Strategy Paper

Horticulture for Food & Nutritional Security

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taas
Progress Through Science

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Progress Through Science

Trust for Advancement of Agricultural Sciences (TAAS)

GOAL

Ensuring an accelerated movement for harnessing agricultural sciences for the welfare of people.

MISSION

Promoting growth and advancement of agriculture through scientific interactions and partnerships.

OBJECTIVES

- To act as a Think Tank to deliberate on key issues relating to agricultural research and innovation for development (ARI4D) and influence policy decisions
- To organize workshops, conferences, brainstorming sessions, policy dialogues, seminars and special lectures on emerging issues and new developments in agricultural sciences
- To disseminate knowledge among stakeholders through publication of proceedings, strategy papers and policy briefs
- To recognize and award the scientists of Indian and foreign origin for their outstanding contributions towards Indian agriculture
- To facilitate scientific interactions and partnership building of non-resident Indian agricultural scientists

Horticulture for Food & Nutritional Security

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1. Introduction

Horticulture has emerged as one of the potential agricultural enterprise in accelerating the growth of economy in India. It offers not only a wide range of options to the farmers for crop diversification, but also provides ample scope for sustaining large number of agro-industries, which generate huge employment opportunities. Diversification of horticulture has emerged as the best option for addressing nutritional adequacy, enhancing employment opportunities, farm income, use of natural resources and above all, emerging enterprises. The emerging trend worldwide and also in the country is indicative of a paradigm shift in dietary needs of the people, with rise in the income there is more demand of horticultural produce. In the current scenario, where more than 300 million people are malnourished, and millions of people are below poverty line, there is need for improving quality of life through ensuring food and nutritional security. Further, population of the country by 2050 is expected to be around 1,620 million of which 52 per cent will be living in urban areas falling under higher income brackets. It is estimated that per capita household demand of fruits (kg/year) will be 115.50 by 2050. With the global share of 2.3 per cent land, 4.2 per cent water, the per capita availability of these resources in India is 4-6 times less than the world average; the pressure on limited resources will increase further. Rise in population and per capita income would impact the demand of high-value crop produce (fruits, vegetables, meat, eggs, milk, and fish) and value added fruit products. The report of committee on Doubling Farmers Income (DFI), 2018, estimated that by the year 2022- 23, production level of 451 mt has to be achieved. The report states that it can be achieved through 2.8 per cent increase in area and 3.1 per cent in productivity (DFI, 2018). It is evident that from the year 2000 to 2016, horticulture has growth rate of 5.8 per cent owing to technological advancements, investment and enabling policy environment. Many new technologies pertaining to seeds and planting material, drip and fertigation, greenhouse, hydroponics, marketing models and quality assurance through branding have been adopted and the success stories are replicated. The past trend shows that target of production envisaged in 2000, for 2021 is achievable, as we have already reached the production level of 314.67 mt in 2018-19. Thus, there are several opportunities and challenges, which will need attention. The issues which require to be addressed are innovation in technologies through institutional support as well as import of knowledge and technological backing for development through skills. Development strategies should be for cluster approach linked with post-harvest management and marketing, quality seeds and planting material, precision farming and smart horticulture, environmentally controlled horticulture, and enhanced ICT use to add efficiency to input management, knowledge transfer etc., and major emphasis needs to be given to value chain development and management for better profits.

Indian horticulture development has many phases of growth, characterized by pleasantry, a hobby in pre-independent India, which moved further to adopt innovations in fifth phase of growth heralding Golden Revolution. Government of India (GoI) has accorded high priority for the development of this sector, particularly, since the VIII Plan and beyond, which has impacted production, reaching to 314.67 mt, in 2018-19, from 96 mt in 1990-91, contributing 34.45 per cent to the AGDP only from 15.08 per cent cropped area. This trend of development in horticulture has been termed as Golden Revolution. However, challenges to feed growing

population suiting to their dietary behavior and nutrition requirements, is demanding technology-led development, backed by enabling environment and resource utilization strategies. Change in dynamics of horticulture is now for health care through the use of horticultural produce for the treatment of many diseases, therapy, and environment services and above all to the improved quality of life. The paradigm shift necessitates for knowledge empowered human resources, who can provide leadership in technology development and policy formulation to attract investment, and keep the pace of development. Horticultural crops are now playing unique role in India's economy by improving the income of the rural populace and provide enormous opportunities to small and marginal farmers with higher return per unit of land than any other staple crops, besides overcoming vitamin and micronutrient deficiencies and is emerging as the main growth engine of Indian economy.

2. Status of Horticulture

India has a wide variety of climates wherein a large number of horticultural crops comprising fruits, vegetables, ornamentals, mushroom, plantation crops, spices and medicinal & aromatic crops are grown. After attaining independence in 1947, major emphasis was laid by the GoI for attaining self-sufficiency in food grain production especially cereals resulting in Green Revolution during the mid-sixties. After the situation on food front improved over the initial Five Year Plan periods, horticulture started getting due attention during the VII Plan period onwards. The reasons which attracted the attention of GoI on diversification to horticulture were due to significant fatigue in rice-wheat based cropping system and also increase in small landholdings making farming economically non-viable. Therefore, there has been a shift from the production of staple commodities to high value horticultural crops and its products fetching more income to farming communities. Horticulture has been found to be the best option in view of several advantages, namely, production of more energy resulting in high returns per unit area compared to field crops and earning more foreign exchange. These crops also have high potential for efficient utilization of wastelands, and need comparatively less water consumption than food crops. These are also rich sources of vitamins, minerals and carbohydrates and have thus assumed a great importance both in food and nutritional security. These crops have a high potential for value addition for sustaining large number of agri- and pharma- industries generating huge employment opportunities besides being environment friendly. The rapid change in demographic profile of the country is resulting in increased consumption of high value food items due to increased realization about their role in health and nutrition. In spite of global emphasis on cereal crops, there has been sustained interest in horticultural crops all over the world. In global trade, the share of horticulture produce and products has increased significantly. The fruit and vegetable production has been increasing throughout the world and particularly Asia contributes over 70 per cent share in the total world's production.

2.1 Drivers for Horticulture R&D

Starting with the VII Five Year Plan, the financial allocation for horticulture R&D rose tremendously from a meagre Rs 3.5 crores and Rs 25 crores in VII Plan to Rs 1050 and Rs 15,946 crores in the XII Plan, respectively (Fig. 1). The increase in budget was 300 times for research and 638 times for development between these plans which resulted in establishment of a sound R&D infrastructure and launching of several flagship programs.

2.1.1 Establishment of a Sound Research & Education Infrastructure

Horticulture Research and Education infrastructure in India witnessed a major boost during the last 35 years. After independence of the country, there were only 3 institutes, viz., Central Potato Research Institute (ICAR-CPRI) at Shimla, Central Tuber Crops Research Institute (ICAR-

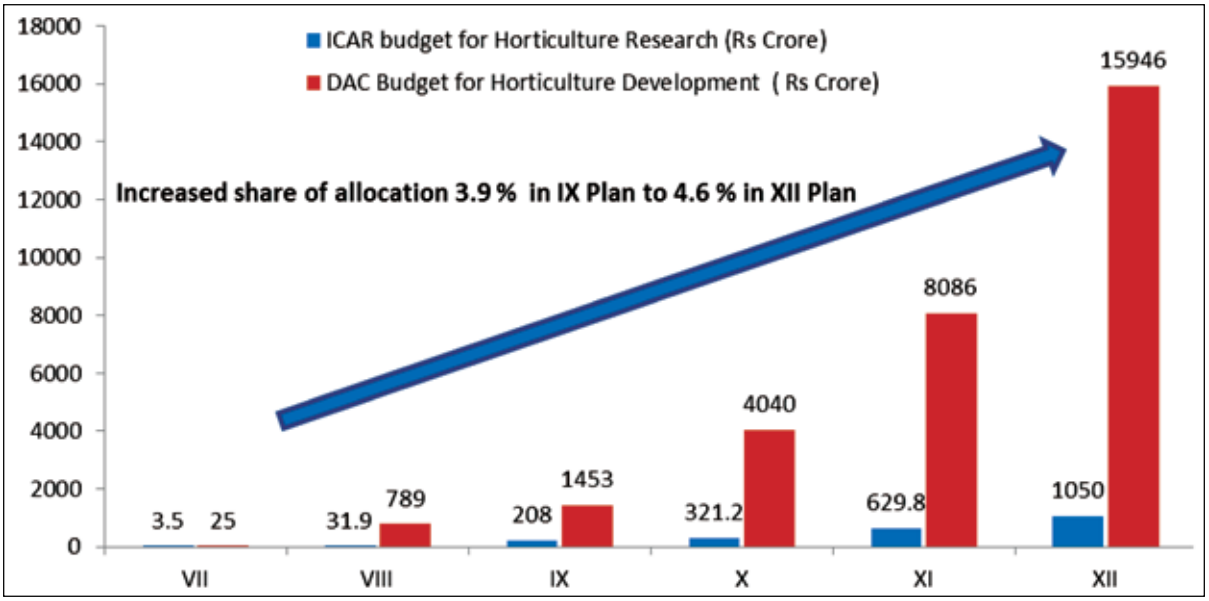

Fig. 1. *Plan expenditure in horticulture research and development in India*
Source : DAC&FW, 2019

CTCRI) at Thiruvananthapuram and Central Plantation Crops Research Institute (ICAR-CPCRI) at Kasaragod (Kerala). Subsequently, in 1967, the Indian Institute of Horticultural Research (ICAR-IIHR) was established in Bengaluru. However, major institutional development took place between 1985 and 1996 when a number of Institutes, Directorates and National Research Centres (NRCs) were established and simultaneously upgraded. These include, Central Institute of Subtropical Horticulture (ICAR-CISH), Lucknow; Central Institute of Temperate Horticulture (ICAR-CITH), Srinagar (J&K); Central Institute of Arid Horticulture, (ICAR-CIAH), Bikaner; Indian Institute of Vegetable Research (ICAR-IIVR), Varanasi; Central Citrus Research Institute (ICAR-CCRI), Nagpur;; Indian Institute of Oil Palm Research (ICAR-IIOPR), Pedavegi; and Indian Institute of Spices Research (ICAR-IISR), Kozhikode; Directorate of Onion & Garlic Research (ICAR-DOGR), Rajgurunagar, Pune; Directorate of Floricultural Research (ICAR-DFR), Pune; Directorate of Cashew Research (ICAR-DCR), Puttur (Karnataka); Directorate of Medicinal & Aromatic Plants Research (ICAR-DMAPR), Anand; Directorate of Mushroom Research (ICAR-DMR), Chambaghat, Solan; and National Research Centre for Banana (ICAR-NRCB), Tiruchirapalli; National Research Centre for Grapes (ICAR-NRCG), Pune; National Research Centre for Litchi (ICAR-NRCL), Muzaffarpur; National Research Centre for Orchids (ICAR-NRCO), Pakyong (Sikkim); and National Research Centre for Seed Spices (ICAR-NRCSS), Ajmer. Subsequently, the Central Island Agriculture Research Institute (ICAR-CIARI), Port Blair (Andaman & Nicobar Islands)) was transferred to Horticulture Science Division of ICAR and National Research Centre on Pomegranate (ICAR-NRCP), was also established at Solapur. As a result, the current infrastructure includes 12 Central Institutes with 25 regional stations, 5 Directorates and 6 National Research Centres. In addition, 13 All India Co-ordinated Research Projects (AICRPs) with 215 centres are also operative at different research institutes and State Agricultural Universities (SAUs). A number of Central Universities and SAUs including 7 Horticultural Universities, one each in Andhra Pradesh, Haryana, Himachal Pradesh, Telangana and Uttarakhand and 2 in Karnataka, 39 SAUs, 2 deemed to be universities, 3 CAUs and 3 CUs with horticulture discipline, and 52 colleges of horticulture have also come up to meet the growing requirement of specialised manpower in horticulture sector. Besides ICAR, a number of institutions under the aegis of GoI's departments, viz., DST, DBT, DoEF&CC; DRDO, Ministry of Commerce & Industry, Ministry of Food Processing Industries, etc. and CSIR have been working on different aspects of horticulture R&D.

2.1.2 Development infrastructure

For systematic development of horticulture, a large number of organizations have been established to promote the horticulture development in the country by Government of India under four Ministries, namely, Agriculture and Farmer's Welfare, Food Processing Industries, Commerce & Industry and Rural Development. Notable among them are the National Horticulture Board (NHB), Bee Board, Coconut Development Board (CDB), National Cooperative Development Corporation (NCDC), National Agricultural Cooperative Marketing Federation of India Ltd (NAFED), National Horticultural Research and Development Foundation (NHRDF), Small Farmers' Agri-Business Consortium (SFAC) under Ministry of Agriculture and Farmers' Welfare and Spice Board, Tea Board, Coffee Board, Rubber Board under the Ministry of Commerce & Industry to name a few. Separate Department of Horticulture have been established in most of the states. Even separate ministries dealing with horticulture have been carved out of agriculture departments in several of the horticulturally important states. A few Central and State funded institutions have been established like National Centre of Organic Farming (NCOF), Ghaziabad; Central Institute of Horticulture (CIH), Medziphema (Nagaland); International Horticulture Innovation and Training Centre (IHITC), Jaipur etc. to promote horticulture by GoI. The country also has the world's largest network on extension activities comprising 11 Agricultural Technology Application Research Institutes (ATARIs) and 720 Krishi Vigyan Kendras (KVKs) under the aegis of the ICAR for technology assessment, demonstration, transfer and capacity building. The horticultural R&D infrastructure in India is thus today one of the best in NARS compared to several of the advanced countries.

2.1.3 Launching of flagship programs

The main challenges to horticulture sector have been the investment and capital, access to technology and the initial learning curve to develop the required skills. The various universities and institutions are engaged in region and crop-specific education and research related to improvement, production and post-harvest management in horticultural crops. A large number of central sector schemes have been launched during the past few Five Year Plans for development of horticulture. An attempt to address many of the issues was made through mission mode approach to horticulture by launching of technology mission for development, to start with in North East in 1999, extending it to Himalayan states, the Technology Mission for North Eastern States and other Himalayan States (TMNE) in 2001-02, and to the whole country in 2005 as National Horticulture Mission (NHM), National Bamboo Mission (NBM) (2006-07), National Mission on Saffron (2010), etc. All the on-going schemes, however, now stand merged in the Mission for Integrated Development of Horticulture (MIDH), a centrally sponsored scheme launched for holistic growth of the horticulture sector covering all the horticulture crops. Mission and National Program on Micro-Irrigation ushered in horticulture revolution referred to as 'Golden Revolution', in the country, providing opportunity for the farmers to enhance farm income and attract educated youth to farming, as horticulture proved to be economically rewarding and intellectually satisfying. For doubling farmers' income, horticulture was identified to be a prime mover in achieving the targeted goal. National Agriculture Policy (2000) categorically emphasized on integrated development of horticulture, which should be knowledge based, technology driven and farmers' centric. The policy also emphasized on rural institutions, reforms and development of infrastructure. There is no policy document for horticulture, but focus has been given on post-harvest management in the policy paper of food processing industries. Most notably policy change is related to storage, processing and marketing of horticultural produce. Backward and forward linked marketing with reform in agriculture produce marketing act, encouragement for contract farming are some of important policy changes which are likely to impact production, quality and competitiveness of horticultural produce. Other area of reform needed is in aggregating of land law, which can help in better investment as well as adoption of technology. To enhance the delivery, there is a need for innovations in PPP mode for its better adoption in agriculture.

2.2 India - A Global Horticulture Stronghold

India occupies a place of pride in the world for production of different horticultural crops. From VIII Five Year Plan onwards, this sector has witnessed tremendous growth in area, production and productivity. As a result, India is now the second largest producer of fruits and vegetables in the world after China with a share of 12.2 and 10.7 per cent of total global production, though the fruit productivity is higher than China. Among fruits, India is the largest producer of banana (26.2%), mango and guava (41.9%), lemon and lime (16.4%), papaya (44.4%), pomegranate, sapota and *aonla*. India also produces 21.04 per cent of grape, 10.4 per cent of citrus fruits and 14.96 per cent of pineapple. Among vegetables, India is the largest producer of okra (73.6%) and pea in the world while second largest producer of potato (12%), dry onion (22.1%), brinjal (27.1%), tomato (11.1%), cauliflower (36.4%) and cabbage (11.9%). In plantation crops, India tops in coconut and areca nut production and is the second largest producer of cashew nut after Vietnam. In spice crops, India ranks first in the production of chilli (dry), coriander, fennel, aniseed, cumin, while in turmeric, garlic, ginger and small cardamom, India ranks second whereas in pepper, it occupies the third position.

2.3 Area, Production and Productivity of Horticultural Crops

The area under horticulture crops has increased from 12.8 mha in 1991-92 to 25.87 mha in 2017-18 resulting in cumulative increase of 99 per cent during the last 28 years. During the same period, total production increased from 96.6 mt to 314.67 mt registering a cumulative increase of 223 per cent. (Table 1 & Fig. 2) The average productivity also witnessed a significant increase from 7.5 to 12.3 mt/ha in the same period with cumulative increase of 62 per cent. The total production and average productivity of horticulture crops would have been much more but for the large areas under tree fruits, which remain in non-bearing stage for 3-5 years after planting. The area and production in different group of crops and their share in gross area and production of total horticultural crops is given in table 1. It can be seen that the share of vegetables including tuber crops in total area and production of horticultural crops was the highest being 40.34 per cent and 59.15 per cent, respectively during 2017-18 followed by fruit crops with the share in area and production being 25.58 per cent and 31.23 per cent. Plantation crops and spices contributed 14.72 and 15.25 per cent of the area while the lowest area and production at present are under floriculture, medicinal and aromatic plants. The sector-wise position is briefly given below:

Table 1: Area, Production and Productivity of Horticultural Crops

(Area: 000'ha; Production 000'tonne and Productivity : t/ha)

Crops	1991-92			2017-18			% Change			% share in 2017-18	
	Area	Prod	Prodty	Area	Prod	Prodty	Area	Prod	Prodty	Area	Prod
Fruits	2874	28632	10.0	6506	97358	15.0	126.4	240.0	50.2	25.58	31.23
Vegetables	5593	58532	10.5	10259	184394	18.0	83.4	215.0	71.7	40.34	59.16
Flowers (loose)	53*	233	4.4	324	1962	6.1	511.3	742.1	37.7	1.27	0.63
(Cut**)		555***			823			48.28			
M&A plants	192**	NA	NA	720	866	1.2	93.4	327.6	121.1	2.83	0.28
Spices	2005	1900	0.9	3878	8124	2.1	65.1	141.2	46.1	15.25	2.61
Plantation crops	2268	7498	3.3	3744	18082	4.8	99.1	222.8	62.1	14.72	5.80
Total	**12770**	**96562**	**7.6**	**25431**	**311714**	**12.3**	**126.4**	**240.0**	**50.2**	**100**	**100**

Data for Flowers* 1993-94; Cut flowers** in million No and M&A Plants***- 2004-05
Source: NHB, 2004-05; NHB, 2018

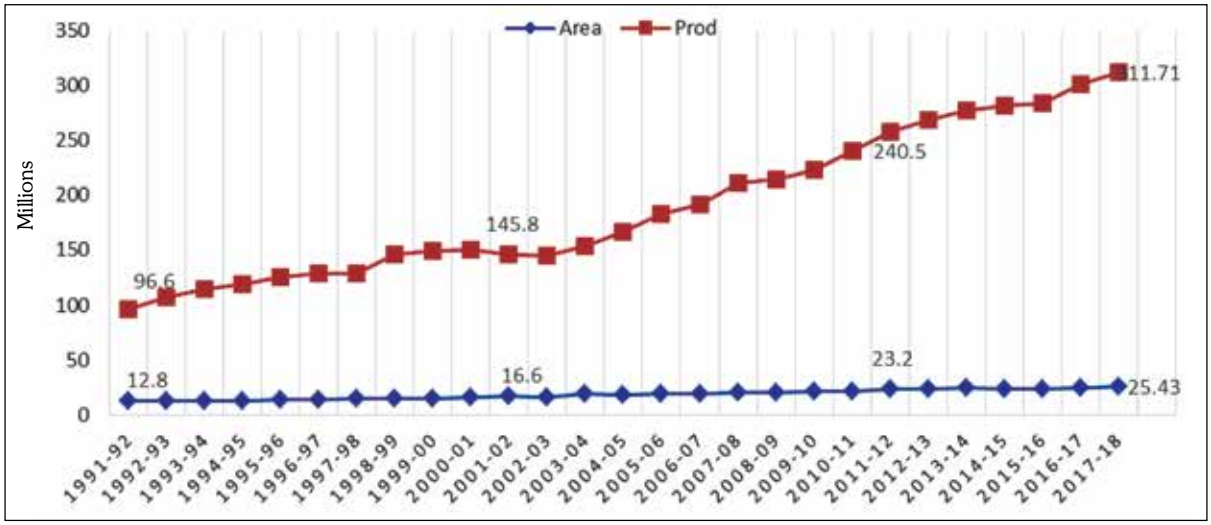

Fig. 2. *Trends in area (mha) and production (tonne) of horticultural crops during the period 1991-92 to 2017-18*
Source: http://nhb.gov.in/statistics; MoA&FW (2018)

2.3.1 Fruits

A large number of fruits such as banana, citrus, grape, guava, jackfruit, litchi, mango, papaya, pineapple, and sapota (tropical and subtropical); apple, peach, pear, plum, apricot, almond and walnut (temperate); and *aonla*, ber, pomegranate, custard apple (*Annona* sp.), fig, *phalsa* (arid zone) are grown in different parts of the country. Among fruits, banana and mango account for more than half (55%) of total fruit production, with production of banana alone accounting for about 33 per cent. Share of citrus fruits is also significant and these account for about 12 per cent of overall area under fruits. Andhra Pradesh, Maharashtra, Uttar Pradesh, Gujarat, Karnataka are the major fruit growing states. The area under fruits increased from 2.84 mha in 1991-92 to 6.51 mha in 2017-18. The production in the same period increased from 28.63 to 97.36 mt. From 1991-92 to 2017-18, area, production and productivity of fruit crops showed a change of 126.4, 240 and 50.2 per cent, respectively. During the same period, the productivity increased from 10.0 mt/ ha to 15.0 mt/ ha mainly due to improvement in the availability of quality planting material, adoption of hi-tech horticultural practices including high density planting, canopy management and micro-irrigation. While, the productivity per unit area in India is higher than the China, later excels in total production. The per capita availability of fruits at present is 202 g per person/day.

2.3.2 Vegetables

More than 40 vegetables belonging to solanaceous, cucurbitaceous, leguminous, cruciferous (cole crops), root crops and leafy vegetables are grown in the tropical, subtropical and temperate regions of India besides potato, tuber crops and mushroom. Important vegetable crops grown in the country are beans, bottle gourd, brinjal, cabbage, carrot, cauliflower, chilli, cucumber, okra, onion, pea, pumpkin, radish, and tomato. Uttar Pradesh is the largest vegetable producing state followed by West Bengal, Madhya Pradesh, Bihar, Gujarat, and Maharashtra and Odisha. The area under vegetable crops increased from 5.59 mha in 1991-92 to 6.76 mha in 2004-05 and 10.25 mha in 2017-18. The production during the same period increased from 58.53 to 101.43 and 184.39 mt. Between 1991-92 and 2017-18, productivity of vegetable crops increased from 10.5 mt/ ha to 18 mt/ ha mainly due to improvement in the quality seed production, adoption of high-yielding cultivars, F_1 hybrids and disease and pest resistant varieties with suitable production technologies. The per capita availability of vegetables at present is 384 g per person/day.

Potato is the leading tuber crop among vegetables, occupying 20.88 per cent of area (2.14 mha) and contributing 27.83% (51.31 mt) of the total vegetable production in India. Its

productivity has increased from 14.7 mt in 1991-92 to 23.95 mt/ha in 2017-18. Production and supply of quality planting material, high yielding, disease and pest resistant varieties and technologies suited to different regions enabled to enhance the productivity. There are also 15 different other root and tuber-producing vegetables grown in our country. These include 2 major crops (cassava and sweet potato); aroid species (*Calocacia*, *Amorphophallus*, *Xanthosoma*, *Alocacia* and *Cyrtosperma* sp.); yams (lesser, greater and white yam) and minor tuber crops (yam bean, coleus, arrow root etc).

Another vegetable crop with high nutritional value and export potential is makhana (*Euryale ferox*). Its total production is estimated at 5,000 tonnes with 80 per cent being produced only in northern part of Bihar state. There is scope for promoting its cultivation besides opportunities for investment in makhana processing units.

2.3.3 Mushroom

Mushroom production in India had a beginning in late sixties in Himachal Pradesh and Jammu and Kashmir. Commercial mushroom production, however, is a few decades old. The production of mushroom has been increasing at a fast pace from 17,000 t in 2013-14 to 1,29,782 t in 2015-16 and 487,000 t in 2017-18. Of this, 75 per cent production is under button mushroom (*Agaricus bisporus*), 16.66 per cent under *Pleurotus* sp., 7.14 per cent under paddy straw mushroom (*Volvariella volvacea)* and the remaining 3.30 per cent under the two less commonly cultivated species *Calocybe indica* and *Lentinula edodes*. Mushroom demand is growing at the rate of 25 per cent per year and its cultivation and spawn production offer establishment of small scale enterprises option. Mushrooms have excellent food value and their cultivation can eliminate protein malnutrition besides providing remunerative employment opportunities. Some specialty mushrooms like Shiitake, *Cordyceps militaris* or *Ophiocordyceps sinensis* are also being collected from natural environments from Himalayas.

2.3.4 Floriculture

India is known for growing a number of traditional flowers such as jasmine, marigold, chrysanthemum, tuberose, crossandra and aster. Commercial cultivation of cut flowers, e.g. roses, orchids, gladiolus, carnation, anthurium, gerbera and lilies has also become popular particularly under protected cultivation. West Bengal leads in cut flowers production followed by Chhattisgarh. Tamil Nadu is the leading producer of loose flowers followed by Andhra Pradesh (mainly Kadiyam area), Madhya Pradesh and Karnataka. However, total share of floriculture in horticulture crop production of the country is at present quite insignificant being 1.2 per cent. The area under floriculture has however increased from 53,000 ha to 3,24,003 ha while production of loose flowers from 2,33,000 to 19,62,000 tons of loose flowers annually between 1993-94 and 2017-18. The production of cut flowers has reached 823 million flowers annually during 2017-18.

2.3.5 Plantation crops

There are two groups of plantation crops, namely, coconut, areca nut, oil palm, cocoa and cashew nut dealt by the Ministry of Agriculture & Farmers' Welfare and tea, coffee and rubber dealt by the Ministry of Commerce & Industry. There is a sizeable area under plantation crops in India. These crops are primarily concentrated in South India in the states of Kerala, Tamil Nadu, Karnataka and Andhra Pradesh contributing about 68.19 per cent of area and 81.73 per cent of total production. Tamil Nadu has reported the highest productivity of 6.78 mt/ha. Kerala accounts for the highest area of 26.45 per cent and production of 31.78 per cent whereas Andhra Pradesh accounts for 8.52 per cent area. The area under plantation crops has increased from 2.27 mha in 1991-92 to 3.74 mha in 2017-18 resulting in cumulative increase of 65 per cent during the last 28 years. During the same period, total production of plantation crops increased from 7.50 mt to 18.08 mt registering a cumulative increase of 141 per cent. The average productivity also witnessed a significant increase from 3.3 to 14.8 mt/ha in the same period with cumulative increase of 45.5 per cent.

Coconut has the largest share of area (56.0% of 2.1 mha) followed by Cashew nut (28.63%; 1.06 mha), while 91 per cent production is contributed by the coconut among all plantation crops. Cocoa cultivation has been gaining momentum in Kerala, Andhra Pradesh, Tamil Nadu and Karnataka. The area and production under cocoa in India is reported as 82,940 ha with a total production of 1,89,200 t and average productivity of 580 kg per hectare. Currently, the country is importing 60 per cent of its demand for cocoa from other countries.

2.3.6 Spices

India is known as the home of spices as it is now the largest producer, consumer and exporter of spices and its products in the world. India produces over 50 spices including black pepper, cardamom (small and large), chilli, coriander, cumin and garlic, ginger, turmeric and a variety of tree and seed spices which contribute 2.2 per cent of the total horticulture crops production in the country. Chilli, garlic and ginger account for a major share in spice production. The spice production in India is of the order of 8.12 mt from an area of about 3.78 mha. Major spice growing states are Rajasthan, Andhra Pradesh, Madhya Pradesh, Gujarat, Kerala, Tamil Nadu and Karnataka. Area and production of spices in the country have registered substantial increase during the last 20 years with average increase of 93.4, 327.6 and 121.1 per cent in area, production and productivity, respectively.

2.3.7 Medicinal and aromatic plants

India is considered a trove of medicinal and aromatic plants. These plants provide raw material for the formulation of indigenous medicines, production of flavours, herbal cosmetics, perfumery, etc. The agro-climatic conditions of India provide an ideal condition for natural growth of a variety of medicinal plants and herbs important in pharmaceutical industry. An estimated area of 7,20,000 ha area is reported during 2017-18 under cultivation of important medicinal and aromatic plants with an annual production of 8,66,000 t. National Medicinal Plant Board (NMPB) has prioritised 32 medicinal plants for their cultivation. Important species of medicinal plants cultivated include *Aloe vera, ashwangandha, bach*, *brahmi*, *Coleus, Dioscorea*, *guggal* glory lilly, *isabgol, kalmegh, patchouli*, periwinkle, *sarpgandha* and *satavari*. Some important aromatic plants commercially cultivated include lemon grass, vetiver, *patchouli*, palmarosa, citronella mints, geranium, lavender, basil, jasmine etc.

2.4 Horticulture Trade

The trade in horticultural crops has become increasingly globalized. This has been possible because of advanced technology, change in consumer preferences, and year round supply. As a result, large volumes of fruits and vegetables more from one continent to another, reducing seasonality of produce market. Also, multiple, regional and bilateral trade agreements and reduction of tariff barrier as a result of World Trade Organization (WTO) negotiations, have further boosted the trade and access to markets, thus providing consumers with an expanding array of fruits and vegetables.

2.4.1 Exports: Gaining high grounds

India exports a wide range of horticultural produce and products to other countries. Important fruits exported include mango, banana, papaya, guava, pomegranate and walnut, while important vegetables exported are onion, okra, bitter gourd, green chillies, potato and mushroom. The export from India has enhanced 22 times during the last 27 years. These have been gaining higher ground over past several years and have shown a growth of about 12 per cent annually. The fresh and processed products including mango pulp, dried and preserved vegetables and 'other' processed fruits and vegetables together constitute about 28 per cent of the total exports. The value of total horticulture crops exported increased considerably from

Rs. 28,785 million in 1991-92 to Rs. 6,22,758 million during 2017-18. Plantation crops and spices together contributed 65 per cent of exports followed by fresh fruits and vegetables (14%) (Table 2). Of the 60 agri-export zones identified in the country, 52 focus on horticulture crops. Major export destinations for Indian horticultural produce and products include Bangladesh, Malaysia, Nepal, the Netherlands, Pakistan, Qatar, Saudi Arabia, Sri Lanka, UAE and UK. The loose flowers are exported to gulf, while dry flowers to USA, Japan, Australia, Russia and European countries. The total flower exports during 2017-18 were Rs. 50,731.24 lakh.

2.4.2 Imports: Nullifying the exports

The import value of all horticulture products in 2016 was of the order of US$ 6943 million resulting in about 10-fold increase in import in the last two decades resulting from phasing out of quantitative restrictions (Fig. 3). In recent years, import of horticultural crops has been increasing for meeting local requirements of certain commodities. Starting in the second half

Table 2: Export performance of different groups of crops based on value of exports (lakh Rs.)

Produce/Product	1991-92	2001-02	2011-12	2017-18	CAGR (%)
Fresh fruits & vegetables	28065.9	94812.4	456986.2	892747.9	13.67
Processed fruits & vegetables	9680.9	72359.1	422922.1	861652.4	18.09
Fruits & vegetables seeds	1609.2	6456.6	28776.4	67089.6	14.82
Floriculture	1480.2	11532.5	36532.2	50731.2	13.99
Spices*	38096.0	194054.9	1322023.0	2008491.0	15.82
Plantation crops* (Coconut**, Cashew nut Areca nut, Cocoa)	52793.0	197911.0	546424.7	888657.0	11.02
Tea* and Coffee*	156126.0	281414.0	861315.0	1164201.0	7.73
Herbal products*	-	-	169697.0	294006.0	2.06
Total	**287850.9**	**858541.0**	**3844677.0**	**6227576.0**	**12.06**

Source: APEDA (2019); *http://nhb.gov.in/ statistics; **CDB (2017-18)

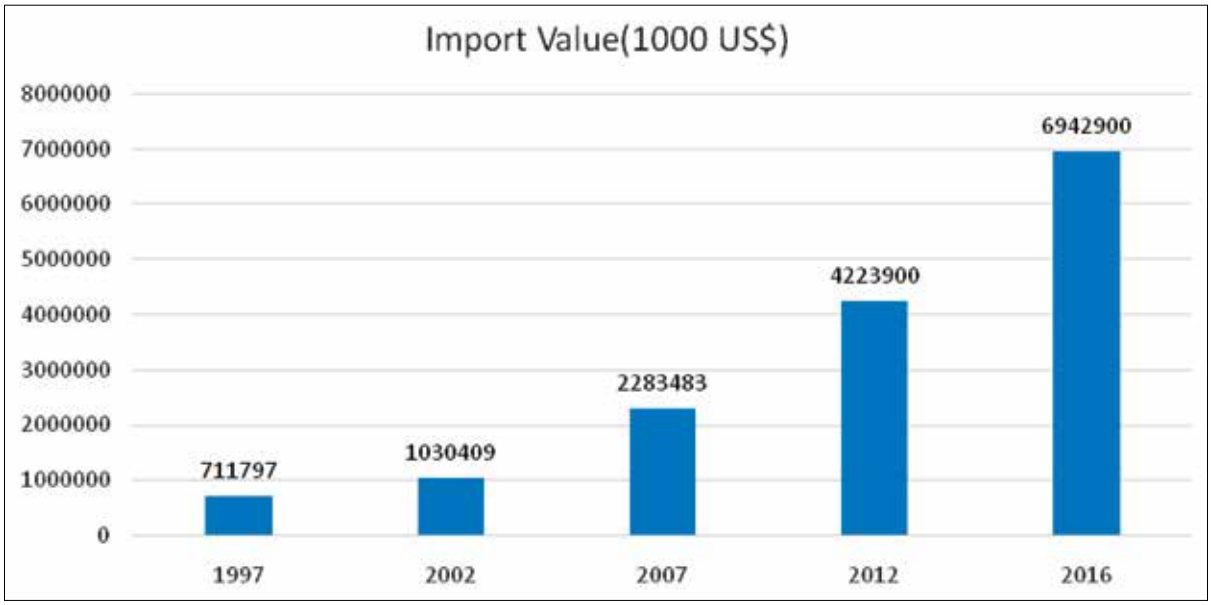

Fig. 3. *Import value of different horticultural crops;* Source : FAOSTAT, 2019

of the 1990s imports of fresh fruits, especially apple, have risen considerably. However, import penetration remains insignificant in terms of the share in total consumption. Import of fresh fruits, however, is about 1 per cent of domestic production, and is also negligible for most fresh vegetables. Many fruits and vegetables produced in India are also being imported in India on a large scale. The import of total horticultural produce and products are growing at the rate of 0.56 per cent in quantity and 2.93 per cent in value. The highest growth rate both in quantity and value was seen in fresh vegetables, followed by spices and fresh fruits import. Growth has also been rapid for import of certain processed products like juices and dried vegetables, though the single most dominant item in this category continues to be dried peas. At present, India is importing 23,70,476 tonnes of produce and products valued at Rs. 3,27,342 million (Table 3). The countries from which these crops are imported are United States of America, Pakistan, Sri Lanka, China and Iraq respectively. Among plantation crops, cashew nut accounts for the largest share in imports both in quantity and value but the large quantity of this is exported after processing. It is mainly imported from Ivory Coast, Guinea, Tanzania and Nigeria. Imports of some commodities are adversely affecting the domestic market. For instance unchecked import and rampant adulteration of saffron from Iran is pushing prized saffron production in Jammu and Kashmir to the verge of extinction.

Table 3: Import of principal horticultural commodities during last 3 years

Produce/ Product	2011-12		2015-16		2017-18		CAGR (%)	
	Qty (t)	Rs. Lacs	Qty (t)	Rs. Lacs	Qty (t)	Rs. Lacs	Qty (t)	Value
Fresh fruits	723271	461083.62	839543	1107156.92	994701	1252453	1.19	3.77
Fresh vegetables	5040	731.24	140728	39444.72	15656	2563.99	4.29	4.76
Processed fruits & juices		31493.4	38962.5	52648.89	53613.07	80333.02	1.19	3.53
Processed vegetables	0	12019.12	15379.02	12033.21	15023.85	13385.57	-0.09	0.40
Fruits / vegetable seeds	13180.92	38014.6	14328.07	70303.49	16043.61	76448.82	0.73	2.62
Floriculture	0	6863.54	4768.81	11440.01	6243.19	13646.07	1.00	2.58
Spices	146767.74	228484.58	193437.5	539994.73	220665.8	637750.1	1.52	3.87
Plantation crops (Coconut**, Cashew nut Areca nut, Cocoa)	1082102.24	652595.38	1215049.3	1048581.56	946569.7	1061638	-0.49	1.82
Tea	22429.49	21890.97	23722.24	37746.54	24742.93	35548.61	0.36	1.81
Coffee	46055.69	46951.67	65612.8	80183.28	77217.19	99650.67	1.93	2.83
Total Horticultural imports	**2038847.08**	**1500128.12**	**2551531.24**	**2999533.35**	**2370476**	**3273418**	**0.56**	**2.93**

Source: APEDA (2019); *http://nhb.gov.in/ statistics; *MoA&FW (2018); **CDB (2017-18)

3. Major Technologies Developed

Several new technologies have been developed by farmers and adopted to improve the production, productivity and post-harvest management of horticultural crops by different research and development organisations in the country.

3.1 Production of Planting Materials and Seeds

Horticulture sector is facing an acute shortage of planting material as most of the nurseries are unorganized and government agencies are unable to provide adequate quantity of quality planting material to the farmers. As per government estimates, hardly 30-35 per cent of the requirement of planting materials for horticultural crops is met through public sector agencies like SAUs, ICAR institutes, state seed agencies, and such others. There is dire need to make available large number of planting material in different horticultural crops to fill the gap of 65-70 per cent requirement so that most of the farmers who do not have access to elite certified planting material and face the problem of low production and productivity and quality of produce, may have access of quality planting material and benefit from good produce. Massive area expansion requires improved varieties for re-planting, planting in marginal and arid areas.

3.1.1 Improvement in conventional methods

This has been one of the priority area of R&D in horticulture. For propagation of high quality planting material, vegetative propagation techniques have been standardised in most fruit crops and standards for accreditation of nurseries have been developed and are being enforced by the National Horticulture Board (NHB). Techniques for mass production of seedlings in green house have been developed and commercialised in vegetable and flower crops. Vegetable nurseries have been established for plug plant production in many states both in public & private sectors. Grafting in cucurbitaceous and solanaceous vegetables is now possible and is being commercially exploited. Cytoplasmic male sterile (CMS) lines have been developed for production of hybrid seeds in several vegetables namely, chilli, brinjal, tomato, carrot and onion. In potato, seed plot technique has been developed to enable seed production in north Indian plains. True potato seed (TPS) technology has also been developed and is being commercially used particularly in Tripura. In tuber crops, mini set technique has been developed as a viable technology to produce large scale planting material and enhanced multiplication ratio. In coconut, DxT and TxD hybrid plant nurseries have been established to promote use of hybrid plants. In cashew nut, large scale planting material is being produced through wedge grafting. PCR based diagnostics protocols have been developed for rapid detection of citrus greening and tristeza viruses, while ELISA and immunospecific electron microscopy (ISEM) for early detection of several diseases of asexually propagated plants like banana, potato, sweet potato, etc.

3.1.2 Micropropagation

Technology for micropropagation is now available in India in over 200 horticultural crops and provides scope for round the year multiplication of disease free planting material. Micropropagation has been commercially adopted for propagation of banana, papaya, strawberry, vanilla, date palm, small and large cardamom, gerbera, *Chrysanthemum*, carnation, anthurium, orchids, syngoniums and ferns. Shoot-tip grafting is being used commercially for propagation in citrus and for salt tolerant rootstocks used in grape in most grape growing region.

3.2 Crop Improvement

3.2.1 Development of superior clones and varieties

Lot of emphasis has been laid on development and popularisation of superior clones, varieties and hybrids in various horticultural crops. A total of 1,596 improved varieties have been developed with high productivity, good quality, pest and disease resistance and tolerance to abiotic stresses. Of these, 146 superior clones and varieties have been identified/ developed in 24 fruit crops. These include highly coloured, dwarf and regular bearing varieties of mango; gyno-dioecious and dwarf varieties of papaya; soft seeded and colour fleshed guava and pomegranate varieties; low chilling varieties of temperate fruits namely pear, peach and plum;

clonal selections and varieties in mango, grape, sapota, passion fruit, lime, *bael,* jackfruit, *jamun* and walnut. High yielding varieties have also been developed in *aonla* and *ber* and high pulp content varieties in custard apple.

As many as 485 varieties (including pure line selections and 155 hybrids) have been developed in different vegetable crops. A number of F_1 hybrids have been developed in ash gourd, bitter gourd and bottle gourd; cabbage and cauliflower; brinjal, capsicum and tomato; okra and watermelon. In addition, a number of varieties tolerant or resistant to major diseases and pests e.g. bacterial wilt in brinjal, chilli, sweet pepper and tomato; bacterial blight in cowpea and french bean; powdery mildew in chilli, pea and watermelon; downy mildew in muskmelon and watermelon; yellow vein mosaic in okra and fruit and shoot borer in tomato have been developed. Chilli cultivars resistant to aphid, mite, thrips and a tomato variety resistant to root knot nematode have also been released. Varieties tolerant to climatic stresses e.g., high/low temperature, high humidity and salt tolerance have also been developed in cauliflower, cabbage, tomato, carrot, radish and turnip. In potato, 48 varieties have been developed for different agro-climatic regions including varieties resistant to late blight and several varieties suitable for processing. Over 85 varieties have been released in tropical tuber crops including sweet potato (37), cassava (16) and different yams. Eight strains have been developed for commercial production in mushroom.

Commercial varieties developed in flower crops cover bougainvillea, China aster, *Chrysanthemum*, crossandra, marigold, rose and tuberose. A number of 124 varieties in medicinal plants and 8 in aromatic crops have been developed with high yields and nutraceutical content to minimize over exploitation of the natural wealth available in the forests thus enabling commercial production of many medicinal and aromatic crops in the horticulture based cropping systems. Besides a number of F_1 hybrids are also being made available by the private sector in vegetable and ornamental crops.

In plantation crops, 217 varieties have been released. These include coconut varieties with high fruit, copra and oil yield besides use as tender coconut. A number of improved varieties with high yield potential have also been released in areca nut. In cashew, 42 superior varieties, 29 developed through selection and 13 hybrids have been released, many of which are now under commercial cultivation. In spices, 106 varieties in 15 spice crops have been released by various organisations for different traits including higher yield and superior quality.

3.2.2 Introduction and commercialisation of less exploited crops

While continuing to grow the traditional fruit crops, a number of less-exploited new crops namely, kiwi (*Actinidia chinensis*), kokum (*Garcinia indica*), passion fruit (*Passiflora edulis)*, leh berry *(Hippophae rhamnoides),* oil palm (*Elaeis guineensis***)** and noni *(Morinda citrifolia)* have been introduced on a commercial scale in India. Emphasis has also been laid on promotion of non-traditional fruits like custard apple, fig, *aonla,* ber, pomegranate, date palm through development of new varieties and technologies resulting their expansion in large areas in different parts of the country. Limes and lemons have revolutionized citrus production, thereby ensuring year round availability. Many exotic temperate vegetables, namely, asparagus, broccoli, brussels' sprout, cherry tomato, baby corn and mushrooms are also now a part of Indian cuisine. Introduced from New Zealand, kiwi fruit has been commercialized in North West and North East (Sikkim, Meghalaya and Arunachal Pradesh) hills of India. A tree borne oilseed fruit crop reported to be introduced in India from Zanzibar, Kokum is growing wildly in tropical rain forests of Western Ghats in Konkan, Goa, Gujarat (Surat district), West Bengal, south Karnataka, Kerala and evergreen forests of Assam, Khasi and Jaintia hills. It has been commercialized through large scale use of a number of improved varieties released by the DBS Konkan Krishi Vidyapeeth, Dapoli, (Maharashtra). Amrita (S-8) released in 1998 is now commercially adopted in several states. Introduced from

Sri Lanka, passion fruit is a high value export oriented crop. A new variety of passion fruit, named 'Kavery' has been developed by crossing green variety of passion fruit with purple variety from Sri Lanka at ICAR-IIHR Central Horticultural Research Station, Chethalli. Commercial cultivation of passion fruit is now underway in Nilgiri hills and Kodaikanal (Tamil Nadu and Kerala), Kodagu (Karnataka) and north-eastern states. Four processing units have already been installed and are producing passion fruit juice. A multipurpose, medicinal and nutraceutical fruit, seabuckthorn (Leh berry) available wild/grown in forests is now being commercially promoted in high altitude cold desert regions of Himachal Pradesh and Jammu & Kashmir. A refreshing product named 'Leh berry juice' from this fruit is already available in the market. Among vegetable crops; gherkin, baby corn, cherry tomato, broccoli and asparagus are now grown widely on a commercial scale. A large number of exotic flower crops have also been introduced and grown in the country, notably, *Lilliums*, tulips, *Alstromeria*, gerbera, *Lisianthus*, besides the leading flowers viz., rose, carnation, and chrysanthemum grown under protected structures. Mushrooms, are now well accepted both in peri-urban and rural areas and have become a part of Indian cuisine. Oil palm cultivation has been successfully adopted in several states of India. Massive area expansion has been planned in bamboo under the National Bamboo Mission launched by the Government of India.

3.2.3 Transgenic crops

Though India has R&D program for GM based crop varieties, no GM variety is being cultivated commercially except Bt cotton. However, many biotech varieties in horticultural crops are under different stages of development. With the current regulatory system in the country, the interest of people cannot be protected. To harness the benefits of GM crops, it is necessary that clear policy on GM food crops is in place at the earliest. Global area under transgenics has increased from 102 mha in 2006 to 189.9 mha in 2017. So far, 24 countries are growing genetically modified (biotech) crops and India now ranks 5th in total area (11.4 m ha; 6%) under cotton, behind the corresponding areas for USA (73.1 mha, 40%), Brazil (42.2 mha, 26%), Argentina (24.3 mha, 12%) and Canada (13.1 mha, 7%). Transgenic fruit varieties have been developed in a number of horticultural crops, e.g., banana, grape, papaya, plum and strawberry worldwide. In vegetables, transgenics have been developed in cabbage, cauliflower, tomato, muskmelon and watermelon. Commercial transgenic varieties have been developed by Australia, Canada, China, India, Japan, the Netherland, Russia and USA while 18 countries including Bangladesh, India, Philippines, South Korea, Mexico, Colombia, USA, Norway, Canada, Australia, Japan and European Union are cultivating these varieties in over 50,000 ha area.

3.3 Production Technology

3.3.1 Canopy management/ high density planting

Technologies of canopy management and high density planting (HDP) are being standardised in fruit crops for higher productivity and better quality produce e.g., in mango, guava, litchi, citrus, grape, pomegranate, papaya, pineapple, cashew nut and coconut. Technology for meadow orcharding through HDP and canopy management has also been standardized in guava. Coconut and areca nut based high density multi-species cropping systems have been developed for better productivity and stability of income in Kerala.

3.3.2 Efficient use of inputs

Effective water and nutrient use efficiency has been achieved through introduction of micro-irrigation and fertigation (application of 100% soluble fertilisers through irrigation). Its requirement in several fruit, vegetable and plantation crops has been standardized. Tissue culture plants coupled with micro-irrigation and fertigation have increased considerably per ha yield and quality in banana in Maharashtra. Balanced use of inputs coupled with proper choice of varieties, salt and

drought tolerant root-stocks have revolutionized grape production in the country. Use of dwarfing rootstocks and improved training systems has resulted in manifold increase in yields in apple. Large scale expansion of area under micro-irrigation and promotion of beehives in horticultural plantations have enhanced productivity of crops. Sampling techniques and optimum leaf nutrient standards have been developed for several perennial crops to enable better fertilizer management.

3.3.3 Use of growth regulators and biostimulants

Several plant growth regulators, biostimulants and chemicals are now being commercially employed by the farmers for improving productivity and quality of horticultural crops. These include- IBA for rooting in cuttings, dormex for hastening bud break in grape, paclobutrazol for flower induction in mango, ethrel for flowering in pineapple, urea sprays for crop regulation in guava, NAA and 2,4 D for control of fruit drop in mango and citrus, and gibberellic acid (GA) in improving berry elongation and quality of grape. Maleic hydrazide is also being used as a sprout suppressant in potato and onion for prolonging storage life. Certain bio-stimulants, microorganisms other than fertilisers affect plant growth when applied to crops in low quantities. Biostimulants like microbial *Trichoderma* spp. and non-microbial sea weed extracts have helped in enhancing yield and quality of greenhouse grown vegetables, such as spinach, lettuce, zucchini, squash etc. through stress.

3.3.4 Rejuvenation and replanting

A large number of plantations are old and senile and require rejuvenation or replanting. Rejuvenation technology has been developed for such crops like mango, guava, *aonla*, litchi, apple etc. Such plants re-fruit and give commercial crops within three to four years of rejuvenation treatment. Best time of rejuvenation pruning is December-January. A project on coconut and apple replanting has also been undertaken in Kerala and Himachal Pradesh respectively.

3.3.5 Mechanisation

While India has 3.2 million tractors (largest number in the world), most field operations are carried out manually or with animal power. However, several tools and implements have been developed to enhance efficiency of field operation. These include: tractor operated pit hole digger and tractor drawn implements for potato cultivation from sowing to harvesting, Fruit harvesters for mango, guava, sapota, pomegranate and citrus including manually portable ladders and tractor drawn hydraulically operated platforms and a tree climber for coconut have also been developed to help in harvesting. Seed and fertilizer drills for several vegetables and potato, graders and washers developed by different institutes have also become popular among the growers. Automatic grafting machines available in advanced countries have also been procured and are being adopted. Self-propelled pruners for tree crops and vineyards are now available with some growers. Media sievers and plastic bag fillers for nurseries are also now available.

3.4 Alternate Horticulture Systems

A number of alternate horticulture crop production systems developed in various countries have been successfully introduced and successfully adopted in India. These include:

3.4.1. Protected cultivation

It is gradually becoming popular for production of quality horticultural crops, namely, strawberry, tomato, cucumber, capsicum, rose, gerbera, lilium, etc. Aeroponics is emerging as a hi-tech area of horticulture crop production and is already being exploited for multiplication of potato seedlings and production of some leafy vegetable crops on a commercial scale. Hydroponics and vertical farming with soil-less cultivation are also getting popular with certain groups of enthusiasts in metropolitan cities.

3.4.2 Peri-urban & urban horticulture

It is emerging as a new area for cultivation of horticulture crops grown for human consumption and ornamental use within the surroundings of urban areas.

3.4.3 Organic farming

It has emerged as a popular alternative in areas with depleted natural resources and a number of states have been declared fully organic particularly in the North East India, e.g., Sikkim, Meghalaya, and Mizoram.

3.5 Post-Harvest Management

3.5.1 Handling

Tremendous improvement has been made in harvesting, ripening methods, packaging, storage, transport and overall handling of horticultural crops. This includes: i) improvement in packaging technologies which is evident from the product range available in the retail chains, super markets and hyper markets; ii) storage capacity of horticultural produce in the country has increased over the years with the establishment of a large number of produce specific cold storage units; iii) controlled atmosphere (CA) storage and bulk storage facilities. Better post-harvest management of flower crops has resulted in mushrooming of a large number of florist shops both in metropolitan cities and small towns; iv) a well-developed dry flower industry is also now established in the country; v) post-harvest management of mango through vapour heat treatment has made mango exports to USA and Japan a reality; and vi) irradiation facility for potato and onion for long duration storage has become a reality; and massive infusion of private investment is being made in postharvest management & retail marketing of horticultural produce.

3.5.1 Value addition

Several new products and technologies have been developed and commercially exploited both by public and private sector. These include raisin and wine production (grape), chips and fingers (potato), concentrate (banana), gherkin in brine, pouched coconut water, snowball tender coconut etc. Several dehydrated and other products, juices from several crops like passion fruit, Leh berry, pomegranate, noni, etc. have been commercialized. Consumer-friendly products like frozen green peas, ready to use salad mixes, vegetable sprouts, ready-to-cook fresh cut vegetables, and ready to use cooked vegetables are now major retail items. Pigment extraction from flowers especially marigold, calendula etc., has assumed commercial proportions leading to exports of nutraceuticals.

4. Food to Nutritional Security

This is consecutively seventh year when production of horticultural crops surpassed food grain production. Starting from 2012-13 with 269 mt production against 257 mt of food grains, it has touched 311.71 mt in 2017-18 against 284.83 mt of food grains and in 2018-19, it has increased to 314.67 mt as against 281.37 mt of food grains. This has been possible due to proactive government policies, increased infra-structural support, as well as farmers' zeal due to growing market and a quicker cash flow (Fig. 4).

Seeing the world scenario, the present availability of food grains, and fruits and vegetables is not adequate either to meet the food or nutritional requirements of the increasing population. The global production of food grains during 2017 was 2980.17 mt with a population of 7.6 billion. The world's population is expected to grow to almost 10 billion by 2050. The population is moving from rural areas to urban locations particularly in the developing countries and as a result rural population is estimated to increase 30 per cent by 2030 from 71 per cent in 1950 (FAO, 2017).

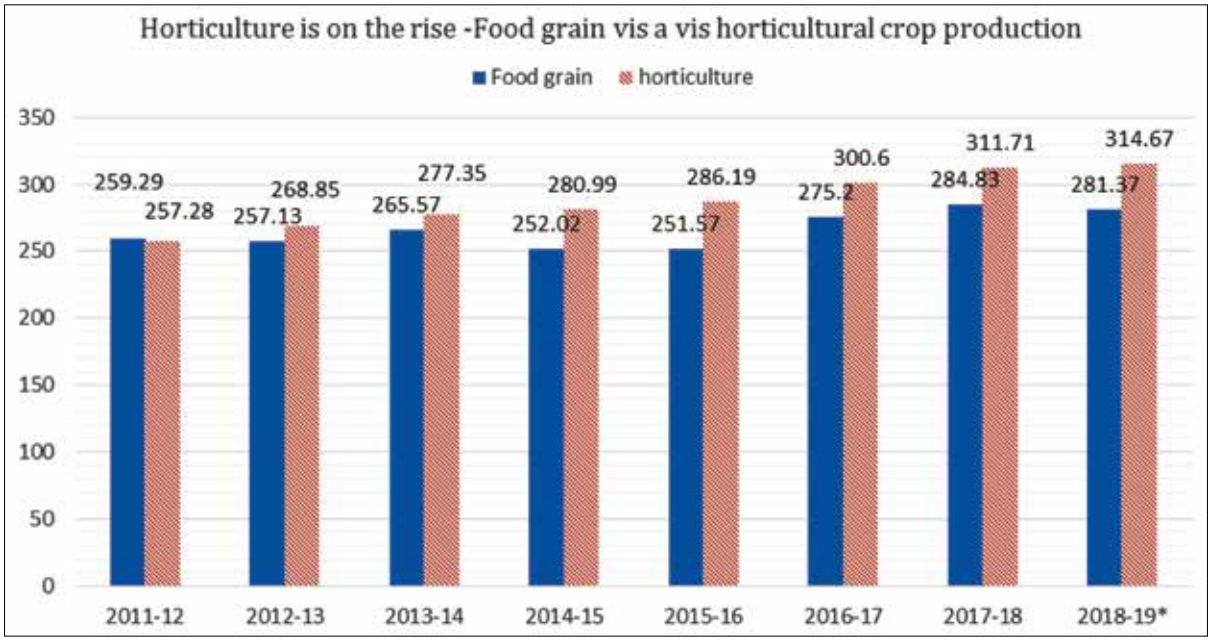

Fig. 4. *Foodgrain vis-à-vis horticultural crop production since 2011-12*
Source: DAC&FW Annual Report, 2018-19

As per ICAR Vision 2030, the demand for fruits and vegetable would increase to 110 and 180 mt, envisaging an increase of 155 and 95 per cent, respectively over the base year of 2000. At present, food security is primarily addressed through access to adequate food grains which does not seem feasible. There has to be therefore, increasing emphasis on horticulture crop production to meet both food and nutritional security in view of malnourishment, changing dietary pattern, limited land and shrinking water resources, yield plateauing in different crops and climate change.

About 815 million people of the 7.6 billion people in the world, are suffering from chronic undernourishment and around 12.9 per cent share belongs to developing countries, including two thirds in Asia and South Asia. About 2.1 billion people are overweight or obese. Consumption especially of fruits and vegetables has also increased at an annual growth rate of 18 to 21 per cent for fruits and 10 to 15 per cent for vegetables. Urbanization and industrialization is increasing pressure on land resource. About 17 per cent of world's population is living in India with only 2.6 per cent of the world's geographical area. Projected yields in cereal crops have started showing tendency towards plateauing, in spite of increasing investments and technological innovations to boost productivity. The inputs for agriculture production are diminishing. The decline in the share of agriculture in total production and employment poses serious challenges across regions. Therefore, there is need to diversify to high energy and nutrient-rich crops. Increased demand of food with prevalent farming practices is creating more intense competition for natural resources resulting in increased greenhouse gas (GHG) emissions, water scarcities, soil depletion, environmental degradation, deforestation, loss of biodiversity, and the spread of trans-boundary pests and diseases of plants etc. due to depletion of ozone layer altering the composition of incoming radiations. There is, therefore, need to develop future food production technologies which cause minimum stress on natural resources and least damage to eco-system. Food losses and waste claim a significant proportion of agricultural output, and reducing them would lessen the need for production increases. Agriculture production is required to increase by 70 per cent to meet global food needs. With time, the concept is changing from food security to nutritional security addressing both food energy deficiency and micro-nutrient malnutrition. A minimum of 400 g fruits and vegetables per person are recommended. While consumption of fruits and vegetable in the diet is increasing, there is insufficient availability and intake resulting

in 14 per cent of gastro-intestinal cancer deaths, 11 per cent of ischemic heart disease deaths, 9 per cent of stroke deaths globally. 1.7 million (2.8%) deaths worldwide are attributed to low fruit and vegetable consumption. Substantial growth in income of developing countries has resulted in dietary transition towards higher consumption of fruits and vegetables and other food sources relative to that of cereals and thus need commensurate shifts in output (Chadha *et al*., 2012).

5. Impact of R&D in Horticulture

Initiatives taken by the public, and private sector organizations and progressive farmers besides proactive policies of the government have brought about a sea change in the horticulture sector which is detailed below:

5.1 Production and Productivity

Average productivity of horticultural crops as a whole increased from 7.5 to 12.16 tonnes/ha with cumulative increase of 62 per cent. It is the world leader in production of mango, banana, papaya, pomegranate, sapota, acid lime and *aonla*. In vegetables, India ranks first in production of okra in the world (73% of world production) and second in brinjal (27.55%), cabbage (13%), cauliflower and broccoli (36%), onion (19.90%) and tomato (11%). India also leads in productivity of grape in fruits and cauliflower in vegetables in the world. Potato R&D has resulted in total replacement of imported varieties by improved indigenous potato varieties which have been instrumental in rapid growth in area, production and productivity during the last six decades or so. As a consequence area, production and productivity have increased 8, 25 and 3 times respectively resulting in a virtual potato revolution. Similarly research initiatives on tuber crops have impacted growth of these crops substantially by contributing to about 0.75 per cent agricultural GDP. As a result of R&D activities, a virtual revolution is taking place in mushroom production in our country and its production has spread to almost all parts of the country. As a result, there has been sudden spurt in mushroom production in the states of Haryana, Himachal Pradesh, Uttar Pradesh, Uttarakhand and Punjab. Oyster mushroom and paddy straw mushroom cultivation have specially picked up in Tamil Nadu and Odisha respectively. Production of mushroom has registered manifold increase from a meagre 500 tonnes in 1961 to 487,000 tonnes in 2017-18. Over the last decade itself, there has been 157 per cent growth in production of flowers, ornamental plants, cut greens and dry flowers. *Rosa demascena* is now extensively cultivated for extraction of essential oils, rose water, *attar, gulkand* in some pockets of Rajasthan and Uttar Pradesh. There has been a significant increase in the production of floricultural crops including both loose and cut flowers. Oil palm considered not suitable for cultivation in India has successfully adapted as an irrigated crop in 13 states of India. Starting virtually from scratch, it now covers an area of 2,82,566 ha with crude palm oil production of 2,17,258 tonnes (2016-17). About 58 organisations and entrepreneurs are now associated with oil palm development in India. Sixteen companies are operating Oil Palm Development Program in the states of Andhra Pradesh, Karnataka, Odisha, Tamil Nadu, Gujarat, Chhattisgarh, Mizoram, Maharashtra and Goa and 26 oil palm mills with a total capacity of 286 tonnes/hour have been established.

India is the largest producer of the coconut in the world contributing 31 per cent of global production. The coconut palm provides food security and livelihood opportunities to more than 12 million people in India and supports 15,000 coir based industries employing nearly 6 lakh workers of which 80 per cent are women folk. India is the second largest cashew producer in the world. Overall adoption of cashew technology (40%) has already reached with 46 per cent of the farmers. The average productivity of raw cashew nut in India has risen from 749 to 1,282 kg/ha in Maharashtra as a result of use of grafted plants of high yielding varieties coupled with

proper management even in comparatively low rainfall zones. India is now the largest producer of areca nut and ranks first in both area and production. Areca nut industry forms the economic backbone of nearly six million people in India and contributes over 4,500 million rupees annually to the GDP of the country. India is known as the home of spices being the largest producer, consumer and exporter of spices and spice products in the world. Area and production of spices in the country have registered substantial increase during the last 28 years with average increase of 93.4, 327.6 and 121.1 per cent in area, production and productivity, respectively. Chilli, garlic and ginger account for a major share in spice production. Spices especially turmeric and ginger have been introduced to non-traditional areas like Maharashtra, Punjab, Gujarat and Uttarakhand. Technology has also percolated to remote and inaccessible tribal areas of Andhra Pradesh (Chintapalli), Odisha (Pottangi) and Chhattisgarh (Raigarh) providing employment opportunities and enhancing the economic status especially of tribal women.

5.2 Planting Materials

Significant developments in production of planting material and registration of nurseries have resulted in availability of a large quantity of quality, disease free, planting material of high yielding varieties. Commercial use of micro-propagated banana plants has resulted in significant yield increase. Raising of vegetable seedlings in polyhouse has emerged as a good option for producing quality planting material particularly plug plant production. In potato, the development of seed plot technique, TPS, micro-propagation techniques and aeroponic for mini-tuber production have helped in production of healthy disease free seed and planting material.

5.3 Production Technology

Hi-tech horticulture particularly high density planting, canopy management, rejuvenation, promotion of beehives for pollination have resulted in enhanced productivity in a number of crops. High density planting has become a success story in several crops but not limited to apple, banana, cashew, guava, litchi, mango, papaya, and pineapple. Development of technologies have resulted in massive area expansion, and replanting of old senile and uneconomic cashew gardens with high yielding varieties in all major cashew growing states. Micro-irrigation is now virtually a rule in new horticultural plantations. Fertigation and use of liquid fertilisers has picked up. Protected cultivation has become quite popular for commercial cultivation of a number of vegetables and cut flowers and has also emerged good option for producing quality produce and allows for efficient use of land. Hybrid vegetables have revolutionized vegetable cultivation. There has been virtual revolution in potato production and processing. With appropriate choice of suitable varieties for specific seasons, we can now grow brinjal, cabbage, carrot, cauliflower and radish round the year. Until 1978, *kharif* onion cultivation was common only in the states of Maharashtra, Gujarat, Andhra Pradesh and Tamil Nadu which has now extended to Northern Indian States as a result of development of variety N-53.

5.4 Horticulture: A Growth Driver

The impact of the above initiatives has become quite visible and their role in development of this sector has been recognised in the country. Horticulture has emerged as the growth driver of agriculture in India. Future of sustainable agriculture in the country lies in promoting technology-led horticultural development. The highest annual growth of 9.5 per cent has been recorded in fruit production as well as 7 per cent in vegetable production during the period 1991-92 to 2018-19. Currently, a shift from production of bulk/staple commodities to high value horticultural produce and products is in offing. Horticulture has emerged as a means for sustainable intensification and diversification globally to enable remunerative, viable,

sustainable, alternate production systems in agriculture and an economically viable option for small holders. Production environment and market opportunity today is much different than in the past. With the horticultural crop production at 314.67 mt, the sector has emerged as a key driver of GDP contributed by Indian agriculture by contributing a share of to more than 34.45 per cent horticulture output in agriculture.

5.4.1 Post-harvest technology

Post-harvest management of mango through vapour heat treatment has made mango exports to USA and Japan a reality. Irradiation facility for potato and onion for long duration storage has become a reality. Storage capacity of horticultural produce has increased with the establishment of a large number of cold stores. CA storage facilities are now available in several towns. The Government's focus on cold chain is manifested in the addition of over 34 mt of cold storage capacity, by MIDH, APEDA, MoFPI and Department of Animal Husbandry, Dairying and Fisheries. Cold chain is emerging as a promising sector for private investments. Improved post-harvest handling, ripening, packing and packaging technology are evident from quality and the range available in super markets and long distance markets. Value added products like dry flowers, pot pouries, potted plants and essential oils have penetrated in both the retail and super market chains. India has attained self-sufficiency in seed spices and is exporting around 10 per cent of its annual produce. The demand of Indian seed spices is increasing day by day in developed and non-traditional countries. There has been increase in diversity of horticultural produce and products.

5.4.2 Trade

There has been significant increase in export of various horticulture commodities. Exports of horticultural produce and products have increased at a commutative annual growth rate of 12.06 per cent and have 22 times during the past 27 years. International trade in fruits and vegetables has expanded rapidly. The numbers of commodities as well as varieties produced and traded have increased significantly. Indian horticulture has gradually penetrated in the international market with significant increase in exports of fruits (mango, banana, pomegranate, etc.), vegetables (okra, gherkins, etc.), flowers and cashew. The trade related policies have been looking outward and there has been enhancement in foreign direct investment. Niche markets for organized products have been growing. Income in horticulture sector has been increasing and driving the supply chain in joint ventures. Contract farming has become popular amongst the cash strapped farmers. Comparative advantages offered by horticulture crops through higher labour requirement have provided additional employment opportunities. Floriculture exports from India comprised fresh cut flowers, loose flowers, dry flowers and potted plants. Of this, export of dry flowers contributes nearly 50-60 per cent of floriculture exports. Due to practical application of scientific and technical developments, floriculture has attained a commercial status in the past four decades. The transition of Indian floriculture from pushcart transportation to chartered plane transport has been phenomenal and the industry is growing at the rate of 8-10 per cent per annum. There has been a great surge in production, consumption and export of cut flowers. Cultivation of high value flower crops like Asiatic lily, protea, heliconia, bird of paradise has been increasing. The domestic consumption of loose flowers e.g. rose, marigold, china aster, jasmine, coriander and barleria has increased tremendously. Till 1993, Indian contribution to world trade in mushroom was almost nil. However over the years, India has emerged as the second largest exporter of mushrooms replacing Taiwan. It also accounts for 20 per cent of US imports of sliced button mushroom. The impact of the above initiatives has become quite visible and their role in development of this sector has been recognised in our country.

6. Future Strategies

Keeping in view the increasing requirements of horticultural produce for food and nutritional security, exports, food processing and pharma industry, future strategies need to be focused on achieving self-sufficiency in production of quality planting material and seed, expanding existing area under cultivation, improving productivity, quality, saving post-harvest losses, adoption of alternate horticulture systems, production of healthy pest free produce and products and improving the transfer of technology. The following initiatives (Chadha *et al.*, 2010; 2019) are suggested to achieve these objectives:

6.1 Exploitation of Genetic Materials

6.1.1 Evaluation and conservation of perennial crop germplasm

While a large number of collections of species and varieties are being maintained by different institutions and universities in the country, their detailed evaluation needs to be done so that superior genotypes may be utilized fruitfully. Besides, conservation of horticultural germplasm for use of future generations is very important. Live plant collection and their conservation is a great challenge. Present methods to conserve the vegetative propagative materials limit options of their conservation, hence there is need to give emphasis on refining the present technologies of germplasm conservation.

6.1.2 Exploitation of wild relatives

Wild relatives of horticultural crops are largely untapped for abiotic and biotic stress tolerance and could greatly expand the available gene pool. These species can play an important role in developing genetically superior varieties. Most wild species have neither been systematically collected nor evaluated either for morphological or molecular traits as their collection and utilisation is not an easy task. Many of the wild species are already facing danger of extinction. Exploitation of wild species and incorporating their desirable genes in cultivated species is, however, a difficult task and resultant hybrids are often sterile with low yield and poor quality. Hybridisation barriers are the major hindrance in exploitation of wild relatives. However, in the era of climate change resulting in serious incidence of pests and pathogens, utilisation of wild relatives in addressing global food security is urgently called for by using advanced crop improvement techniques including biotechnological tools.

6.1.3 Exploiting and commercialising less exploited crops

Many crops and species both exotic and indigenous are still unexploited sources of gene pool for several important horticultural traits including nutritional composition, phytochemicals and resilience to climate change due to their wider adaptability. Several exotic fruits have also acclimatised well and acquired good variability due to natural cross pollination but not well exploited. These potential fruits are required to be promoted in suitable agro-ecological regions of the country. Some of these are mangosteen, rambutan, avocado, longon, *jamun, bael*, durian, Malayan apple, wax apple, rose apple, star fruit, dragon fruit etc.

6.1.4 Change in breeding objectives and methods

While there are several common problems, many are unique to different horticultural species. It, therefore, calls for target specific breeding with focus on seedlessness, tree architecture, nutrient use efficiency, rootstocks, abiotic and biotic stress resistance, shelf-life improvement and better varieties for processing, nutraceuticals and pigments, secondary metabolites (polyphenols, limonoids, furanocoumarins, and carotenoids), high protein and biofortified varieties. Selection and breeding of rootstocks is very important, though difficult, for the traits like dwarfing, tree

longevity, propagability, productivity and graft compatibility, etc. While conventional breeding has to be continued for germplasm enhancement and breeding new varieties/ hybrids, integration of advanced precision breeding tools such as genomic selection (GS), marker assisted selection (MAS) and molecular breeding along with conventional breeding can ensure precision and faster pace to ensure desired results. Understanding of the genetics of important horticultural traits has been difficult in perennial crops. Molecular markers help to determine location of genes that control important traits. Owing to their highly heterozygous nature and long juvenility, MAS has reduced the time required and cost of breeding efforts substantially and needs promotion particularly in fruit crops. Similarly, techniques such as double haploid, cisgenesis, genetic engineering and gene editing CRISPR/Cas9 also need to be used for improvement of horticultural crops.

6.1.5 Exploiting biotechnological tools

The challenge of faster crop improvement demands use of frontier technologies. Genetic modification has achieved great success globally but in India except cotton, nothing substantial has come out. Some of the traits that are being modified through genetic engineering include high productivity, viral, pest, drought and herbicide resistance, increasing shelf-life and improving nutritional quality. Such varieties have been developed in a number of fruits and vegetable crops in the world. While there have been lot of developments in transgenics globally, the Government of India policy on release of genetically modified (GM) varieties for commercial cultivation is still unclear. There is, therefore, an urgent need to harmonize Government regulations to facilitate trans-boundary movement of transgenics. While, several issues, need to be debated, the fact that over two dozen countries are already practising commercial cultivation of several GM crops cannot be ignored. The new tools have ushered new life to automation and second generation sequencing enabling decoding of genomes in several horticultural crops, namely, apple, banana, grape, papaya, cucumber, melon, potato and tomato with far reaching application. The genomic sequence information generated can be used for mining useful genes and precision breeding using molecular markers. Remarkable advances made in the field of biotechnology offer opportunities to mitigate various problems in a suitable manner by using this technology.

6.2 Achieving self-sufficiency in healthy planting materials

Most of the planting material of horticultural crops is vegetatively propagated and involves the risk of disease transmission. Hence, it is essential to ensure availability of good quality planting material from duly high-tech accredited nurseries which is a pre-requisite for increasing area, production, productivity and quality of horticultural crops and requires sizeable investments. Supply of such a huge quantity of disease-free, true to type quality planting material is a big challenge and needs to be addressed urgently in mission mode. In recent years, significant developments have taken place in this regard. However, a number of constraints are required to be tackled for achieving these objectives in different groups of horticultural crops.

6.2.1 Fruit crops

Most fruit crops require a long juvenile period before they come into bearing. Genuine and healthy plant material must be ensured to avoid subsequent losses to farmers. Several constraints need to be addressed which include: i) absence of mother plant blocks/ scion banks of elite trees of different commercial varieties in nurseries; ii) lack of bud wood certification programs in crops like citrus; iii) use of rootstocks, a useful tool to manage tree size, precocity besides their effect on vigour and their tolerance to biotic and abiotc stresses, like salinity, drought and nematodes of scion varieties. However, genetically uniform rootstock material is not available in several

important crops (mango, guava, sapota); iv) procurement of plant material of some fruit crops on quotation basis in different states; v) *in situ* multiplication continues to be done directly in the soil and not in containers (polybags/ trays/ pro-trays) by most nurseries resulting in spread of diseases and pests in plants; vi) practices like sterilization or solarization followed by all modern nurseries in other countries are not common in most Indian nurseries; and vii) while a Nursery Registration and Certification Act is now in force under the *aegis* of NHB, the accreditation process seems to be slow compared to tasks in hand and has the potential to be improved and expedited, and viii) promotion of transgrafting techniques which provide pest and pathogen resistance and impart biotic and abiotic stress tolerance, increase plant vigour and productivity, e.g. crown gall (*Agrobacterium tumefaciens*)-resistant walnut rootstock. It is high time that these aspects are given their due importance in research and development.

6.2.2 Vegetable crops

Vegetable seeds developed and supplied by public sector organizations is often not adequate, while that supplied by the private sector is costly and not always reliable for quality. There is a need to multiply potential hybrids developed by the public sector and made available to farmers. Automated and plug plantlet production technology, vegetable grafting techniques though available are still not fully exploited. While sufficient progress and expansion of area under F_1 hybrids has been made, but some constraints still exists in its availability which need attention; viz., assessment of seed requirements of hybrid seeds required in proper planning of seed production programs, development of sufficient low temperature storage facilities to take care of extra seed stocks from the years of plenty to use as buffer in the years of scarcity, reduction in cost of hybrid seeds marketed by the private sector, development and use of male sterile and gynoecious lines to reduce labour costs involved in hybrid seed production, and more and more seed of public sector hybrids should be multiplied in bulk through National Seeds Corporation (NSC) / private enterprises and made available to the farmers at reasonable prices. These hybrids may be popularized by way of frontline distribution among the farmers. Production of seed of such hybrids may be taken through public-private partnership (PPP) mode to enhance the productivity. Major industry of raising vegetable crop seedlings through plug plants has been developed in Israel, Japan, Spain, the Netherlands, and USA as per requirement. Plug plants establish better in field due to non-damage to roots and help in regulating transplanting and thus need to be promoted. Shoot grafting suppresses soil borne diseases avoiding *Fusarium* wilt (melons and tomato), bacterial wilt (tomato and brinjal), *Verticillium* wilt (tomato) and *Phytophthora* (sweet pepper), etc. and imparts resistance to adverse conditions such as high/ low temperature, drought, salinity and avoid physiological disorders caused due to continuous cultivation. Further concerted efforts on research and development as well as extension are urgently required.

There is need to mitigate the problem of shortage of good quality potato seeds. This needs to overcome through following strategies: i) emphasising rapid multiplication of the seed tubers through tissue culture in conjunction with aeroponic systems to achieve the advantage of better health status of seed stock due to reduced number of field multiplication over the conventional clonal multiplication systems; and ii) reducing cost of mini tuber production to make the system affordable for small and marginal farmers; and technologies need to be developed to produce seeds for relatively warmer areas of eastern plains and Deccan plateau.

6.2.3 Mushroom

There is a great need to pay utmost attention to timely availability of quality spawn, besides monitoring and supply of spawn run substrate in urban and peri-urban areas for increased production of mushrooms.

6.2.4 Plantation crops

Seed gardens for production of TxD and DxT hybrids, root wilt tolerant varieties in coconuts and indigenous tenera seed in oil palm need to be promoted. As regards, cashew nut and cocoa, establishment of nurseries with mother blocks of improved varieties need to be promoted. Quality planting material is required for replanting senile areas and buying the planting materials from unauthorized sources need to be avoided.

6.2.5 Spices

Spices are high value and low volume crops. There is great demand for Indian spices in the international market and these earn considerable foreign exchange. Lack of availability of quality planting material is one of the important production constraints. While there are adequate number of improved varieties in spices, many of them do not reach the farmers due to a few nurseries supplying spice plants. The suggestions include: i) establishment of region specific nurseries of different spice crops; ii) holistic approach to meet the steadily increasing demand of quality planting material of spices by involving all R&D organisations; iii) quality and quarantine checks to avoid pest and disease spread in spice nurseries; and iv) greater thrust for container cultivation and vertical farming for seed production in black pepper, ginger and turmeric under polyhouse conditions.

6.2.6 Medicinal & aromatic plants

Considering the constraint of non-availability of elite planting material and seed of commercial medicinal & aromatic plants, the strategies include: i) role of establishment of separate mother blocks for M&A plants needs to be promoted; and ii) nursery activities should be concentrated in major cultivating areas of respective crops.

6.2.7 Micropropagation

It is perhaps the most popular and widely commercialized global application of plant biotechnology. Micro-propagation has been the most widely spread technology introduced during the last few decades. At present, Asia is reported to produce 80 per cent of world's total tissue cultured plants, of which 90 per cent tissue cultured plants are raised annually in China. In India also, a large number of units are working on developing protocols for multiplication of different horticultural crops including apple, banana, citrus, date palm, grape, papaya, pomegranate and strawberry among fruits; asparagus, potato among vegetables and tuber crops, and anthuriums, orchids, rose, gerbera, carnation, foliage plants among ornamental crops. Protocols are also available for cardamom, pepper and ginger, turmeric and *safed musli* among spices and patchouli and vanilla in medicinal and aromatic plants. The suggestions to be made in improving the production and supply of micro-propagated plants include: i) regeneration protocols in many crops are required to be developed. Efforts should therefore be focused on developing/adopting protocols of commercial crops like litchi, mango, walnut, cashew, coconut, date palm and oil palm; ii) in the domestic market, the largest selling tissue cultured banana, gerberas, anthuriums, and orchids have attained commercial importance and hence need to be given greater attention; iii) micropropagation techniques need to be commercialized in M&A plants to bridge the gaps in planting material requirements in large quantities; iv) tissue culture laboratories need to be strengthened to ensure supply of good quality planting material; v) multiplication stages in the technique such as multiplication of embryonic cells, regeneration and maturation and germination of somatic embryos need to be standardised and perfected; vi) shoot-tip grafting and micro-budding technologies as employed at Central Citrus Research Institute (ICAR-CCRI), Nagpur need to be adopted by other centres involved in citrus nursery promotion; vii) high throughput technology such as

bioreactor has the potential to fulfil the gap of planting material in banana; viii) there is increasing trend for using LED lights in the micro-propagation industry thus saving 40 per cent energy; and ix) national certification of tissue cultured plants being carried out by the Department of Biotechnology (DBT) through Biotech Consortium of India (BCIL), New Delhi needs to be utilised to the fullest.

6.2.8 Development and use of diagnostics

PCR based diagnostic protocols developed for rapid detection of citrus greening and citrus tristeza viruses are now available. Diagnostic technologies like ELISA and ISEM have also been developed for early detection of several diseases of asexually propagated plants like potato. Detection of viruses in view of globalization and international trade of horticultural crops is also very important. However, for efficient diagnosis of virus infection, more work is required for sensitivity, accuracy, reproducibility and suitability of test for onsite detection besides developing such techniques for other important crops.

6.3 Improving Availability of Horticultural Produce

The following strategies are suggested for increasing availability of horticultural produce in the country.

6.3.1 Suitable land use

Due to increasing population, urbanization and industrialization, cultivable land is decreasing over the period. There is, therefore, need for judicious use of land resources after determining their suitability for cultivation of different crops to make best use of their available land resources.

6.3.2 Turning waste-lands into productive areas

In India, about 120 mha land has been classified as degraded and waste land. This area is distributed in different states and comprises a significant area under culturable waste, barren and un-culturable land. This land can be judiciously brought under cultivation of horticultural crops with right land management practices. The following crops are suggested for different land category regions, viz., i) rainfed areas with good soil fertility for mango based cropping system (mango, guava, cowpea, lime, lemon, and french bean); ii) rainfed areas with poor soil fertility for *aonla*-based cropping system (*aonla*, guava, turmeric), *jamun* etc., iii) water logged areas for lotus and *makhana, iv)* flood affected areas for Japanese mint, marigold, vegetables, v) saline patches suitable for *bael, jamun*, *Citronella*, *karonda, mahua*, mint, *phalsa;* vi) ravinous areas for *kair, karonda, khejri;* vii) high value and low water requiring crops viz., seed spices (*dhania, methi, kalajeera, sounf,* etc.). Agroforestry interventions which have better potential to sequester carbon also need emphasis to harness the maximum potential from such land use systems.

6.3.3 Off-season production

Off-season production is needed for production of horticultural produce outside the regular cropping season to ensure availability of fruits and vegetable during low supply period. The strategies recommended include: i) increasing emphasis on off-season production of vegetables under both outdoor and under controlled environment crop production; ii) varieties suitable for different seasons need to be developed in cauliflower, radish, turnip, tomato, onion and potato; iii) improved varieties need to be developed in other commercial horticultural crops for off-season availability and price realization; iv) technologies for off-season production of vegetables using low-cost polyhouses and low tunnels, etc. need upscaling; v) use of plastic tunnels in

arid temperate regions for production of vegetables during extreme cold temperatures needs further upscaling; and vi) gaps in adoption of the technologies need to be studied, refined and standardized to ensure round the year production and availability of the horticultural crops.

6.3.4 Rejuvenation of perennial old and senile orchards

Old and senile orchards having over-aged fruit trees with poor efficiency and extremely low production and productivity per hectare for major fruit crops, need to be either re-planted or rejuvenated. Rejuvenation of these orchards to make them productive and profitable is a short term strategy, while replacing/ replanting them with new plantations is a long- term strategy. The concept of rejuvenation is not fully understood in development programs which in fact means different practices for different orchards e.g. i) old senile orchards which are over grown and have over-lived their utility need to be removed and re-planted with improved varieties for different uses (taken-up on a limited scale in coconut and apple), ii) almost such trees under traditional varieties need be top-worked to replace these with superior varieties; iii) disease and insect-pests infected plants need to be rejuvenated by pruning followed by treatment with suitable pesticides; and iv) unproductive trees need to be rejuvenated with a well worked package of practices. Even though, there have been significant gains from rejuvenated orchards, constraints like trained manpower, tools and machinery continue to hinder faster adoption of the technique. The rejuvenation system needs to be strengthened and its potential fully exploited.

6.3.5 Horti-based cropping systems

In conventional planting, space between two rows remains unutilized till the trees attain full canopy spread. Accordingly, growing of two or more crops simultaneously in the same piece of land results in better land use and more income. Short duration crops are preferred to ensure early bearing and better returns, for example, vegetables, flowers, and medicinal and aromatic plants including shade-loving plants are preferred in fruit orchards not only to enhance the availability of the horticulture produce and reduce cost of cultivation but also improving profitability as these may provide sustainable returns.

6.4 Increasing Productivity

For increasing productivity, use of superior varieties and F_1 hybrids, high density planting, canopy architecture, integrated nutrient management, use of plastics, micro-irrigation, fertigation and pollination, besides use of quality and disease free planting materials need to be emphasized (Chadha et al., 2014; Chadha, 2018).

6.4.1 Promoting use of superior varieties and F_1 hybrids

A large number of superior varieties have been developed in several horticultural crops which include varieties like *Mallika* and *Amrapali* in mango, Sharad Seedless in grape, *Pusa Nanha* and *Arka Prabhat* in papaya, *Arka Sahan* in custard apple, *Narendra Aonla* 7 in *aonla* etc. In vegetable crops, besides a large number of pure line selections, large number of F_1 hybrids have been developed both by public and private sectors with first vegetable hybrid *Pusa Meghdoot* (bottle gourd). The present market value of hybrid vegetable seeds has reached to about 300 million rupees of which okra and chilli each share 12 per cent of area, tomato and onion each 10 per cent, cauliflowers and gourds each 9 per cent. Other important vegetables crops that have significant share in production are cucumber (6%), cabbage (4%), sweet corn (4%), watermelon (4%), other melons (3%), brinjal (2%), radish (1%) and carrot (1%). F_1 hybrids have almost entirely replaced open pollinated varieties of tomato, cabbage, cucumber, squash, melons,

onion and sweet paper in Japan, the Netherlands, Denmark, France, Canada, Australia, United Kingdom and USA. In India, revolutionary progress has been observed in cabbage, cauliflower, tomato, cucumber, bottle gourd and bitter gourd. However, for faster progress, following points need urgent attention: i) need to develop genetic emasculation mechanism and parental lines such as male sterility, double haploidy, self-incompatibility, gynoecism and parthenocarpy; ii) development of hybrids suited for protected cultivation of cucumber, gherkin, melons, sweet pepper, tomato, etc. as well as hybrids having resistance to biotic and abiotic stresses; and iii) also need to develop and promote low cost hybrid seed production technology to reduce production costs.

6.4.2 High density planting (HDP) and canopy architecture

Decline in the availability of cultivable land has necessitated adoption of high density planting (HDP) by use of genetically dwarf cultivars or use of dwarfing rootstock/ inter-stocks, canopy management and use of plant bioregulators. HDP has become need of the hour to ensure early higher and net income returns per unit area in tree crops, besides promoting better utilization of the resources. Canopy architecture is required for utilisation of proper space, nutrients, moisture, solar energy and aeration in the newly established fruit plantations which is now implemented under MIDH and other horticulture developmental programs. However, standardization of planting distances needs further experimentation. The existing gaps needing priority attention include; i) systematic recommendations of cultural practices for high density orcharding are lacking in most of the commercial crops; ii) dwarfing rootstocks and varieties not available in majority of fruit crops; iii) available dwarfing rootstocks not properly tested for their adaptability to edaphic factors and compatibility with major commercial scion varieties; iv) canopy management practices in dwarf trees not fully worked out in all the crops; and v) effect of canopy architecture on tree yield and fruit quality needs to be standardised in important varieties of different fruits and also studied as to how long canopy architecture can sustain high production.

6.4.3 Pollination enhancement through bee activities

Most of the horticultural crops are cross-pollinated owing to incompatibility, dichogamy and other such special peculiarities. Low productivity in most of these crops is caused by lack of/ or inadequate pollination and fertilization. In these crops, fruit set and production has been shown to increase by 15 to 30 per cent if honey-bee hives are kept. Bees play more important role in income enhancement through increasing horticultural crop yield compared to income generated from honey production. Thus, honey bee colonies need to be promoted in all cross-pollinated horticultural crops grown both in open and under controlled conditions to get the desired benefits.

6.5 Reducing Cost of Production

6.5.1. Input use efficiency

Excessive and indiscriminate use of nutrients in commercial horticultural crops has resulted in several problems. Heavy application of nitrogenous fertilizers has resulted in high quantities of nitrates in water bodies in Punjab, Maharashtra and Karnataka states making it unfit both for cultivation and human consumption. Therefore, it is essential to use technologies with high input-use efficiency which include: i) follow approaches that are not adversely affecting yield and quality and are simultaneously cost-effective and ecofriendly; ii) enhance fertilizer use efficiency (FUE) at the right time with right kind of fertilizers; iii) location specific tissue nutrient guides to be made available for different fruit crops to reduce nutrient wastage and enhance production,

productivity and quality; iv) appropriate recommendations for identification and correction of micronutrient deficiencies need to be made for different regions; and v) more emphasis needs to be given to combine micro-irrigation with fertilizer application i.e. fertigation.

In view of the escalating cost of inputs, greater emphasis needs to be given on technologies aimed at conservation of natural resources, low input and cost reduction without adversely affecting crop productivity. The following measures require attention: i) cheaper alternatives and combinations of inorganic fertilizers and liquid fertilizers to economize the cost of production; ii) developing production technology based on agro-ecological regions, harnessing microbial dynamics for enhancing soil health and sustainable production; iii) nutrient management strategies to improve fertiliser use efficiency, thereby reducing fertilizer requirements and associated nitrous oxide greenhouse gas (GHG) emission. This requires emphasis on study of root system, use of nutrient diagnostics, and use of biofertilizers, etc.; iv) fertigation through micro-irrigation wherein fertilizers should be 100 per cent water soluble and selected based on the pH; and v) enhancing water use efficiency through water harvesting, water conservation and pressurised irrigation systems. Micro-irrigation technology is not only effective in water saving but also in fertilizer, labour and energy. It helps in maximising the input use efficiency.

6.5.2 Mechanization

Horticulture not only highly labour intensive, it requires skilled labour for various operations. Over the years, availability of labour has become scarce and now MGNREGA scheme has affected a great deal in non-availability of adequate labour. Mechanization and automation brings down the required cost on labour besides reducing drudgery and improving product quality. Further, modern garden tools of good quality are not available at affordable price. Partial mechanization of input operations like digging of soil, application of fertilizers, weeding, spray of chemicals, micro-irrigation, training and pruning, harvesting, washing, grading, sorting, packaging, processing, value addition in horticultural crops depending upon the orchard size is available. However this area needs thrust to improve efficiency of field and post harvest operations which in turn decrease the cost of management and also improve efficiency. Large number of applications of robotics needs to be upscaled to the field level. Similarly drones or unmanned aerial systems are shifting from novelty to many open field and greenhouse operations in horticultural production such as, collecting data, spraying of nutrients and pesticides etc. There is need to develop low cost inputs of this type. Gaps are still existing in availability of appropriate machinery for smallholders which needs to be addressed and right type of machinery and tools be made available under PPP mode for effective use on small farms.

6.6 Risk Management

6.6.1 Integrated pest management

To minimize the chemical usage and subsequent pollution, it is important to evolve eco-friendly technologies. Integrated pest management (IPM) though widely recommended for reducing insect damage improving crop yield and quality needs efficient integration of various systems in different horticultural crops grown in different regions. There is need for greater emphasis on: i) causes of poor adoption of IPM be identified and rectified; ii) causes and control of many complex diseases and disorders like mango malformation, coconut wilt, pomegranate blight, guava wilt, etc., not fully understood as yet; iii) crop pest surveillance and monitoring system not well developed so far and needs to be paid priority attention; iv) disease forecasting and forewarning systems not available for many horticultural crops which need to be studied further; and v) there is need for continuous updating of IPM package, relevant to farmers' needs in important crops and pests.

6.6.2 Climate change

Various plant processes like vegetative growth, flowering, fruiting and fruit quality are highly vulnerable to climate changes. Some of the prominent effects of climate change observed are flowering and fruit drop, crop duration, fruit size and quality, delayed curd initiation in cauliflower, reduced bulb size in onion, psylla incidence in citrus, crop failure in cumin, etc. It is, therefore, necessary to develop crop and resource conservation based mitigation strategies to counteract the deleterious effect of climate change in horticultural crops. While controllable risks like pests, diseases, weeds, and seed material can be managed with the use of technology, effective monitoring and appropriate usage of inputs, the challenge lies in providing risk management solutions for uncontrollable risks like rainfall deficit, excess and distribution, extreme temperature conditions, hail incidences, extreme wind speeds, humidity variations etc. Besides, there is need to develop abiotic and biotic resistant varieties which are less sensitive to climate change.

6.6.3 Insurance

The perennial horticultural crops are presently not covered by National Agricultural Insurance Scheme (NAIS). In view of high value and vulnerability of these crops, there is an urgent need for inclusion of these crops under the insurance scheme in order to give adequate protection and cover the risk of farmers growing these crops.

6.7 Improving Quality and Food Supply

6.7.1 Good agricultural practices

In order to bring in the international competitiveness for the Indian horticultural produce, there is need to follow good agricultural practices (GAP) as per importing countries. India also needs to implement 'India GAP' in the country in the line with global GAP as early as possible, so that farmers are able to get better price for their produce in domestic as well as international market. Frequent test of the urban water and composts both for microbial activity and heavy metal toxicity needs to be made mandatory to ensure food safety. This requires establishing testing facilities to promote entrepreneurship among youth. India must also strive hard to promote accreditation of production and processing centers with international quality labels like Hazard Analysis and Critical Control Point (HACCP), European System Related to Good Agricultural Practice (EUREPGAP) to install confidence in the minds of International buyers about the food safety of Indian produce. Most developed countries deny access to Indian horticultural products, under the garb of sanitary and phytosanitary (SPS) measures, or at least delay access to the extent possible. Quarantine procedures in India are not strictly implemented and there is a need for authorities to be pro-active in this regard.

6.7.2 Organic farming

With increasing health consciousness and concern for environment, demand for organic products, especially in developed countries, has been increasing a great deal. In the last few years, organic farming in India is being carried out successfully in crops like banana, coconut, grape, sapota, spices, etc. Production and export of organic spices and herbs have also been successfully made. However, suitable package of practices and sound technologies, organic inputs and moderate rate need to be ensured. The strategies recommended to promote the organic farming include: i) strengthening research base and promoting technologies like green manuring, organic matter enrichment, use of biofertilizers and effective recycling of biomass residues; ii) promoting availability and adoption of biofertilizers, biocontrol agents and other eco-friendly inputs; and iii) market promotion and publicity for increasing demand of organic products e.g. spices, medicinal and aromatic plants.

6.8 Promoting Alternate Horticulture Systems

Hi-tech horticulture has scope of exploitation in India, but its high establishment cost and lack of skill development are hampering its promotion in the country. There is, therefore, need to make systematic efforts on cost reduction and affordable technologies for successful exploitation of such system. These alternative systems are briefly described below:

6.8.1. Protected cultivation

The protected cultivation is a better option for efficient use of land and other resources resulting in high productivity and quality of horticultural produce. The technology covers practices like development and use of green houses, insect proof net houses, zero-energy naturally ventilated greenhouses, walk-in-tunnels, high tunnels, etc. depending upon the region and requirement of horticultural crops. While countries like Spain, the Netherlands and Israel have exploited this technology on large scale, the progress of adoption of this technology in India is relatively slow probably due to high infrastructure costs, and its viability only for limited crops such as tomato, capsicum, cucumber, strawberry and a few flower crops. However, the technology needs priority attention in mission mode since it has potential of increasing yields by more than 300 per cent besides saving valuable land resources to be used for other crops. Considering its increasing role, the following aspects need urgent attention: i) development of varieties of vegetables and cut flowers for greenhouse cultivation and training of professionals in handling such units; ii) standardisation of low cost protected cultivation structures and production technology; iii) quality control of greenhouse structures and making available critical inputs required in protected cultivation; iv) developing suitable annual cropping cycles for optimum utilization of protected structures and research requirement on captive production of frost susceptible fruit crops like banana, papaya, strawberry; and v) protected cultivation of some high value horticultural crops has great potential to increase farmers' income and hence must be given priority attention.

6.8.2 Hydroponics

Hydroponics has proved to be highly productive, conservative of water and land and protective of environment. It is getting popular in India very slowly compared to China, which accounts for 85 per cent of world's total indoor cultivation. Inputs like light, temperature, water, root aeration, EC and pH of the solution, nutrient ratio and solution, anchorage of the plants and production technologies for different crops, etc. should be in place. The major challenges needing attention include: i) high initial cost of infrastructure to set up production units; ii) lack of required skill and knowledge to maintain optimum production; iii) hot weather and limited oxygenation in some agro-ecological regions of the country affecting crop production; iv) standardisation of crop/ region specific technologies; and v) identification and development of varieties suitable for hydroponics.

6.8.3 Aeroponics

In aeroponic system of cultivation, nutrient and water mixtures are sprayed by misting on suspended roots under dark at certain intervals with the help of sensors. It allows optimum nutrient uptake, intensification of growing of plants and limits diseases and insect-pests. The system conserves space, water and is less cumbersome but demands constant supervision. The technology has been successfully used in India for potato and yam micro-tuber production and tomato, lettuce and ginger crop production. In the system, the potato seed multiplication rate has increased tremendously and the technology has been transferred to more than 43 companies by ICAR-CPRI, Shimla. Despite several merits, high initial investment in

infrastructure and skill requirement for crop production have resulted in slow progress of the technology in the country. There is need to develop cost effective models affordable by small seed companies and farmers.

6.8.4 Aquaponics

Aquaponics is a mode of organic agricultural practices that involve a symbiotic combination of aquaculture and hydroponics. Production of vegetables and fish with the same water and nutrients results in effective utilisation of water and its nutrients. Aquaponics, though started in Kerala, is yet to prove its economic viability on a commercial scale. Concerted research efforts are needed to make large scale use of aquaponics viable.

6.8.5 Conservation horticulture

Conservation agriculture (CA) strives to achieve satisfactory profits through high and sustained production levels while concurrently conserving the environment. It is based on enhancing natural biological processes above and below the ground and is characterized by minimum mechanical soil disturbances, having permanent organic soil cover and diversified crop rotation in case of perennial crops. Though much talked about, its ground implementation particularly in horticulture crops is very slow. Further specific technology for conservation agriculture is also not available and needs to be studied and documented.

6.9 Promoting Urban and Peri-Urban horticulture

Over 35 per cent of Indian population live in urban/peri-urban areas which is expected to increase by over 40 per cent by 2030 and 65 per cent by 2050. Small to medium size land holders within outskirts of 21 large cities need to be encouraged to adopt peri-urban and urban horticulture. For which, activities like protected cultivation, plug plant production, terrace and roof top cultivation of vegetables, pot plants, fruit and flower nurseries, mushroom production, bee keeping, flower production etc. need to be promoted in mission mode manner.

6.9.1 Vertical farming

The vertical farming is a system of closed vertical growing of plants e.g. green walls, biowalls, which look good, enabling producers to achieve round the year production of crops. Vertical gardens are easy to install, give aesthetic look and have excellent heat absorption and pollution control abilities. Vertical gardens installed on the walls hold plants and thus a key to healthy cities as they fight both indoor and outdoor pollutions. They help to lower carbon footprints of a building by filtering carbon dioxide and other air pollutants. Therefore, this system has the potential to ensure sustainable availability and affordable quality of fresh perishable horticultural crops to the ever-increasing urban populations. The systems of soil less cultivation including hydroponics, aeroponic and aquaponics are utilised in vertical production systems. Multi-storey vertical farming under protected cultivation in peri-urban areas is now catching up to meet the requirement of fresh vegetables which can be seen in public places, airports, metro pillers, bridges, elevated roads in many metro cities. However, several issues such as economics of production, regulations, lack of expertise, etc. are major constraints in promoting successful vertical farming. Compatible crops for vertical gardens are broccoli, lettuce, spinach, coriander, mint and herbs, which are also recommended for micro-greens. Other crops such as rosemary, thyme, fennel, strawberry, ornamental foliage and ornamental greens are used for growing under vertical gardening.

6.9.2 Micro-greens

Micro greens are tiny edible plants rich in antioxidants such as iron, zinc, magnesium, copper and other nutrients, which can be grown round the year. These are older than a sprout which do not have leaves and younger than a full grown seedling. Their stems and leaves are edible and are reported to contain higher nutrient levels than their mature counterparts. They can be produced quickly and can be grown year round. The plants are ready to harvest within 7-14 days after germination. This makes them a good addition to any diet. These are versatile, healthy and convenient to grow in green houses and even in the window sills. Commonly used crops for micro-greens are amaranths, basil, sugar beet, broccoli, cabbage, carrot, cauliflower, celery, dill, fennel, fenugreek, kale, lettuce, mint, parsley, radish and spinach.

6.10 Pre and Post Harvest Management & Value Addition

6.10.1 Promoting pre-harvest fruit bagging

This farmer-oriented technology is the safest approach for protection of fruits from several biotic stresses, and is integral part of fruit production in several countries and thus, needs popularisation. It is a laborious process and needs development of biodegradable bags which can decompose after use. There is need to develop biodegradable bags, and standardise the specifications for different kinds of bagging and stage of putting and removal of the bag to achieve the maximum benefits.

6.10.2 Reducing post-harvest losses

The post-harvest losses in perishable horticultural produce are estimated from 6 to 40 per cent. Despite several infrastructural development schemes of National Horticulture Board, Agricultural and Processed Food Products Export Development Authority (APEDA), National Cooperative Development Corporation (NCDC) and different commodity boards, the available cold storage facility is inadequate to store high amounts of perishable horticultural produce (current space stores only 11%). The storage capacity and organised marketing are expected to grow at 13 per cent and 7-20 per cent per annum, respectively. There is also big gap in the availability of reefer van (refrigerated transport), its high cost having been the major challenge. The following measures are recommended to reduce the post-harvest losses in horticultural commodities: i) replacing use of calcium carbide- (banned but commonly used) by ethylene, a natural ripening hormone, which facilitates onset of ripening particularly in climacteric fruits like mango, banana, avocado, papaya and tomato resulting in better colour development and quality produce; ii) adequate ripening chambers need to be properly utilised. Crop specific ethylene doses, exposure time and ripening temperature required to be standardised for precise application and gainful utilisation; iii) focus needs to be given in providing adequate pack houses; iv) emphasis on latest technologies of post-harvest management. e.g. controlled atmospheric storage (CAS) and modified atmospheric packaging (MAP); v) cold storage capacity/multipurpose cold storages (though low in capacity but high in revenue generation) need to be popularised; and vi) provision of refrigerated transport calls for private investment in the sector.

6.10.3 Developing value chains

R&D institutions in horticulture in the country need to lay greater emphasis on designing farmer-centric and technology-led innovative value chains in different horticultural crops to improve farmers' income in the short run and develop sustainable horti-business in the country in the long run.

6.11 Horticulture for Health and Nutrition

Horticultural crops are rich sources of dietary fibres and micronutrients and are associated with good health improvement in gastrointestinal health, reduced level of cancer, cardiovascular diseases, diabetes, anaemia and other chronic diseases. There is, therefore, need for breeding nutrient dense varieties and biofortification of widely consumed horticultural crops. With increased income, urbanization and changing eating habits, the demand for processed food has increased manifold. Due to rapid expansion of internal and external markets and processing industries, it is essential to develop such techniques, which can reduce post harvest losses, do value addition and improve quality of the product. India has a huge potential to produce value added products like potato, banana chips, dried onions and garlic powder, ginger and garlic paste, juice and concentrates, squashes, canned beans, frozen beans, cauliflower and okra; chilli sauce, etc. for both domestic and export markets. The suggestions needing urgent attention include: i) development of new products in fruits, vegetables and flowers to cater the emerging demands of the market; and functional foods to address the nutritional disorders; ii) identification of bioactive components of different crops for production of processed products, nutraceuticals, pharmaceuticals, cosmeceuticals, pigments, essential oils, natural colorants and dyes and standardising manufacturing process of their manufacturing; iii) developing strategies for evolving new flavours, fragrances and products; iv) pigments, alkaloids, oleoresins and essential oils from plants act as natural pharmaceuticals to control some of the ailments plaguing the humankind and needs attention; v) spices and spice products are finding diverse uses in health care and wellness industry . There is, therefore, a great need to strengthen knowledge in their therapeutic application in view of increasing global demands; and flowers rich in pigments like carotenoids and flavonoids which act as anti-oxidants to scavenge the free radicals to prevent cancer and coronary artery diseases (Chadha *et al.*, 2012).

Research on large scale production of these natural metabolites and establishment of large scale industries to isolate and commercialize such compounds is the need of the hour. The recent initiatives of contract farming of marigold flowers to isolate the carotenoid pigments for natural colour for poultry industry and the nutraceuticals like lutein for correcting the age related blindness need to be upscaled.

Horticultural produce is associated with good health improvement. The average availability of fruits and vegetables has reached to 586 g as against the recommendation of 400 g per person per day. However, uneven distribution and consumption of fruits and vegetables by the rural and urban population lead to low Human Development Index (0.624). Since consumption of horticultural produce leads to good health and is able to fight many disorders and diseases, future efforts need to be directed to exploit horticulture crops for nutraceuticals, phytochemicals, antioxidant potential, oils, natural colours, oleoresins, etc. Food and Nutritional security (household health) can also be achieved by promoting courtyard farming, kitchen gardening, turf/roof gardening, etc.

6.11.1 Emphasis on settling-up of Farmers' Producers Organization

Marketing infrastructures particularly for perishable commodities in India is quite inadequate. Marketing system in *mandis* is non-transparent and marketing cost is heavy due to role of over 6-7 intermediaries. This calls for innovations in marketing of perishables. The GoI has taken many initiatives through amendments in Agricultural Produce Market Committee (APMC) Act, which passed the way for contract farming, direct purchase centres and provision of special markets for fruits and vegetables besides scaling-up of a unified market. Contract farming has been in

existence in high value commodities like baby corn, sweet corn, chillies, onion, gherkins and papaya. A number of initiatives in organised retailing have also been taken. However, setting up of Farmers' Producers Organisations (FPOs) mandating primary producers as members resulting in formation of corporative entity (a hybrid between cooperative society and a private limited company) largely proven successful and need to be promoted. It is estimated that over 3000 Farmers, Producers Committees (FPCs) have been established so far in the states of Madhya Pradesh, Rajasthan, Maharashtra and Bihar.

6.12 Improving Transfer of Technology and Skill Development in Horticulture

6.12.1 Trained manpower

The rise in growth rate of horticulture sector has increased the gap between demand and supply of trained manpower. Although a number of universities and institutes offer specialization in horticulture, critical gaps still remain in availability of trained manpower. The academic curriculum of the graduate and post-graduate education in SAUs/CAUs needs to be redesigned as per market demand like geographic information system (GIS), remote sensing and space technologies; information technology, bioinformatics, robotics, automation, etc. and hands-on training, nanotechnology, new biomolecules, bioreactors, etc. rather than only conventional system. Further, the lack of knowledge and skills to carry out different technical and management operations and activities by non-horticulture and sometimes even horticulture staff have been major threat to sustain the pace of development projected in coming years. Hence, emphasis on hands-on training on emerging horticultural technologies is needed.

6.12.2 Attracting youth in horticulture

Hi-tech horticultural innovations, protected cultivation, hydroponics, aeroponics, aquaponics, nursery production, mushroom cultivation, bee keeping and production, marketing and drying of flowers; and management issues, viz., marketing, post-harvest requirements, value addition for providing gainful employment is expected to attract the youth. Training programs, therefore, need to be organized at accredited centers.

6.12.3 Role of information communication technology

There is need to promote use of information communication technology (ICT) in the horticulture extension systems. In view of the concept of cluster development in different crops, there is need to move towards specialization in horticulture advisory services and development of commodity based extension systems.

6.12.4 Big data use in horticulture

Authentic or reliable database is the basis of formulation of any fruitful program or policy by any government. However, the database in horticulture sector is rather complex owing to diversity in crops. There is also no clear estimate available for backyard gardens and kitchen gardens and mixed plantations. Initiatives like Coordinated Horticulture Assessment using Management using geoinformatics (CHAMAN) is a good step taken by the GoI, however, use of big data is an urgent need of the hour and must be paid priority attention.

7. Way Forward

While a virtual revolution in horticulture has been observed in the horticulture sector in the country as evidenced by record production surpassing food grain production continuously for the past seven years, improved productivity and increased exports, the demand of

horticultural produce is increasing at a very fast rate due to demographic change, change in food habits from predominantly cereals to a richer mix of vegetables and fruits resulting in increased consumption due to realization of nutritional and health properties. Diversification to horticulture has been a fruitful proposition to farmers as it has brought substantial changes in the income particularly for small and marginal farmers. The requirement of horticultural crops particularly fruits and vegetables by 2030 would reach to 550 mt while significant development has taken place in food availability, a lot needs to be done to achieve high production levels in years to come. Though the conventional horticulture will continue to grow with small and marginal farmers, a shift to 'Hi-tech horticulture' has become extremely important. Besides, it is necessary that future efforts of research and development are directed on the following issues:

7.1 Exploitation of genetic diversity

Conservation of vegetatively propagated plants and collection, evaluation and utilisation of genetic resources of cultivated and wild relatives of horticultural crops should continue to receive priority. Wild relatives along with exotic and indigenous species of horticultural crops are largely untapped/unexploited for abiotic and biotic stress tolerance and need to be exploited to develop better varieties of different fruit crops e.g., mangosteen, rambutan, avocado, longon, *jamun*, *bael,* durian, Malayan apple, wax apple, rose apple, star fruit, dragon fruit and tamarind and several domestic crops. These have potential to be exploited for food, nutraceutical, economic values and also in the development of wastelands. There is also scope of commercialising many under-exploited crops. Breeding objectives need to focus on target-specific breeding with focus on seedlessness, tree architecture, nutrient use efficiency, rootstocks, abiotic and biotic stress resistance, shelf-life improvement, processing varieties, nutraceuticals and pigments, secondary metabolites (polyphenols, limonoids, furanocoumarins, carotenoids), high protein and biofortified varieties and crops. To address the problem, biotechnological tools like use of genomics, molecular markers, cisgenic and transgenic, trans-grafting, etc. need to be exploited to obtain desired results.

7.2 Achieving self-sufficiency in quality planting material

As per estimates, hardly 30-40 per cent of the requirement of planting materials for horticultural crops is met through public sector agencies like SAUs, ICAR institutes, state seed agencies, and other such agencies. Hence, there is dire need to make available large number of quality planting materials in different horticultural crops to fill the gap of 60-70 per cent requirement so that most of the farmers who do not have access to elite certified planting material and face the problem of low production and productivity and quality of produce, may have access of quality planting material and benefit from good produce. Further, efforts need to be directed to standardising micro-propagation protocols for production of quality planting materials in large quantities. Emphasis should also be laid on establishment and accreditation of nurseries and tissue culture units. In vegetable crops, emphasis on making availability of low cost F_1 hybrids from the public system, standardization and expansion of area under plug plant production and continued research on use of rootstock for vegetable grafting. Management of quality and health of plants also needs to be ensured through use of different diagnostic tools such as ELISA, ISEM, PCR based diagnostic, etc.

7.3. Improving productivity and availability of horticultural produce

Due to increasing population, urbanization and industrialization, cultivable land has shrunken drastically, hence best use of the available land resources may be assured. Efforts are also needed

to convert culturable waste, barren and un-culturable land into productive area using suitable operational techniques. Off-season production is needed outside the regular cropping season to ensure availability of fruits and vegetables during low supply period which can be fulfilled under protected cultivation. Old and senile orchards need to be rejuvenated or re-planted. Also, the vacant spaces between two rows of perennial crops during initial growth phase need to be utilized by growing horticultural and shade loving crops like tuber crops, medicinal and aromatic plants and plantation crops like cocoa. Promotion of integrated farming system having horticulture as one of the components seems a viable and sustainable option for reducing cost of production and enhancing regular income and employment opportunities to small and marginal farmers besides climate resilience. To improve the production and productivity, recent advances in hi-tech interventions e.g. use of F_1 hybrids, high density planting, canopy architecture, rootstocks, micro irrigation, fertigation, plant growth regulators, rejuvenation, protected cultivation, organic production, GAP, pollination support, mechanisation and efficient utilisation of inputs etc. will continue to receive priority in R&D. Honey bee colonies need to be promoted in all cross-pollinated horticultural crops grown both in open and under controlled conditions for enhancing productivity.

7.4 Reducing cost of production

There is an urgent need to harness the use of omics, genomics, proteomics, metabolomics, phenomics in bringing precision in crop improvement and production. Use of drip irrigation and nano-technologies for enhancing nutrient and water productivity and efficiency, new molecules of pest and disease management need concerted efforts. However, systematic research is needed to standardise these technologies in different crops and varieties. Innovative horticultural practices are required to bring about mechanization both in open field and greenhouse operations to avoid youth from shifting from villages to cities. Protected cultivation, hydroponics, aeroponics, acquaponics, vertical gardening, low cost polyhouses, insect proof nethouses, urban/peri-urban horticulture, pre- and post harvest management and value addition, use of ICT, emphasising FPOs, etc. need to be promoted at a faster face in the light of above advantages.

8. Conclusion

The strategy paper gives an account of the present status, the challenges and the way forward in horticulture R&D. What finally emerges is that India has a large production base, a wide variety of horticulture produce and nearness to the export markets. India also has good natural resource base, an adequate horticultural infrastructure and excellence in certain areas. The challenges are the fast growing population, shrinking land and other natural resources, the fast eroding gene pool, some production constraints, especially of planting material, rootstocks, abiotic and biotic stresses, lack of skilled human resource in newly emerging technologies and huge post-harvest losses due to absence of dedicated cold chain. Given the challenges, the country confronts the R&D workers, who have worked tirelessly to transform Indian horticulture in keeping with the demands of resurgent India. Nature has placed India in a position of advantage and it is important for horticulturists, farmers and entrepreneurs to sustain the already achieved Golden Revolution in horticulture in years to come.

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