous plants makes better rainfall absorption and hydrologically best suited plantation. Rao *et al.* (2012) reported that in D. strictus, throughfall varied from 43 to 72%, stemflow varied from 7 to 22% and interception losses varied from 12 to 50% of the rainfall.

Bamboos take care of both excess water due to high intensity rainfall and lack of water due to extended drought periods through addition of soil organic matter through litterfall which helps in absorbing higher amount of water without causing surface run off, and improving water absorption capacity during extended drought.The litterfall amount varies with the composition of the mixed forest, the stand density and human activity Litter in bamboos in India varies from 4.2-11.2 t ha^{-1} $year^{-1}$ (Tripathi and Singh, 1994; Shamnughavel and Francis, 1996). The litter of bamboo stand has the capacity to absorb the moisture 2.7-2.9 times of its dry weight (Xie, 1999). Shading by bamboo canopy reduces evapo-transpiration and helps in conserving soil moisture. Bamboo stands also filter gravel and coarse sediment (Gupta, 1975) and enhance water infiltration by the penetrating dense rooting system (Sujatha *et al*., 2008). Further, larger quantity of culm stumps, dead rhizomes and roots remain in bamboo forest after felling, leaving lots of non-capillary pore which can retain large amount of moisture.

Table1: Biomass production by different bamboo species

Species	Country	Total biomass (t/ha)	Culm weight (t/ha)	Leaf weight (t/ha)	Branch weight (t/ha)	Coarse root weight (t/ha)	Fine root weight (t/ha)	Annual productivity (t/ha/yr)	Reference
Dendrocalamus strictus	India	4 - 22	7.8 - 30				7.0 - 8.7	1.8 - 7.7 #	Tripathi and Singh (1994)
Gigantochloa ater; G. verticilata	Indonesia	45	34.4	4.7	6.0	10.5 + 2.1	18.9		Christanty *et al.* (1996)
Bambusa bambos	India	122 (at 4) 225 (at 6) 287 (at 8)	93 (at age 4) 187 (at age 6) 243 (at age 8)	1.9 (at age 4) 3.5 (at age 6) 4.0 (at age 8)					Shamnughavel and Francis (1996)
Dendrocalamus strictus	India	30 (at 3) 36 (at 4) 49 (at 5)	24 (at age 3) 38 (at age 5)	6.1 (at age 3) 7.9 (at age 4 10.7 (at age 5)		11.9 (at age 3) 14.0 (at age 4) 18.8 (at age 5)	3.6 (at age 3) 5.3 (at age 5)		Singh and Singh (1999)
Phyllostachys pubescens	Japan	138	116.5	5.9	15.5	16.7	27.9	18.1	Isagi *et al.* (1997)
Dendroca lamus latiflorus Munro.	China	28.49	16.67	3.37	8.45	3.31	1.10		Lin Yiming (2000)
Dendrocalamopsis oldhami	China	134.49	95.51	14.81	28.17	12.00	9.60		Lin Yiming (1998)

Bamboos for Maintenance of Soil Health : Due to high biomass accumulation and abundant litterfall, bamboos helps in maintaining andimproving the soil physical, chemical and biological properties. Bamboos have high silica, rich litter production of leaves and twigs which slowly decomposes returning substantially amounts of N, K, Mg, Ca and P. (Shanmughavel *et al*., 2000). The high fine root content helps in recovering most of the nutrients leached deeper in the soil profile (Christanty *et al*., 1996). Improvements are also reflected through lower bulk density, lower surface resistance to penetration, increased porosity, higher rain water infiltration and greater aggregate stability. Canopy shade also alters soil conditions to promote microbial activity and the rate of soil mineralization (Arunachalam and Arunachalam, 2002).The changes/improvements in soils are however, species-specific and dependent on size and age of the clump and site conditions.

The ability of bamboos to grow in a wide variety of soils, from marginal to semi-arid, makes bamboo perfect for rehabilitation. Singh *et al.* (1999) reported that *Dendrocalamus strictus* plantation has an efficient restoration potential and positive rehabilitation effect on mine spoil land in a dry tropical region in India. In Japan sasa bamboo have been found to play a significant role in preventing soil from acidification in mountainous area. It acts as a biological pump to return basic cations from the lower layer of soil (20–30 cm) to the surface, and retaining them within the ecosystem (Takamatsu *et al.,* 1997).

Bamboos for Microclimatic Amelioration : Bamboos bring microclimate changes under their canopies by providing shade which prevents the soil to become too dry and help in maintaining microclimate. Shade helps in reducing soil and air temperature, irradiance and wind speed which directly influence the soil water evaporation and humidity. Study conducted by Arunachalam and Arunachalam (2002) revealed that air and soil temperature were significantly reduced and relative humidity was significantly higher under bamboos (Table 2) as compared to grasslands.

Table 2: Microclimatic variability under different species

Species	Air temperature (°C)	Relative humidity (%)	Light intensity (lx)	Soil temperature (°C)
B. nutans	25	57	1680	22
B. arundinacea	26	54	690	19
D. hamiltonii	25	55	2620	20
Grassland	28	47	2800	24
LSD at 0.05 level	1.2	3.7	841.4	1.9

Source: Arunachalam and Arunachalam (2002)

Bamboos for Carbon Sequestration: Sequestering carbon through tree based system is now being considered as an attractive economic opportunity for carbon trading. Due to its rapid biomass accumulation and effective fixation of solar energy and carbon dioxide, the carbon sequestration ability of bamboo is very high. According to an estimate, one quarter of the biomass in tropical regions and one-fifth in subtropical regions comes from bamboo (Anonymous, 1997). Each acre of bamboo can isolate up to 40 tons of CO_2. In homegardens of north east India, C estimate in aboveground vegetation in bamboo farming system ranged from 6.51 (2004) to 8.95 (2007) Mg ha^{-1} with 87%, 9% and 4% of the total C stored in culm, branch and leaf respectively. The rate of C sequestration was 1.20–1.46 Mg ha^{-1} yr^{-1}, with a mean of

1.32 Mg ha^{-1} yr^{-1} (Nath and Das 2010). Using bamboo for construction purpose can also lead to long term storage of carbon. It is estimated that a 1,000 sq. ft. green home built by bamboo living has over 15 tons of CO_2 locked up (sequestered) within its fibers (http://www.linkedin.com/groups/2012-International-Training-Course-on 1485.S.146339971). Therefore, by promoting bamboo based land-use systems, higher C storage can be achieved.

Bamboos for Employment Generation and Livelihood Security

Bamboo is an important resource in socio-economic context (Pande *et al.,* 2012). Bamboos have rural, domestic and industrial uses enabling it to play a vital role in economy and manpower generation. Various aspects of manpower generation in raising bamboos, their maintenance, harvest, transport, storage and end uses have been studied and quantified. Every hectare of bamboo plantation generates about 160 workdays. An average of 8-10 workdays is needed to harvest one tonne of bamboo. Five workdays per tonne are generated by transportation and handling of bamboos. For weaving into usable products, 80 workdays are required for processing one tonne of bamboo. In cottage industries, about 600 workdays are required per tonne of bamboo in the primary processing. Considering the above figures, the summary of employment potential of bamboo is given in Table 3. In terms of income generation, at an average wage of US $ 2 per day, the annual wage bill will come to US$ 1,032 million per annum (Swamy, 2011).

Table 3: Summary of employment potential of bamboos

Use	Quantity	Mandays (Per annum) (million)
Silviculture	25000 ha	75.00
Bamboo plantations	6 million tonnes	40.00
Harvesting	6 million tonnes	100.00
Transport/storage/handling	6 million tonnes	30.00
Weaving into products	3 million tonnes	240.00
Industrial labour	3.3 million tones	7.33
Cottage industries	40 000 tonnes	24.0
Total		516.33 i.e. 516 million man-days

Source: Swamy 2011

Summary

Bamboos due to its fast growth can contribute significantly in enhancing productivity. During the past, major work on bamboos has been focused on developing propagation protocols, cultivation, management and utilization. Bamboos have huge potential in conserving the natural resources. They have huge potential for checking soil erosion, water conservation, improving soil health and providing environmental, and economic security. Therefore future research efforts are required to quantify both tangible and intangible benefits of bamboos.

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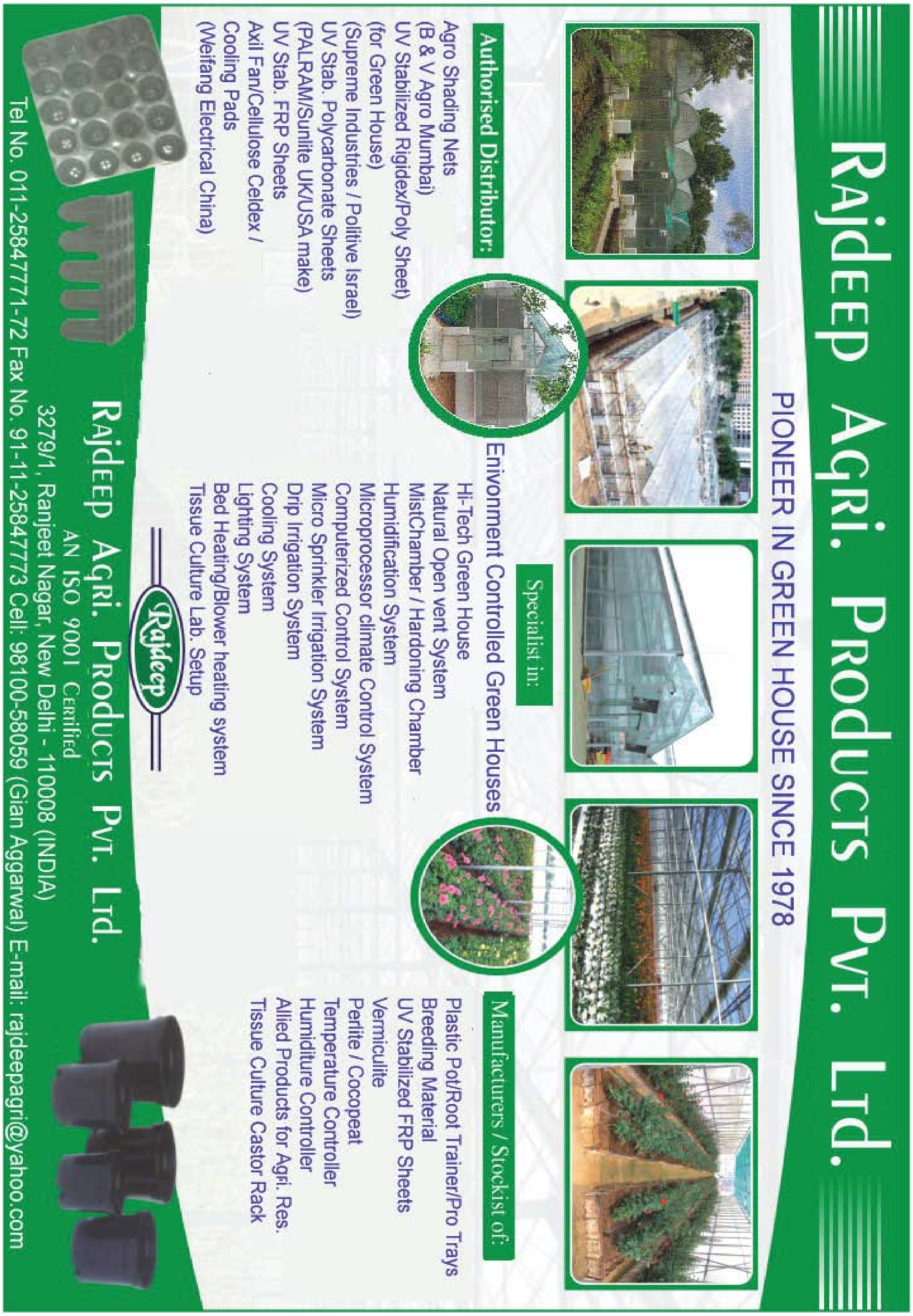
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