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Horticulture for Food and Nutrition Security

Preamble

India supports more than 17% of the global population with only 2.4% land cover. The agricultural sector is an important contributor to the Indian economy (17.6% of GDP), besides providing nearly 54% of the country's employment. Despite several challenges, namely tumultuous weather, seasonal cyclones, occasional drought, demographic pressure, industrialization, urbanization, unprecedented use of insecticides and pesticides, and compulsion for the migration of people from rural to urban areas, especially for employment, the country witnessed record food grain production of 277.49 million t during 2017–18.

Food and nutritional security are the key SDGs. There has been appreciable progress on the food front including horticulture. Foodgrain production increased five-fold, horticulture nine-fold, milk six-fold and fish nine-fold in 2015–16, compared with production in 1950–51. However, economic access to nutritious food continues to be a cause of concern. Currently, more than 350 million people continue to suffer from malnutrition, which is a cause of various types of diseases and premature deaths of children and women. Therefore, the country can only be food-secure if the citizens have economic access to nutritious food to meet their physical needs. In this context, horticultural crops (fruits, vegetables, potatoes, tuber crops, mushrooms, plantation crops, spices etc.) have emerged as the best options, not only to provide required nutrients but also to enhance access to food through enhanced farm profitability. The current trend shows that dietary habits are changing with increasing income, from cereal-based diets to cereal plus vegetables/fruit-based diets. Resultantly, there is a growing demand for fruit and vegetables. It has been recognized that the horticulture sector is the best option for agricultural diversification to ensure food, nutrition and healthcare. Horticulture provides a wider choice for farmers and also complements the food sector, i.e. with potato, tuber crops, banana and vegetables. A new paradigm shift in farming in the recent past has been towards horticulture-based farming systems to ensure greening, environmental services and to provide nutritious food while enhancing farm profitability (GoI, 2011).

Horticultural Development

At present, horticulture is considered to be a sunrise sector of the Indian economy. It is growing rapidly and offers good options for agricultural diversification. Horticulture is not merely a means of diversification but has become an integral part of food, nutritional security and poverty alleviation. This sector alone provides livelihood for 30–40% of India's population. As per the estimates of the Ministry of Agriculture and Farmers' Welfare released in January 2018, the

production of horticulture crops has already hit a record 305.4 million t in 2017–18, about 1.6% higher than the previous year's production (299.85 million t) and 8% higher than the previous five years' average (http://www.livemint.com). Even in 2016–17, with impressive production of 299.85 million t, horticulture contributed around 30% of agricultural GDP. Over the past few years, horticulture has made remarkable progress in terms of expansion of both area and production under different crops, increase in productivity, crop diversification, technological interventions for production, and post-harvest and forward linkages through value addition and marketing.

Among the eight different groups of the horticulture sector, fruits and vegetables form the single largest sub-sector accounting for 78.4% of the area and over 92% of the total production. Horticultural production has shown a quantum jump in the recent past. Estimated area and production during 2016–17 showed an increase of 17.4% and 32.3%, respectively, over 2011–12. This is suggestive of both area- and productivity-led growth. During the last decade, the horticulture sector as a whole registered a compound growth of over 6%. The increase had been more significant in fruits and vegetable crops. The present status of Indian horticulture is given in Box 11.1.

Horticulture for Nutrition and Health

Horticulture has emerged as an important sector in agriculture with coverage of nearly 24.9 million ha, having an annual production of 305.4 million t, surpassing even foodgrain production. The year 2017–18 marked the sixth straight

Box 11.1. Present status of Indian horticulture.

- Production of horticultural crops like vegetables and fruits has touched a record 305.4 million t in 2017–18, about 1.6% higher than the previous year and 8% higher than the previous five years' average, the agriculture ministry said in its report in January 2018. It was 299.85 million t in 2016–17. It has surpassed foodgrain production (277.49 million t) from a much smaller area (25.11 million ha). The record production during 2017–18 will mark the sixth straight year of horticulture production outstripping that of foodgrains, suggesting a structural change in Indian agriculture where farmers are increasingly growing perishable commercial crops due to a growing market and a quicker cashflow, as these crops require less time from sowing to market.
- Production increased from 167 million t in 2004–05 to 305.4 million t in 2017–18, showing an increase of 81%.
- Productivity of horticultural crops is much higher compared to productivity of foodgrains (11.94 t/ha against 2 t/ha). Productivity of horticultural crops increased by 31.9% between 2004–05 and 2016–17.
- Within horticulture, production of vegetables had been 181 million t in 2017–18, about 1% higher than the year before, while that of fruits was almost 95 million t, 2% higher than the previous year.
- Data showed that during the year, the area under different perishable crops stood at 24.9 million ha, about 0.3% higher than the year before. Between 2015–16 and 2017–18, productivity of horticultural crops rose from 11.7 t/ha to an estimated 12.3 t/ha.
- Disaggregated data on estimates of production of specific crops showed onions at 21.4 million t, about 4.5% lower than the year before, and potatoes at 49.3 million t, marginally higher than the 48.6 million t in 2016–17. Production of tomatoes is estimated to rise 7.7% in 2017–18 to 22.3 million t.
- Area increased from 18.7 million ha in 2005–06 to 25.11 million ha (about 16% of arable land) in 2016–17.
- Horticulture contributes 38% to the Gross Net Value (GNV) of agriculture.
- There has been a 45% increase in per capita fruit and vegetable availability.
- Exports increased by 315% over ten years.
- Price volatility continues to be a major risk in horticulture, with the price of onions, tomatoes and potatoes plunging below growing costs several times during 2015–16. While farmers in Madhya Pradesh were forced to sell onions for Rs 2/kg in June 2015–16, in northern India farmers from Punjab, Haryana and Uttar Pradesh were forced to dump their potato crop for want of buyers around the same time.

year that India's horticulture production outstripped foodgrain output, indicating a structural change in Indian agriculture. The fact that horticultural crops are now grown in over 10% of India's gross cropped area is indeed a success story. It also signals the success of small and marginal farmers in growing more fruits and vegetables, driven by higher demand. Changes in area and production clearly indicate that production gain is due both to area and productivity increase. Fig. 11.1 depicts the trend of horticultural crops in India, whereas Fig. 11.2 indicates annual production during the 12th Plan period and future projections (million t). Tables 11.1 and 11.2 indicate actual and projected production of horticultural crops for the 12th Plan period and the value of horticultural crops, respectively, while Table 11.3 provides wider options in terms of calories. Fruits and vegetables are also a rich source of vitamins, minerals, proteins and carbohydrates, which are essential in human nutrition. Hence, these are referred to as protective foods and assume great importance for the nutritional security of people. Thus cultivation of horticultural crops plays a vital role in national prosperity and is directly linked to health and well-being. The emphasis on horticulture is a recognition of the need for attaining nutritional security and for sustainable income. Healthier diets will improve the learning capacity of children

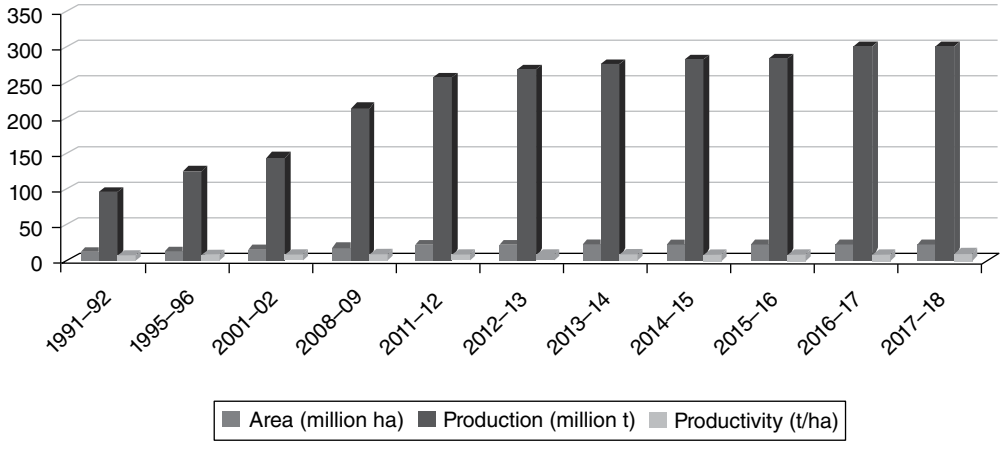

Fig. 11.1. Area, production and productivity of horticultural crops in India. (From: Ministry of Agriculture and Farmers' Welfare, Government of India)

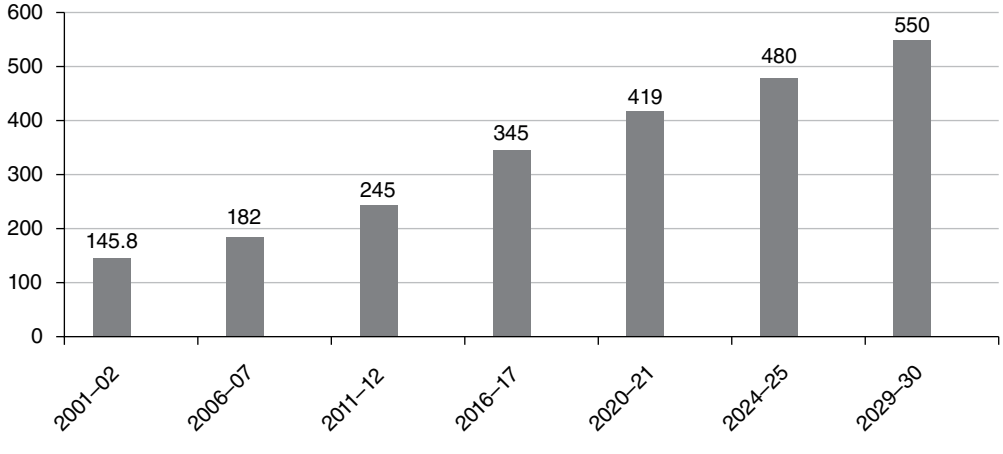

Fig. 11.2. Annual production during the 12th Plan period and future projections (million t). (From GoI, 2011)

Table 11.1. Actual and projected production of horticultural crops for the 12th Plan period.

Crop group	Base period production (2009–10)	Target production at the end of the 12th Plan (2016–17)	Compound annual growth rate (%)
	Production (million t)		
Fruit and nuts	71.40	104.00	6.5
Vegetables	123.80	199.19	8.7
Spices	4.01	5.14	4.0
Coconut	10.81	15.35	6.0
Plantation crops	1.54	2.18	6.0
Tuber crops	12.0	15.36	3.0
Flowers (cut and loose)	1.46	2.99	15.0
Miscellaneous crops	0.60	1.02	10.0
Total horticulture	**225.62**	**345.23**	**6.7**

Coconut conversion = 1450 nuts/t; cut flowers conversion = 15,000 = 1 t; estimated production = 295.35 million t (2016–17)

Table 11.2. Value of horticultural crops (at constant prices).

Crop group	Value of 2009–10 production (Rs million)	Value of 2016–17 production (Rs million)	Growth rate (%)*
Fruits	335,580	546,995.4	9.0
Vegetables	348,740	556,240.3	8.5
Spices	47,117	68,555.9	6.5
Coconut	30,484	47,128.5	7.8
Plantation crops	7,238	11,189.9	7.8
Tuber crops	451,200	719,664.0	8.5
Flowers	343,100	686,543.1	14.3
Miscellaneous	98,700	133,245.0	5.0
Total horticulture	**1,662,159**	**2,769,562.0**	**9.5**

*2004–05 = base period (GoI, 2011)

Table 11.3. Number of calories available in fruit and vegetables (per 100 g). (FAO, 2013)

Fruits	Calories (per 100 g)	Vegetables	Calories (per 100 g)
Apple/plum	56	Broccoli	25
Avocado pear	190	Brinjal	24
Banana	95	Cabbage	45
Chickoo	94	Carrot	48
Cherry	70	Cauliflower	30
Date	281	Fenugreek (*methi*)	49
Grape (black)	45	French beans	26
Guava	66	Lettuce	21
Pomegranate	77	Mushroom	18
Lychee	61	Onion	50
Mango	70	Pea	93
Orange	53	Potato	97
Strawberry	77	Spinach	26
Peach/pear	50	Tomato	21
Pineapple	46	Watermelon	26

and the working capacity of adults, leading to higher incomes and a reduction in poverty (http://www.agricoop.nic.in; MoA and FW, 1991–92 to 2016–17; GoI, 2011).

Horticultural crops provide ample opportunities for healthcare. According to the Food and Nutrition Board of the National Research Council, men and women between 23 and 50 require about 2800 and 2200 calories/day, respectively, to maintain good health. Pregnant women and lactating mothers will need an additional 300–500 calories/day (Peter, 2015). Thus, fruits and vegetables provide better options for meeting the energy requirements of humans (Table 11.3). It is pertinent to mention that fruits (aonla, bael, jamun, papaya), vegetables (carrot, cauliflower, onion, garlic, leafy vegetables), spices (ginger, turmeric, black pepper, fenugreek, ajowain) and ornamental plants (Ashoka, Ficus, Catharanthus) protect us against various kinds of diseases. Spices like turmeric, chilli and cumin have been recognized to protect against cancer. Noni (*Morinda citrifolia*) is recognized as the best for healthcare as it provides protection against various diseases including HIV. Virgin coconut oil protects from HIV and coconut water provides all the nutrients a child needs.

India is the second-largest producer of fruits after China, with an estimated production of 92.84 million t of fruits from an area of 6.48 million ha (as per NHB Review Committee meeting, 16 May 2017). 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. To some extent, they provide energy-rich food. Banana, jackfruit, annona, sapota and fig contain carbohydrates in the range 19–24% and are good sources of energy compared with potato, colocasia, baby corn, yam and green pea (15.9–24.6% carbohydrates and 79–125 kcal energy). Closely following this group of fruits as good sources of energy are mango, lychee, grape, ber, pomegranate, phalsa and jamun. Fresh avocado is the only high-energy fruit yielding 161–215 kcal per 100 g due to its high fat content (15–26%). But fruits and vegetables are indispensable as a source of vitamins and minerals, which help in building resistance against diseases. Fruits and vegetables provide 90% of the required vitamin C and 60% of vitamin A. Mango and papaya are rich in pro-vitamin A and guava in vitamin C. Banana is a good source of carbohydrate (GoI, 2011).

Fruits yield larger quantities of food/ha compared to cereals. For example, the maximum paddy yield is 3 t/ha, whereas it is 22 t/ha in the case of banana, 45 t/ha in the case of pineapple and 40 t/ha in the case of grape. Much less area is required to obtain the calorific requirement per adult per year (1,100,000 kcal) from growing bananas (0.03 ha) or mangoes (0.16 ha) than from growing wheat (0.44 ha). Fruits are a rich source of organic acids that stimulate appetite and help digestion. Many fruits and vegetables possess laxative properties as they possess dietary fibre and pectin, stimulating intestinal activity. Due to poverty, micronutrient deficiency (vitamin A and iron deficiency anaemia) is posing a threat to large masses in Asia and the Pacific regions, which could be minimized through a horticulture intervention and awareness drive.

Towards Achieving Nutritional Security

Vegetables and fruits play a prominent role in prevention of several chronic diseases such as heart disease, cancer, cataracts, osteoporosis, diabetes etc. In order to have a protective effect, it is necessary to consume 400–600 g of fruits and vegetables every day (Peter, 2015). But the consumption level of fruits is low and widely variable from region to region in India. An increase in the intake of fruits along with vegetables will meet the required daily allowance of many nutrients. Although India is the second-largest producer of fruits and vegetables in the world, next to China, per capita consumption is only around 46 g and 130 g, respectively, against a minimum requirement of about 92 g and 300 g as recommended by the Indian Council of Medical Research and the National Institute of Nutrition, Hyderabad. With the present population level, the annual requirement of horticulture produce will be 419 million t by 2020/21 as against the present level of production of 299.85 million t (2016/17).

Challenges Ahead

The growing population in India is a big challenge for meeting food needs worldwide. According to predictions from the Food and Agriculture Organization of the United Nations (FAO), agricultural productivity in the world will sustain the growing population in 2030 but millions of people in developing countries will starve or remain hungry. By 2025, 83% of the expected global population of 8.5 billion will be in the developing world (FAO, 2011). The question before us is: Can we meet food needs and provide nutrition, healthcare, fuel and fibre to a growing population? The answer is: It is difficult, but not impossible. Past experiences build confidence. In the post-independence period, India made steady progress in agriculture when extra land and water was made available, and a few genes performed wonders in ushering in the 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 input of science and technology, challenges ahead could be converted into opportunities for sustainable production. Horticulture has proved to be the best means of diversification for higher land productivity, achieving a gross return/ha, but there is a need to make sustainable efforts in enhancing the production of fruits, vegetables, tubers and plantation crops to meet the growing demands of an ever-increasing population with nutritionally rich horticulture produce. Currently, climate change is posing a threat to horticultural crops due to erratic rainfall, greater demand for water and enhanced biotic and abiotic stresses. The challenges could be addressed through identification of genes tolerant to high temperature, flooding and drought; development of nutrient-efficient cultivars; and a production system for efficient use of nutrients and water. This would need highly prioritized research to address the impact of climate change. Concerted and integrated efforts with effectiveness and efficiency will be essential to meet the ever-increasing demand.

Technological Advancements

At the present time, 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, INM, water management, IPM and disease management, post-harvest technology, processing and marketing. The positive changes in the horticulture sector have occurred because it has received importance from all stakeholders, the public sector, private sector and farmers during the last two to three decades. This is primarily the result of the realization that diversification to horticultural crops is now the major option to improve food and livelihood security. Under NARS, the R&D on horticulture has been strengthened using multicrop and multidisciplinary approaches of (i) genetic improvement; (ii) efficient crop management; and (iii) post-harvest management.

Genetic Improvement

In an endeavour to attain food and nutritional security, germplasm enhancement and its utilization is extremely important in providing strong backing for breeding programmes. Concerted efforts are being made by NARS for documentation, characterization, conservation and utilization of plant genetic resources in horticultural crops, which enabled the conservation of 72,000 accessions of cultivated, wild and related taxa. Now it has become necessary to identify accessions possessing high nutritional value and bioactive compounds that play a great role in nutritional security, and this shall be helpful in breeding varieties with special attributes. Efforts have been made to develop HYV and hybrids of different horticultural crops for different regions. More than 1800 improved high-yielding, high-quality varieties, coupled with disease- and pest-resistant varieties and hybrids, have been released by various institutes/universities for cultivation in diverse agroclimatic conditions of the country. Regular-bearing mango hybrids, export-quality grapes, multiple disease-resistant vegetable hybrids, high-value spices and tuber crops for industrial use have been developed. Improved varieties have revolutionized the horticultural sector. High-yielding Gauri Sankar and Sree Bhadra sweet potatoes have focused on minimizing malnutrition and improving nutritional security. Similarly, breeding to develop grape cultivars suitable for vine making, black pepper

cultivars rich in aroma compound caryophyllene, and 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: Kufri Chipsona in potatoes for chips and the heat-tolerant variety Kufri Surya; high total soluble sugar (TSS) white onions, W448, in the National Research Centre for Onion and Garlic (NRCOG); and papaya varieties for table and papain production are some of the successful research attempts being carried out at various ICAR institutes.

Hybrid technology has revolutionized the production of vegetable crops and demand for hybrid seeds is continually increasing. Hybrids of tomato, chilli, cucumber and muskmelon are being produced at several locations in different states in the country. The All India Coordinated Vegetable Improvement Project (AICVIP) has so far recommended cultivation of over 45 hybrids. Besides, many hybrids of vegetable crops, developed and marketed by the private sector are also available to the farmers. At present, the area under high-yielding F_1 hybrids in important vegetable crops ranges from 17.8% to 31.5%, particularly 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 F_1 hybrids. Keeping in view the dynamic needs, the research efforts in various institutes have focused on development of hybrids with multiple disease resistance, early maturity and utilizing the male sterility system. Cytoplasmic male sterile (CMS) lines have successfully been utilized to produce potential experimental crosses of onion and commercial hybrids of chilli. The parental lines of a number of hybrids developed have been sold on a non-exclusive basis to the seed companies with the aim to promote these hybrids among farmers.

Biotechnological tools have provided ample scope for breeders 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 the 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 the production of hybrids of *Musa acuminata* × *Musa bulbisiana, Carica papaya* × *Carica cauliflora* and interspecific crosses in pineapple and seedless × seedless grape varieties. Use of molecular markers for crop profiling, fingerprinting, molecular taxonomy, identification of duplicates, hybrids, estimation of genetic fidelity and tagging of genes for marker-aided selections are gaining importance. Efforts are under way to fingerprint mango, banana, cashew nut, kiwifruit, walnut, grape, citrus etc. by different research centres. 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 is in progress in many crops such as brinjal, tomato and capsicum, while association mapping (linkage disequilibrium) is used in the case of perennials such as black pepper, cardamom and coconut. Gene pyramiding for useful genes in one background variety of commerce is the mainstay of biotechnological research and is in progress in solanaceous vegetables. To tackle issues of managing disease resistance, resistance to insect pests, nutritional quality improvement and to extend shelf life of fruits and vegetables, efforts are being made to develop transgenics. A large number of transgenics with the *Cry-1* AB gene have been produced with resistance to the most damaging insects, usually lepidopterans. Nutritionally improved transgenic potatoes have also been obtained by transferring the amaranth seed albumin gene (AmA1) from *Amaranthus hypochondriacus* into potato. RNAi technology has succeeded in developing potato which does not sweeten at lower temperatures, and the RB gene transferred in two potato cultivars has given appreciable protection against late blight disease (GoI, 2011).

Efficient Crop Management

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. Suitable rootstocks

and scions become essential to achieve targeted production. Citrus rootstock, Rangpur lime, can adapt to water stress and calcareous soils, and can resist *Phytophthora*. The popular rootstocks for grapes are Dogridge B and 110 R, which can sustain abiotic stresses like drought and soil salinity and provide vigour in the vine. In sapota, khirni (*Manikara hexandra*) has proved drought-tolerant and productive in marginal soil. There have been technological changes in seed production, techniques for production of hybrid seeds using cytoplasmic male sterile lines (CMS), technologies for vegetative methods of propagation and *in vitro* propagation technologies, a success story in banana, potato, citrus and many other crops. Disease-free planting materials are essential for resource conservation, wherein it eliminates the infected plant material and reduces the cost of crop production. Polymerase Chain Reaction (PCR)-based diagnostic protocol has been developed for rapid detection of viruses and phytophthora in citrus, banana, potato, coconut and tuber crops. High-density planting technology has been standardized for many crops and also adopted for growing banana, pineapple, citrus, papaya, mango, cashew and a few other fruit crops. Technologies for high-density planting, canopy management and rejuvenation of old and senile orchards have been developed and successfully demonstrated for many fruit crops. Also meadow orcharding in guava is being adopted for higher productivity.

Among various inputs, fertilizers alone account for 20–30% of the total cost of production. Soil nutrient-based fertilizer application is useful in vegetable crops, but fruit trees rarely respond to nutrient needs based on soil tests; thus leaf nutrient standards have been developed for many fruit crops to enhance the efficiency of fertilizer, but the focus is now required on the use of biofertilizers, Vesicular-Arbuscular Mycorrhiza (VAM) fungi and other beneficial microbial agents for effective nutrient use efficiency. Good water management using well-designed systems is critical for sustaining production and quality of produce, more specifically for horticultural crops. Among others, drip irrigation has proved successful in exhibiting high water productivity by saving irrigation water by 60% in various orchard crops and vegetables, with 10–60% increases in yield compared to conventional methods of irrigation. 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 appropriate time for the specific stage of plant growth. Due to changing dietary habits coupled with health-consciousness, demand for organic food is on the increase these days (GoI, 2011). Protocol for organic production using resistant varieties, management of soil vermicompost and biofertilizer/biopesticides for managing diseases and pests have been developed. Farming system and cropping system approaches have been successfully demonstrated in perennial horticulture. Various farming system models have been developed and suitable crops in the early years of tree plantation to maximize output in different agroclimatic conditions have been selected. The elephant foot yam is widely grown as an intercrop in lychee, coconut and banana orchards. Spices like black pepper, ginger, turmeric, vanilla, nutmeg, clove and some medicinal plants are the ideal intercrops for coconut.

Most of the horticultural operations in India are done manually or with animal power. Wherever farming operations are mechanized, crop productivity is high. Several machines and tools have been developed to enhance the efficiency of the farm operation. In fruit crops, tractor-operated pit-hole diggers and bucket excavators have been developed and need adoption. Hi-tech horticulture has become the order of the day; it 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, soil-less culture and biological control (Singh *et al*., 2015). Precision farming calls for efficient management of resources through location-specific hi-tech interventions. 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 practised are banana, grape, pomegranate, capsicum, tomato, chilli, cashew and selected flowers. The chemical control measures for various pests and diseases, such as fruit fly, stem and fruit borer, leaf gall midge, aphids, mites and moths, and diseases like scab, powdery

mildew, leaf spot, brown spot, gummosis and canker have been worked out, but there is a need for ecofriendly practices. 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 measures. Several biocontrol agents have been identified for various fruit crops but new biocontrol agents from the native zone are required to be identified. Disease forecasting models are useful in determining the role of climatic factors in disease appearance and progression and in devising suitable management strategies (Singh, 2009).

Post-harvest Technology

Production and consumption of fruits and vegetables can help in achieving nutritional security. However, consumption of fruits and vegetables is low in most of the developing world due to lack of buying power. In developing countries, an estimated 25–30% of produce is lost on account of post-harvest events. Increased investment in post-harvest research is therefore justified. Post-harvest losses invariably occur due to improper ripeness, poor initial quality, mechanical damage, inadequate sanitation, inadequate drying, decay, improper temperature and delays between harvesting and market. Some key interventions to reduce losses include selecting varieties with good shelf life, harvesting at proper maturity, avoiding sun exposure to reduce water loss and temperature gain after harvest, cooling (or drying) quickly to the lowest safe temperature, protecting from physical damage, maintaining the cold chain (or dry chain), and expediting marketing whenever possible. For example, using storage containers like reusable plastic containers and plastic bags can improve the quality of produce over time by protecting it from damage and also by serving as a moisture barrier to reduce water loss. Many post-harvest fruits and flowers are regulated by ethylene, a major cause of post-harvest loss, and modulation by ethylene synthesis can improve the life of horticultural crops (GoI, 2011).

In order to make horticulture a viable enterprise, value addition is essential. Harvest indices, grading, packaging and storage techniques have to be standardized for major horticultural crops. Value addition through dehydration of fruits and vegetables, including freeze-drying, dried and processed fruits, vegetables, spices and fermented products has also been developed. Potato chips, spice flakes, fingers and French fries are becoming popular as fast foods. New products like juice punches, banana chips and fingers, mango nectar, fruit wines, dehydrated products made from grape, value-added coconut products like snowball tender coconut, coconut milk powder and pouched tender coconut water (Cocojal) etc. are also becoming popular these days. Improved blending/packaging of tea and coffee has opened new markets. New products such as tetra-pack-filled fruit juices are now household items. As food consumption patterns are changing towards more convenient foods, the demand for products like pre-packed salads, packed mushrooms and baby corn, and frozen vegetables is increasing and these items are sold in shopping malls. Consumer-friendly products like frozen peas, ready-to-use salad mixes, vegetable sprouts and ready-to-cook fresh-cut vegetables are major retail items, which have already started appearing in retailers' windows. In order to reduce dependence on refrigerated storage, low-cost, eco-friendly cool chambers for on-farm storage of fruits and vegetables have lately been developed. Standardization of modified atmosphere packaging and storage systems with greater emphasis on safety (pesticide-free), nutrition and quality are also becoming important.

Supply Chain Management

In India, most exporters still rely on the traditional wholesale market to procure fruits and vegetables. The marketing channels for fruits and vegetables vary considerably by commodity and state, but they are generally very long and fragmented. The majority of domestic fruit and vegetable production is transacted through wholesale markets, depending on the state and the commodity. Farmers may sell to traders directly

at the farm gate or at village markets, or directly to processors, cooperatives and others. In the majority of states, the Agricultural Produce Marketing Committee (APMC) regulations have also prevented the private sector from investing in wholesale markets and marketing infrastructure. As a result, most markets have rudimentary infrastructure, particularly for storing and handling perishable products. Recently, there has been an emergence of more coordinated supply chains for fruits and vegetables in India catering to the export market and to the high-end domestic market. The coordinated supply chain involves structured relationships among producers, traders, processors and buyers, whereby detailed specifications are provided as to what and how much to produce, time of delivery, quality and safety conditions, and price. The coordinated supply chains fit well with the logistical requirements of modern food markets, especially for fresh and processed perishable foods. These chains can be used for process control of safety and quality and are more effective and efficient than control only at the end of the supply chain. Recently, a terminal market for fruits and vegetables has been set up in Bangalore known as SAFAL. The market receives sorted, graded and packaged produce from these associations and centres, which is then auctioned at the market. SAFAL has also forward linkages to a number of retail outlets. The market has modern infrastructure including temperature-controlled storage facilities and ripening chambers. Normally, small and marginal fruit and vegetable growers are unable to get an acceptable price for their produce due to small marketable surplus and the highly perishable nature of the produce. Support for such farmers is the need of the hour. For this they should form fruit and vegetable cooperative societies/self-help groups (Singh, 2009).

With a view to establishing a complete supply chain, from farm to market, the infrastructure facilities will have to be created at the following levels: (i) small pre-cooling units and/or evaporative cooled chambers in the production areas where the field heat of the produce is to be removed at a fast rate to bring down the temperature of the produce to the desired level before putting the product into cold storages. The refrigerated transport units, from farm to cold storage, are also utilized as mobile pre-cooling units for this purpose; (ii) collection centres near to the farms; (iii) medium or small cold storages having multi-product, multi-chamber facilities, which are the most popular segment where horticulture produce is stored in transit godown; (iv) specialized cold storages with the facility of built-in, pre-cooling, high humidity and controlled/modified atmosphere are required for storage of the produce for a longer period. These specialized storages are essential for extending the shelf life of the produce, and without these facilities proper storage of the produce to meet demand in the off season is not feasible; (v) other components like ripening chambers close to the markets and display cabinets at retail outlets; and (vi) linkages for conversion of fresh produce into other marketable forms.

The Way Forward

In order to achieve household nutritional security, the role of horticulture will be important. The progress in the last 50 years has been phenomenal. For the last four continuous years, horticultural production has surpassed foodgrain production in the country, and during 2017–18, the production of horticultural crops (299.85 million t) has exceeded that of foodgrain crops (305.4 million t) considerably. For an accelerating expected growth rate of 5–6%, a national strategy is needed for both horizontal and vertical expansion of ecoregion-specific horticultural crops. Greater thrust is needed to produce and make available disease-free saplings and seeds to farmers. For this, the role of the private sector will be crucial. On one side, area expansion programmes did not have proper back-up of seed and planting materials; infrastructure created in the form of plant disease-forecasting labs, tissue analysis labs, biocontrol labs etc. are yet to be created and used fully for the benefit of production and plant protection purposes. Rejuvenation of old and senile plantations also has not picked up; and private sector investment in post-harvest management and marketing infrastructure has not materialized to the desired extent. On the other side, various schemes dealing with horticulture development need integration. Moreover, in order to achieve the desired growth rate in a sustainable manner, there is a need for prioritization in a rational manner and to set targeted

productivity for major crops according to production clusters/states. Prioritization may vary from state to state and from one production cluster to another. The crops of significance for achieving higher growth rates are known as 'focus crops'. However, crops having special significance in terms of the local economy (e.g. lychee, saffron, strawberry, passion fruit, dates etc.), important for processing (peas, white onion etc.) or for export (grapes, white onion, walnut, almond etc.) are also to be included in this category. Banana, mango, citrus, papaya, guava, apple, pineapple, sapota, grapes, pomegranate and lychee are considered as focus fruit crops at the national level. Stone fruits, too, have a significant role in export. Likewise, potato, tomato, onion, brinjal, cabbage, cauliflower, okra and green peas are priority vegetable crops. Drumstick, white onion and curry leaves are also included, keeping in view their export demand. Coconut, cashew nut and areca nut are the focus crops among plantation crops (NAAS, 2009).

For an integrated development of the horticulture industry, and also to achieve targets for feeding the population as well as meeting the requirements of the processing industry and exports, emphasis on quality production needs to be integrated with post-harvest management of the highly perishable horticultural crops. Considering the role horticulture has to play and the constraints on its development, as well as the mandate to double food production and reduce the gap between requirement and availability, the following priority areas (Singh, 2009; Singh *et al.*, 2016) are identified to be given due consideration for better post-harvest infrastructure: (i) technical/financial support for all round development of the horticulture sector; (ii) emphasis on increasing production with an objective of achieving complete nutritional security; (iii) adoption of appropriate post-harvest management technologies for maximizing return to the farmers/growers; (iv) feasibility studies for setting up the marketing, processing plants, cold storage, transportation systems for raw and processed perishable horticultural products, and undertaking designing, planning and execution of projects on that basis; (v) promotional activities to boost the process of employment generation, to increase the income of small and marginal farmers and the involvement of women and backward communities in the horticulture development process; (vi) encouraging the shifting of food habits from quantity to quality food through increased availability and mass-media promotion of health-oriented benefits of fruits and vegetables; and (vii) stimulating private investment, particularly in the fields of infrastructure, marketing and R&D with particular emphasis on the special needs of the processing industry and exports (Singh *et al.*, 2016).

The horticulture sector in India is suffering due to natural, manmade, technical and economic reasons. Some of the reasons behind the crippling growth that are obstructing the growth of the horticultural sector include: (i) inadequate availability of disease-free, high-quality planting material; (ii) slow dissemination and adaptability of high-yielding cultivars/hybrids; (iii) lack of post-harvest management technology and infrastructure; (iv) weak database and poor market intelligence; (v) instability of prices, with no support price mechanism; (vi) inadequate technical human resources in the farming system; (vii) poor credit supply and high rates of interest, coupled with inadequate crop insurance schemes; (viii) poor linkage between R&D, industry and farming communities; (ix) late implementation of government policies and schemes; and (x) absence of a horticultural crop suitability map of India based on agroclimatic conditions and depicting the most suitable areas for optimum productivity of a particular crop (Singh, 2009) .

Thrusts and strategies (Singh, 2009; Singh *et al.*, 2010) needed to address the above problems include: (i) improving production and productivity; (ii) reducing cost of production; (iii) improving quality of products for export; (iv) value addition, marketing and export; (v) price stabilization; (vi) strengthening of organizational support; (vii) availability of adequate human resources; and (viii) addressing relevant policy issues. Besides these improvement programmes, the government has to concentrate on the WTO issue with regard to marketing and trade-related affairs. For sustainable development of horticulture, the prerequisite infrastructure should be made available by the authorities concerned. The standard of horticulture produce should be maintained in line with quantity and quality approaches to capture markets and fulfil the nutritional standards. The establishment of an organizational framework for horticulture will lead to an organized and coordinated dispersal of functions.

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