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Food Security and Livelihood Improvement through Hi-tech Horticulture

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ABSTRACT

In the changing global scenario, food, nutrition, health care and livelihood security are the matter of great concern to human, social and economic development. There has been appreciable progress in food production including horticulture. However, access to nutritious food continue to be a cause of concern since, more than 350 million people continue to suffer from malnutrition which is a cause for various types of diseases and premature death of children and women. Therefore, a country could only be food secured if the citizens have access to nutritious food having balance diet to meet their need for productive and effective life. In this context, horticultural crops (fruits, vegetables, potato, tuber crops, mushroom, plantation crops, spices etc.) have emerged as a best option not only to provide required nutrients but also to enhance access to food through enhanced farm profitability. The current trend shows that dietary habit is changing with increasing income, from cereal based diet to nutritious diet. Resultantly there is a growing demand for horticultural produce. It has been proved beyond doubt that the sector is best option of diversification for complimenting food, nutrition, health care and livelihood security.

Keyword: Horticulture, health care, human nutrition, nutritional security, climate change, cropping systems and Hi-tech horticulture

I. Horticulture: Why it is best option?

Horticulture has wider adaptability and provides wider choice to farmers, for growing wide range of crops in different environments, soil and climate conditions. Horticultural crops can be grown even in marginal and degraded soils and has enriched the farmers having degraded land by having choice of crops and practices. There are many horticultural crops which are complementary as food, i.e. potato, tuber crops and banana and vegetables. Fruits and vegetable therapy is now a practice to have good health without medication and many crops are used as herbal medicine. New paradigm, therefore, has to be horticulture based farming system for greening, environmental service and to provide nutritious food and enhanced farm profitability.

1.1 Horticulture for health care

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, phalsa), vegetables (carrot, cauliflower, onion, garlic, beans, cucurbits, leafy vegetables), spices (ginger, turmeric, black pepper, fenugreek, ajawan) 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, fruits and vegetable provide wider option (Table-1) for meeting the energy requirement for the human system.

Table 1: Number of calories available in per 100 gram of fruits or vegetables

Fruits	**Calories in per 100g**	**Vegetables**	**Calories in per 100g**
Apple/Plums	56	Broccoli	25
Avocado Pear	190	Brinjal	24
Banana	95	Cabbage	45
Chikoo	94	Carrot	48
Cherries	70	Cauliflower	30
Dates	281	Fenugreek (Methi)	49
Grapes Black	45	French beans	26
Guava	66	Lettuce	21
Pomegranate	77	Mushroom	18
Guava	49	Onion	50
Litchi	61	Peas	93
Mangoes	70	Potato	97
Orange	53	Spinach	26
Strawberries	77	Tomato	21
Papaya	32	Tomato juice 100ml	22
Peach/pears	50	Watermelon	26

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.

1.2 Scenario of Horticulture and Human Nutrition

Horticulture has emerged as a core sector in agriculture passing through the various phases with coverage of nearly 21.2 million ha, having an annual production of 234.5 million tonnes, which includes a wide variety of crops, vegetables, root and tuber crops, mushroom, floriculture, medicinal and aromatic plants, nuts, plantation crops including coconut and oil palm which are grown in different agro-climatic conditions. Though these crops occupy hardly 9% of the cropped area they contribute over 30.4% to the gross agricultural output in the country. Fruits and vegetables are also rich source of vitamins, minerals, proteins, and carbohydrates etc. which are essential in human nutrition. Hence, these are referred to as protective foods and assume great importance as nutritional security of the people. Thus, cultivation of horticultural crops plays a vital role in the prosperity of a nation and is directly linked with the health and happiness of the people. The emphasis on horticulture is recognition of the need for attaining nutrition 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.

India is the second largest producer of fruits after China, with a production of 75.22 million tons of fruits from an area of 6.45 million hectares. A large variety of fruits are grown in India, of which mango, banana, citrus, guava, grape, pineapple and apple are the major ones. Apart from these, fruits like papaya, sapota, annona, phalsa, jackfruit, ber, pomegranate in tropical and sub-tropical groups and peach, pear, almond, walnut, apricot and strawberry in the temperate group are grown in a sizeable area. In human nutrition, fruits and vegetables play an important role towards the making of a balanced diet. To some extent, they provide energy rich food. Banana, jackfruit, annona, sapota and fig contain carbohydrates in the range 19 to 24 percent and are good sources of energy comparable to potato, colocasia, tender maize, yam and green peas (15.9 to 24.6 per cent carbohydrates and 79 to 125k cal energy). Closely following this group of fruits as good sources of energy are mango, litchi, grapes, ber pomegranate, phalsa and jamun. Fresh avocado is the only highest energy yielding fresh fruit yielding 161 to 215 kcal per 100g of edible portion due to its high fat content (15-26%). But, fruit and vegetables are indispensable as sources of vitamins and minerals, which help in building resistance against diseases. Fruits and vegetables furnish 90% of the vitamin C and 60% vitamin A in the world. Mango and papaya are rich in pro-vitamin A and guava in vitamin C, Banana, among fruits is a good source of carbohydrate.

Fruits yield larger quantities of food per hectare compared to cereals. For example paddy yield (max.) is 3 tonnes/ ha whereas it is 22 tonnes/ha in case of banana; 45 tonnes/ha in case of pineapple and 40 tonnes /ha in case of grapes. Much less area is required to obtain the calorific requirement per adult per year (11,00,000 kcal) from growing banana (0.03 hectare) or mango (0.16 hectare) than from growing wheat (0.44 hectare). Horticultural crops in general are poor sources of protein as they contain less than 2% protein. Fruits are a rich source of organic acids like citric acid in citrus fruits and tartaric acid in grapes, which stimulate appetite and helping digestion. Papaya contains protein digesting enzymes. Many fruits and vegetables possess laxative property due to the presence of dietary fibre and pectin, which stimulate intestinal activity. Due to poverty, micronutrient malnutrition, is posing a threat to vulnerable sections in Asia and the Pacific regions. This is manifested in the form of vitamin A deficiency, iron deficiency anaemia and iodine deficiency disorders. The first two could be minimized, as discussed earlier, through horticulture intervention and awareness drive.

1.3 Production needed to achieve nutritional security

Vegetables and fruits appear to be playing a prominent role in prevention of several chronic diseases such as heart disease, cancer, cataract, osteoporosis, diabetes, etc. The active constituents responsible for this property have been shown to be a number of nutrients,

phyto-chemicals and fibre. Apart from micronutrient related function, the bioactive phyto-chemicals prevent degenerative processes by antioxidant activity. In order to have protective effect, it is necessary to consume 400-600g of fruits and vegetables every day. But, the consumption level of fruits is low and widely variable from region to region in India. Fruit consumption level is as low as 1g/day/person in the states of Manipur and Nagaland to 70g/day/person in the Union territory of Chandigarh. An increase in the intake of fruits along with vegetables will meet the required daily allowance (RDA) of many nutrients. India with more than 75.22 million tonnes of fruits and 141 million tonnes of vegetables is the second largest producer of fruits and vegetables in the world next only to Brazil and China. However, per capita consumption of fruits and vegetables in India is only around 46kg and 130g against a minimum of about 92g and 300g respectively recommended by Indian Council of Medical Research and National Institute of Nutrition, Hyderabad.

II. Challenges ahead in food production

The growing population is the major concern and is the big challenge for meeting the food needs worldwide. According to one of the predictions from FAO, the agricultural productivity in the world will sustain the growing population in 2030, but millions of people in developing countries will starve for food nutrition and remain hungry due to shortage. By 2025, 83% of the expected global population of 8.5 billion will be in the developing world. The question before us is-can we meet food needs and provide nutrition, health care, fuel and fiber 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 1011 million people and have surplus too beside appreciate growth in horticultural and livestock. 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 before us now are much greater than before. In the prevailing circumstances of shrinking farming 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 be the best mean of diversification for higher land productivity has been achieved with context to gross return per hectare. But there is need to make the sustainable development in production of fruits, vegetables, tubers, plantations and tuber crops for meeting the growing demand of rising population with nutritionally rich horticulture produce.

2.1 Impact of climate change

Climate change has been perceived as threat and will have impact on horticultural crops, due to erratic rainfall, more demands for water and enhanced biotic and abiotic stresses. However, the changes will not only be harmful, as enhanced CO_2 concentration may enhance photosynthesis and increased temperature may hasten the process of maturity. 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. These challenges could be addressed through identification of the gene tolerant to high temperature, flooding and drought, development of nutrient efficient cultivars and production system for efficient use of nutrients and water. Strategies have to address the enhanced water efficiency, cultural practices that conserve water and promote

crop. Development of climate resilient horticultural crops which are tolerant to high temperature, moisture stress, salinity and climate proofing through genomics and biotechnology would be essentially required. This would need highly prioritized research to address the impact of climate change. We must have also to enhance the knowledge to address all the strategies which can convert the challenges into opportunity. Concerted and integrated efforts with effectiveness and efficiency will be essential to meet the ever increasing demand.

2.2 Research system of Horticulture in India

The research system for horticultural crops in India is well organized and committed. The research for horticultural crops is being carried out at 10 ICAR institutes (with 24 regional stations) 6 Directorates and 7 National Research Centers (on major crops). Multi-disciplinary and area specific research is also conducted under All India Co-ordinated Research Projects each on Tropical, Sub-Tropical, Arid Fruits, Vegetables, Potato, Tuber Crops, Mushroom; Floriculture, Medicinal and Aromatic crops, Betel vine, Palms, Cashew, and Spices at 254 centers located at various research institutes and State Agricultural Universities. In addition, 5 network projects have been approved in XI plan to address specific issues. Research on horticulture is also undertaken in multi-disciplinary institutes, departments of horticulture in 34 Agricultural Universities, two Deemed Universities and 3 Universities of Horticulture and Forestry. Besides the above, traditional Universities, and other Central organizations like the Council of Scientific and Industrial Research, Department of Biotechnology, Atomic Energy Research Centre, Defense Research Development Organization and others also undertake research projects in basic/strategic area. The Horticulture Division of ICAR is responsible for national level planning and promotion of major research program in relation to horticultural crops. The main focus of program is to safeguard the genetic resources, develop suitable cultivar of different crops and augment the production and protection technologies and also technologies for enhanced shelf-life. Outreach research programs to combat the serious diseases caused by *Phytophthora*, *Fusarium*, *Alternaria* and viruses have been initiated cutting across the discipline. Five National Research Centers on Cashew, Onion and Garlic, Mushroom, Medicinal and Aromatic Plants and Oil palm were upgraded to function in directorate mode. AICRP on floriculture has been strengthened and upgraded to Directorate of Floriculture. Two genomic network projects are being operated in at various ICAR institutes on horticultural crops namely, International Solanaceae Genome Network program and International Network on Improvement of Banana and Plantain. Several international programs have been taken up which address the issues.

2.3 Technological advancement in Horticulture

In the present time, diversification, market orientation and commercialization, involving the introduction of new crops and varieties, increased share of horticulture in the cropping pattern, diversion into processing and export oriented production of a large number of crops are the most important changes noticed in the recent past. Several technological innovations have been advanced in the complete value chain involving technology for orchard establishment, availability of true to type planting material, plant architecture engineering and management, mulching, fruit thinning, integrated nutrient management, water management, integrated pest and disease management, post-harvest technology, processing and marketing. The positive changes in horticulture sector have occurred because it has received the off importance from all the stakeholders, public sector, private sector and farmers during the last decade. This is primarily the result of realization that diversification to horticultural crops is

now the major option to improve livelihood security and health care. Keeping in view the dynamic needs of diverse stakeholders under the National Agriculture Research System, the R&D on horticulture has been undertaken in several multi-crop and multi-disciplinary institutes and the several technologies has emerged.

2.4 Genetic diversity management in Horticulture

In the endeavor to attain the food and nutritional security for the increasing population, improvement in the productivity through germplasm enhancement and its utilization is important. In order to provide strong backing to the breeding programmes, germplasm collection efforts were strongly supported by the national research programme. Concerted efforts made for documentation, characterization, conservation and utilization of plant genetic resources in horticultural crops enabled to conserve 72,600 accessions of cultivated, wild and related taxa. To fulfill the dynamic needs, nutritional and health care of the people, it has become necessary to identify accessions possessing high nutritional value and bioactive compounds which play a great role in health care which shall be helpful in breeding varieties with special attributes.

2.5 Crop improvement in Horticultural crops

Efforts have been made to develop high yielding varieties and hybrids of different horticultural crops for different regions and have been widely adopted for cultivation by farmers in the various parts of the country. More than 1796 improved high yielding, high quality coupled with disease and pest resistant varieties and hybrids have been released by various institutes/ universities for cultivation in diverse agro-climatic conditions of the country. Regular bearing mango hybrid, export quality grapes, multiple disease resistant vegetable hybrids, high value spices and tuber crops of industrial use have been developed. Improved varieties have revolutionized the horticultural sectors. High-yielding Gauri Sankar and Sree Bhadra sweet potatoes have focus in minimizing malnutrition and improving nutritional security. Similarly, breeding to develop grape cultivars suitable for vine making, black pepper cultivars rich in aroma compound 'Caryophyllene', development of processing tomatoes etc. are some of the research programmes being carried out in various horticultural institutes. Varieties are being bred for processing qualities such as Kufri Chipsona in potato for chips making, high TSS white onion in NRCOG W448, grape varieties suitable for vine making, papaya varieties for table and papain production are some of the successful research attempts being carried out at various ICAR institutes.

2.6 Hybrid technology for high productivity and quality

The hybrid technology has revolutionized the production of vegetable crops and demand for hybrid seeds is continuously increasing. Hybrid of tomato, chilli, cucumber and muskmelon are being produced at several locations in the different states in the country. Besides this, imported seeds of mostly for cole crops are available to the Indian farmers. All India Co-ordinated Vegetable Improvement Project (AICVIP) has so far recommended for cultivation of more than 45 hybrids. Besides, many hybrids of vegetable crops, developed and marketed by private sector are also available to the farmers. At present, area under vegetable hybrids accounts for 10% of total area. Area under high yielding F1 hybrids in important vegetable crops ranges 17.8-31.5% in tomato (31.5%), cabbage (31.39%) and brinjal (17.8%) and areas under capsicum and chilli are also under expansion. High production, earliness, superior quality, uniform produce and resistance to biotic and abiotic stresses are the main advantages of F1 hybrids. Keeping in view the dynamic needs, the research efforts in various institutes

has focus on development of hybrids with multiple disease resistance, early maturity and utilizing male sterility system. CMS lines have successfully been utilized to produce potential experimental crosses of onion and commercial hybrids of chilli. Nuclear male sterile lines (GMS) of tomato, brinjal and chilli were introduced/established and are being successfully utilized for developing a number of cost effective experimental crosses at various centers. Hybrid seeds of chilli (CH-1, CH-3, CCH-3), brinjal (Kashi Sandesh), tomato (TH-1) are being now produced by the farmers by up scaling their skill. The parental lines of a number of hybrids developed have been sold on non-exclusive basis to the seed companies with aim to promote these hybrids among the farmers.

2.7 Biotechnological interventions for crop improvement

Biotechnological tools have supplemented various conventional approaches in conservation, characterization and utilization in horticultural crops for increasing the production and productivity. These tools have provided ample scope for the breeder to improve diverse traits, including yield, disease resistance, abiotic stress tolerance and quality more precisely and in reduced time. Use of meristem culture and micro grafting, is successful in citrus for elimination of viruses. Anthers of capsicum variety Arka Gaurav and tomato hybrid Avinash-2 responded to culture with an embryogenic like response without an intervening callus phase. Androgenesis has been successfully used for brinjal, pepper, cabbage, cauliflower, potato, asparagus and carrot, whereas gynogenesis has been successful in onion. Embryo rescue has been successfully employed in production of hybrids of *Musa accuminata* × *Musa balbisiana*, *Carica papaya* × *Carica cauliflora*, interspecific crosses in pineapple and seedless × seedless grape varieties. Use of molecular markers for crop profiling, finger printing, molecular taxonomy, identification of duplicates, hybrids, estimation of genetic fidelity and tagging of genes for marker aided selections is gaining importance. Efforts are under way to fingerprint mango, banana, cashew nut, kiwifruit, walnut, grape, citrus, etc. by different research centers. DNA sequence has been isolated for root-knot nematode resistance (Mi) gene in tomato and is being used to facilitate breeding this valued trait into new varieties and even other species. QTL mapping are in progress in many crops such as brinjal, tomato, capsicum while association mapping (linkage disequilibrium) is used in case of perennials such as black pepper, cardamom and coconut. Gene pyramiding for useful genes in one back ground variety of commerce is the mainstay of biotechnological research and is in progress in solanaceous vegetables. Efforts are in progress at various institutions in India to tackle issues of managing disease resistance, resistance to insect pests, nutritional quality improvement and to extend shelf life of fruits and vegetables through development of transgenics. A network project is in operation which involves 6 horticultural crops (banana, brinjal, cassava, papaya, potato and tomato. A large number of transgenics with Cry-l AB gene have been produced with resistance to the most damaging insects, usually Lepidopteron followed by Coleopteran and Dipterans. Nutritionally improved transgenic potatoes have been obtained by transferring the amaranth seed albumin gene (AmA1) from Amaranthus hypochondriacus in to potato and also succeeded in reversing the sweetening process in potato by using invertase inhibitor gene. RN Biotechnology has succeeded in developing potato which does not sweeten at lower temperature. RB gene transferred in two potato cultivar has given appreciable protection against Late blight disease which is a major concern.

2.8 Bioactive components-enhancing nutritive value

One of the most significant contributions of biotechnology is the improvements of nutritional status of horticultural crops. Several nutritional traits such as, carbohydrates, proteins, oils,

fats, vitamins and amino acids constitute the main target of plant biotechnology. A new approach to increase crop Active components such as carotenoids from tomatoes, glucosinolates from Brassica vegetables, phytoestrogens from soybean and phenolics and antioxidants from various plants protect and prevent numerous disease such as cancer and cardiovascular disease. These antioxidants are also associated with slowing the ageing process and improving overall health. Phytoestrogens from Dioscorea species such as wild yam (*Dioscoreavillosa*) also possess numerous physiological benefits. Some sweet potato varieties have anti-diabetic potential. Most of these bioactive components are plant secondary metabolites.

2.9 Horticultural crops as bioreactors for health care

Highly productive crops such as potato, cassava and yams are easy to grow and can generate considerable biomass within a short period. With these features research has been carried out to determine whether transgenic plants of these crops can be exploited for the production of commercial proteins and biochemicals and recombinant biopharmaceuticals such as cytokines, hormones, monoclonal antibodies, enzymes and vaccines. Plant fatty acid biosynthesis is carried out exclusively in the plastid by the fatty acid synthase complex, with desaturation reactions, for example, resulting in production of linoleic, gamma-linolenic and alpha linolenic acids. Hence higher plants do not synthesize long chain polyunsaturated fatty acids (PUFAs). A number of separate desaturase/elongase enzymes are required for conversion of linoleic acid in plants to long chain PUFAs. Getting plant cells to produce the nutritionally important omega-3 fatty acids, eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), likely requires expression of five or six introduced enzymes as well as system engineering to produce high levels and to prevent further onward metabolism of the desire products. While PUFA synthesis from acety1 CoA, as it occurs in plants, needs about 30 enzymes a much simpler pathway, involving a specialized polyketide synthase (PKS), system has been characterized for PUFA production in marine prokaryotic and eukaryotic microorganisms. Transforming plants with an expression cassette comprising a transcriptional/translational initiation region joined to a gene or component of a PKS like system capable of modulating the production of PUFAs, can result in alterations in the PUFA profile in the host cells. In transgenic plants, using a PKS-like system, PUFAs accumulate in the cytoplasm.

III. Rootstocks for production and profitability

Interaction of suitable rootstocks and scions become essential to achieve targeted production. Appropriately selected rootstocks have potential to modify architecture of plants for efficient utilization of resources. It can ameliorate the soil, enhance nutrient and water use, leading to conservation. Therefore, rootstocks have become integrated in production system of grapes, citrus, apple and many fruit crops for successful production. Citrus rootstock, Rangpur lime can adapt to water stress, calcareous soils and resist to Phytophthora. The use of rootstock in grape cultivation has gained popularity, and almost all newer vineyards are being planted on stress tolerant rootstocks only. The popular root stock for grape are Dog ridge B and 110R, which can sustain abiotic stresses like drought and soil salinity and provides vigour of vine needed for production. In sapota, Khirni (*Manilkara hexandra*) has proved drought tolerant and productive in marginal soil. Several components of future commercial fruit growing will depend on successful use of rootstocks for better scion compatibility, canopy architecture,

fruit quality, nutrient absorption, water use efficiency, biotic and abiotic stress tolerance and adaptation under the influence of climate change.

3.1 Quality planting material and seed technology

There have been technological changes in seed production, techniques for production of hybrid seeds, using of cytoplasmic male sterile lines (CMS), technologies for vegetative methods of propagation, now *in vitro* propagation technologies, and a success story in banana, potato and citrus and many other crops. Knowledge has also improved about the diseases being transmitted through vegetative propagation chain, and now diagnostic technologies are available for early detection. Enabling policies have also been changing to make available the best material to farmers However, seed chains addressing the production of nucleus seed, foundation and certified seeds are weak, planning do not commensurate with needs. Management of quality and health of plants needs up gradation, in order to ensure quality seeds and healthy planting material. Therefore, it is essential that dynamics of technologies and policies are analyzed in perspective to address the challenges of the future, because appropriate seeds and planting material hold the key to success in horticulture.

3.2 Diagnostics for health management

Disease free planting materials are essential for resource conservation, where in it eliminates the infected plant material and reduced the cost of crop production. Various diagnostic methods viz. ELISA, Polymerase Chain Reaction (PCR), multiplex PCR, and Real Time PCR are available for different viruses, bacteria and fungi. PCR based diagnostic protocol has been developed for rapid detection of viruses and phytophthora in citrus, banana, potato, coconut and tuber crops have been developed.

3.3High density planting system

High density planting technology has been standardized for many crops and also adopted by many fruit growers in India. It has become a success story in banana, pineapple, citrus, papaya, mango, cashew and few other fruit crops. High density orchards not only have provided higher yield and net economic returns per unit area in the initial years, but also facilitated more efficient use of inputs. In high density planting, closer spacing has given two and half times more yield than normal spacing in mango, guava, papaya and pomegranate. The varieties suitable for high density planting system have also been identified. Technologies for high density planting, canopy management and rejuvenation of old and senile orchards of been developed and successfully demonstrated for many fruit crops. Technologies for meadow orcharding in guava are being adopted for higher productivity. Coconut based high density multi-species cropping system helps to improve soil properties, realize the better stability for the farm net income and generates additional employment.

3.4 Nutrient dynamics for efficient use

Among various inputs, fertilizers alone account for 20-30% of the total cost of production; moreover, the efficacy of fertilizers applied in soil is low due to various losses and soil fixation. Fertilizer use efficiency studies using isotope labeled fertilizers have shown low efficiency of fertilizer use necessitating a system, which can determine the need of nutrients for all stages of growth and also understand the soil ability to supply needed nutrients more efficiently. Soil nutrient based fertilizer application is useful in vegetable crops, but fruit trees rarely respond to nutrient needs based on soil test, thus leaf nutrient standards have been

developed for many fruit crops to enhance the efficiency of fertilizer. Site specific production, diagnostic and advisory recommendations to maximize nutrient use efficiency are being worked out. The nutritional requirement for various horticultural crops for different agro-climatic zones has been worked out and successfully adopted by farmers. But the focus is required for the use of biofertilizers, VAM fungi, biological N fixers and other beneficial microbial agents for effective nutrient use efficiency.

3.5 Water use technology with high efficiency

Good water management using well designed system is critical for sustaining production and quality of produce, more specifically for horticultural crops. If water is applied, when stresses is needed there is crop loss, and if water deficit is experienced at active growth phase or fruit development stages it causes severe loss to production and quality. Therefore, it is imperative to manage the water which answers, when, where and how to draw maximum efficiency and productivity. Therefore scheduling based on plant water balance in consonance with soil and climate is appropriate. The water has to be applied to root zone to save the losses. Since lot of losses is caused during the conveyance, it is essential that appropriate delivery system is used which enhance the efficiency. Initiatives were taken to apply water in such a manner which can provide maximum output. When, where and how water should be applied has been worked out. Among various methods tried drip irrigation has proved successful in exhibiting high water productivity by saving irrigation water from 25-60% in various orchard crops and vegetables with 10-60% increase in yield as compared to conventional method of irrigation. It is one of the latest methods of irrigation which is becoming popular in areas with water scarcity and salt problems. The fertigation has become the state of the art in orchard crops and vegetables because nutrients can be applied to plants in the correct dosages and at the time appropriate for the specific stage of plant growth. Fertigation requirement in fruits (mango, banana, grapes, papaya, and pomegranate, citrus and strawberry), vegetables (tomato, chillies, brinjal, okra, potato, muskmelon, cucumber) and ornamental crops (rose, carnation, gerbera) and plantation crops (coconut, arecanut and coffee) have been standardized to improve the nutrient and water use efficiency which increased from 120 to 290%.

3.6 Green or Organic Horticulture

Changing dietary habits among many segments of the population coupled with health consciousness has resulted in growing demand for organic food. Demand for green food is on increase and harnessing the potential of organic farming which address soil health, human health and environmental health is considered to have greater significance. In last few years, organic farming has attracted many farmers across the country especially combined with ecotourism and have experimented successfully. India is best known as an exporter of organic tea and also has niche market for spices and fruits and vegetables. India also encouraged the production and export of organic food by developing capacity and capability which exists more in horticultural crops. Protocol for organic production may horticultural crops has been worked out which includes use of resistant varieties, management of soil vermicompost and biofertilizer and management of disease and pests using biological control as well as bio-pesticides.

3.7 Horticulture based cropping systems

Farming system and cropping system approach for sustainable use of farm resources and reduced risks have been successfully demonstrated in perennial horticulture various farming

system models have been developed and suitable crops in earlier year of tree plantation to maximize the output in different agro-climatic conditions has also been developed. Shade loving medicinal and aromatic crops like patchouli, rose geranium, long pepper, Sarpagandha, kacholam etc., are successfully grown under coconut and areca nut. The choice of crop selection is mainly based on farmer's need. The elephant foot yam is widely grown as intercrops in litchi, coconut, banana orchards. Spices like black pepper, ginger, turmeric, vanilla, nutmeg, clove and some medicinal plants are the ideal intercrops for coconut. Careful selection of enterprises vis-à-vis optimum allocation of resources available in farming system enables dynamic nature of competition, cost effectiveness and efficiency by improving the efficiency of inputs, enhanced genetic productivity and harnessing complementarities of enterprises.

3.8 Hi-tech Horticulture and Precision farming

Hi-tech horticulture is the deployment of modern technology which is capital intensive, less environment dependent, having capacity to improve the productivity and quality of produce. On the other hand, Precision Farming involves the application of technologies and principles to manage spatial and temporal variability associated with all the aspects of horticultural production for improving crop performance and environment quality. Precision farming calls for efficient management of resources through location-specific hi-tech interventions. Hi-tech horticulture encompasses a variety of interventions such as micro irrigation, fertigation, protected/greenhouse cultivation, soil and leaf nutrient based fertilizer management, mulching for in-situ moisture conservation, micro propagation, biotechnology for germplasm, genetically modified crops, use of biofertilizers, vermiculture, high-density planting, hi-tech mechanization, green food, soil-less culture, biological control etc. Precision farming application of fertilizers has been proved profitable than the recommendations based on package of practices. About 17 Precision Farming Development Centers (PFDC) have been established in different agro-climatic regions. Activities like greenhouse construction, mulching, shade net and plastic tunnels are also being promoted. The crops where some of the components of precision farming have been practiced are banana, grape, pomegranate, capsicum, tomato, chilli, cashew and selected flowers.

IV. Plant health management system

There are several pests and diseases such as fruit fly, stem and fruit borer, bark eating, leaf gall midge, aphids, mites and moths and diseases like scab, powdery mildew, leaf spot, brown spot, gummosis, canker causing serious damage to various horticultural crops. Among different pests, termites, rodents also cause considerable damage particularly in low rainfall areas. The chemical control measures for various pests and diseases have been worked out at various centres, but there is need for eco-friendly practices. During the last two decades IPM has moved from a peripheral position to the central stage of horticultural production programmes. The desirability of controlling pests by the use of integrated pest management is no longer questioned. A variety of techniques have been developed and refined for controlling different insect pests.

Plant health management in horticultural crops involves not only pre-harvest but also post-harvest health management strategies such as production of pest and disease-free planting materials, use of bio-inoculants and other growth enhancing soil amendments, indexing for major pathogens and certification of planting materials, seed plot technique and mother garden technique and other such measures. Several bio-control agents have been identified for various fruit crops but new bio-control agents from the native zone are required to be identified. Disease forecasting models developed are useful in determining the role of

climatic factors in disease appearance and progression and devising suitable management strategy. Efforts are also envisaged towards development of nonlinear stochastic models which would capture better the inherent nonlinearity in the disease incidence over time-epoch.

4.1 Post-harvest technology

In order to make horticulture a viable enterprise, value addition is essential. Harvest indices, grading, packaging, storage techniques have been developed/ standardized for major horticultural crops. Value addition through dehydration of fruits and vegetables including freeze drying, dried and processed fruits, vegetables and spices and fermented products have also been developed. Potato chips, spices flakes and fingers, French fries are becoming popular as fast food business. Development of new products like juice punches, banana chips and fingers, mango nectar and fruit kernel derived cocoa substitute, essential oils from citrus, fruit wines, dehydrated products from grape, pomegranate, mango, apricot and coconut, grape and fruit wines, value-added coconut products like snowball tender coconut, coconut milk powder and pouched tender coconut water (Cocojal) etc. are getting popular day by day. Improved blending/ packaging of tea and coffee have opened new markets. New products such as tetra pack filled fruit juices are now house hold items. Packing materials like Corrugated Fibre board boxes (CFBs), perforated punnets, cling film wraps, sachets, etc. have been standardized for packaging of different fresh horticultural produce.
As food consumption patterns are changing towards more convenient foods, the demand for products like pre-packed salads, packed mushrooms and baby corn frozen vegetables etc. are increasing and are sold in shopping malls. Consumer friendly products like frozen green peas, ready to use salad mixes, vegetable sprouts, ready-to-cook fresh cut vegetables are major retail items, which have already started peeping out of retail windows. In order to reduce dependence on refrigerated storage, low cost eco-friendly cool chamber for on farm storage of fruits and vegetables has been developed. For preventing the post-harvest losses proper storage, cold preservation, packaging and transport methods with Hazard analysis Critical Control Point norms have to be given more thrust. Standardization of Modified Atmosphere Packaging and Storage systems with greater emphasis on safety (pesticide free), nutrition and quality is getting emphasis.

4.2 Mechanization in Horticulture

Most of the horticultural operations in India are done manually or with animal power. Wherever, the farming operations are mechanized the crop productivity is high. Several machines and tools have been developed to enhancing the efficiency of farm operation. In fruit crops, the tractor operated pit whole digger and bucket excavators (JCB) have been developed need adoption. The fruit nurseries mechanization using media siever, media mixer and plastic bag filler have been achieved.

4.3 Way ahead towards ensuring nutritional and livelihood security

There is need to enhance the level of food security and nutrition by improving the efficiency of the horticultural production system and associated support services such as marketing, processing, credit, post-harvest loss prevention, etc. through the application of modern technologies and diversified cropping patterns, that will promote the production and productivity, and provide higher incomes to the small and marginal farming communities in a sustainable manner. The nutritional status of the population can be improved through creating an environment in which households has sufficient access to fruits and vegetables at

affordable prices throughout the year and the necessary knowledge and skills to prepare and consume foods to complement their diet, specifically targeting the poor women farmers and children. Develop sustainable capability among low income communities in increasing productivity and year round production of horticultural crops (fruits, vegetables and spices) through the introduction of superior quality planting materials and seeds and the promotion of production skills. Minimize post-harvest losses, improve postharvest handling and maximize primary producers' profits and income through the promotion of on-farm and community-based produce handling methods as well as to enhance marketing support services. Promote income-generating activities, including agro-processing, to enable the optimum utilization of horticultural produce to supplement family incomes, with additional support form micro-credit and food assistance programs, especially for poor and disadvantaged group. Increase the nutritional awareness among the beneficiaries and develop a comprehensive food based nutrition program to reduce malnutrition in the target groups comprising all groups of population with major focus on women and children.

Production of fruits, vegetables, flowers, spices and plantation crops has been success stories of the last decade, and to continue to build on success, sector has to face challenges. Therefore, there is a need to prioritize the action outlining the research, 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. Strengthen research on impact assessment of 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). 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 demand focused alteration. Therefore, 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 change.

V. Conclusion

The agricultural paradigm is already undergoing a shift with focus from cereal production to diversified farming. Horticultural crops besides improving biological productivity and nutritional standards also have enormous scope for enhancing profitability. This group of crops comprising fruits, vegetables, root and tuber crops, plantation crops, medicinal and aromatic plants, spices and condiments and ornamental crops, would constitute core of any such agro-economic strategy. Past investment has been rewarding in terms of increased production, productivity and export of horticultural produce. However, challenges confronting are still many. Although, the country is second largest production of fruits and vegetables; the availability of fruits and vegetables still continues to be much below the dietary requirements. With increase in per capita income and accelerated growth of health conscious population, demand for horticultural produce is on increase which is expected to further accelerate, which will require more production. But the production has to be competitive both in terms of quality and price. Thus, the potentialities, which exist, need to be harnessed and gains have to be sustained. Development of improved cultivars with high quality characteristics, productivity, resistance to pest and disease and tolerant to abiotic stresses. The technologies must improve the efficiency of water and nutrients and variability in yield, quality and also reduced post-harvest crop losses. Efforts will also be needed to ensure timely availability of quality seed and planting material. Consequently, horticultural

development has to be seen as integrated approach, addressing important gaps, in harnessing the potential through targeted research with focus on enhancing efficiency. Thus, technology driven horticulture is expected to address the concern for complimentary and nutritional security, health care leading to ultimately economic development.

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