INDIAN Horticulture
September–October 2021

Fruits and vegetables, your dietary essentials.

INTERNATIONAL YEAR OF FRUITS AND VEGETABLES 2021

#IYFV2021
Horticulture for food, nutritional and socio-economic security in India

India is bestowed with several agro-ecological regions which provides ample opportunities to grow a variety of horticultural crops which form a significant part of total agricultural produce in the country comprising fruits, vegetables, root and tuber crops, flowers and other ornamentals, medicinal and aromatic plants, spices, condiments, plantation crops and mushrooms. India is the second largest producer of fruits and vegetables in the world. Only 17% of arable land is being utilized for the cultivation of horticultural crops (27.2 million ha) and produced 329.86 million tonnes in 2020-21 with 2.05% higher than the previous year and 8.5% higher than the previous five years. The total production of fruit was 102.76 million MT with an average productivity of 14.51 MT/ha and vegetable production was 196.27 million MT with an average productivity of 17.11 MT/ha.

The horticultural crops contributed 30% to Gross Net Value (GNV) of agriculture. Fruit and vegetable availability per capita increased from 397 g/day in 2004-05 to 540 g/day. Exports increased by more than 3 times in 10 years. After independence, there has been tremendous growth in area and production of horticultural crops but on the other hand productivity has left far behind as compared to several advanced countries. The low productivity is mainly attributed to several factors including cultural practices, environmental, physiological...
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Towards ensuring nutritional rainbow for everyone

The UN General Assembly designated 2021 as the International Year of Fruits and Vegetables (IYFV). The official slogan of the campaign ‘Fruits and vegetables, your dietary essentials’ underlines the importance fruits and vegetables have in nutrition and overall health. The objectives of IYFV are to raise awareness of the health benefits of fruit and vegetable consumption; advocate for healthy diets through increased consumption of fruits and vegetables; promote international efforts to boost fruit and vegetable production and value chains in a sustainable and safe way; bring in focus on the need to reduce losses and waste in fruit and vegetable supply chains from production to consumption; and invite relevant stakeholders to strengthen the capacities of developing countries to adopt innovative approaches and technologies in combating loss and waste of fruits and vegetables. The IYFV 2021 is a step towards achieving UN Sustainable Development Goals.

India is the second-largest producer of horticultural produce, producing about 12% of the global fruit and vegetable production. The Government of India has taken a plethora of steps to further boost the horticulture sector particularly fruits and vegetables. Speaking at a National Conference organized by the Ministry of Agriculture and Farmers’ Welfare in collaboration with the FAO as part of the celebration of the ‘International Year of Fruits and Vegetables, 2021’, Union Minister for Agriculture and Farmers Welfare, Shri Narendra Singh Tomar, told that to promote globally popular Exotic and important Indigenous fruit crops in the country, the Ministry has identified 10 globally popular Exotic fruit crops of commercial importance and 10 important Indigenous fruit crops with high nutritional and nutraceutical properties. A blueprint for area expansion for these crops has been provided to the State Horticulture Departments with set targets for the year 2021-22. During the current year, 8951 hectares area for exotic fruits and 7154 hectares area for indigenous fruits will be brought under cultivation. Operational guidelines for the Horticulture Cluster Development Programme have also been released.

Measures have also been taken to promote the availability, accessibility and affordability of fruits and vegetables. The Government of India through the Mission for Integrated Development of Horticulture has enabled area expansion, development of nurseries and construction of farm ponds beside enabling investments in creation of post-harvest cold chain infrastructure. During the COVID-19 lockdown, the Government took lot of initiatives to build short and inclusive value chains for fruits and vegetables. FPOs were allowed to trade in their agricultural produce directly through online modalities. Similarly, farmers were allowed to trade online from registered warehouses too. ‘Kisan Rath’ app launched as a public-private partnership enabled small and marginal farmers to carry harvested agricultural produce, without delay, from the farmgate to regulated wholesale markets and warehouses. The ‘Kisan Rail’ and ‘Kisan Udaan’ initiatives have been launched to strengthen post-harvest rail and air connectivity.

Our future line of action should focus on strengthening of integrated cold chains at farmgate pack houses; expanding the harvesting window by mainstreaming of fruits and vegetables even during offseason to increase availability; developing nutrient dense biofortified varieties and last but not the least, considering perennial fruit crops as a source of promoting clean environment. It goes without saying that our last mile, more than 700 Krishi Vigyan Kendras (KVKs), need to be aggressively plugged into farmgate supply and value chains to advise on increasing productivity, yield and market reach of fruits and vegetables. I am hopeful that India can achieve the goal of bringing fruits and vegetables to the plate of the poorest of the poor, not as a special food but as a daily necessity.

– Editor
and biological factors. But over the years, climate change is playing a significant role on the occurrence of erratic rain, rising temperature, flood, snowfall, landslides, droughts, etc. resulting in variation in the production pattern of several horticultural crops.

Scenario of horticulture in India
The area and production trend shows that there has been a sharp rise in production of horticulture crops with production during the year 2017-18 (Final) reaching 311.7 million tonnes which is 3.7% higher than the previous year and 10% higher than the past 5 years’ average production. Production of fruits is estimated at 97.35 million tonnes which is 4.8% higher than previous year. Production of vegetables is estimated at about 187.5 million tonnes which is about 3.5% higher than the previous year. With an increase of 3.7%, the production of onion during the year 2017-18 is estimated at 23.26 million tonnes as against 22.4 million tonnes in 2016-17. Production of potato in the year 2017-18 (Final) is estimated at 51.3 million tonnes as against 48.6 million tonnes in 2016-17 (5.6% higher than 2016-17). India is the largest producer of ginger and okra amongst vegetables and ranks second in production of potatoes, onions, cauliflower, brinjal, cabbages, etc. Amongst fruits, the country ranks first in production of bananas (25.7%), papayas (43.6%) and mangoes (including mangosteens and guavas) (40.4%).

Production trend of horticulture in India
The vast production base offers India tremendous opportunities for export. During 2017-18, India exported fruits and vegetables worth ₹ 9,410.81 crore/ 1,459.93 USD millions which comprised fruits worth ₹ 4,229.03 crore/ 655.90 USD million and vegetables worth
Research work is being carried out for improvement and resistance to various biotic and abiotic stresses. Development of varieties and hybrids for high yields, last five decades the main focus was given for the private sector catering to hybrid seeds of vegetables. Hybrid seed production, which led to the emergence of lines and their commercial exploitation economized the pollinated crops. Further, the development of male sterile revolutionized vegetable farming both in self and cross tapping hybrid vigor or heterosis in vegetable crops has flowers and many other crops for various regions. The have been developed and released in fruits, vegetables, ornamental crops, medicinal and aromatic plants and mushroom. In fruit crops, a total of 40 hybrids/varieties in fruit crops have been developed and released for commercial cultivation of which the varieties such as Arka Udaya (mango), Arka Kiran and Arka Mridula (guava), Arka Surya and Arka Prabhat (papaya), Arka Sahan (custard apple) are being popular among the farmers. In vegetable crops, improvement and production work is being carried out in 30 different vegetable crops, and more 136 hybrids were released of which the hybrids/varieties such as Arka Samrat and Arka Rakshak (tomato), Arka Anand (brinjal), Arka Anamika (okra), Arka Khyati and Arka Meghan (chilli), Arka Manik (water melon), Arka Suvidha, Arka Komal and Arka Anoop (French Bean), Garden Pea (Arka Ajit), Arka Garima (cowpea), Arka Jay and Arka Vijay (dolichos bean), Arka Bahar (bottle gourd), Arka Harit (bitter gourd) and Arka Sujat and Arka Sumeet (ridge gourd) are very popular among vegetable growers. Besides, research on improvement and production techniques are being carried out in 19 ornamental crops, 6 medicinal plants and 2 aromatic crops. A total of 75 hybrids/varieties in ornamental crops, 9 hybrids/varieties in medicinal plants and 3 varieties in aromatic crops have been released of which the varieties such as Arka Prajwal (tube rose), Arka Bangara and Arka Agni (marigold), Violet Cushions and Poornima (China aster) and Arka Alankar (crossandra) are being popular among farmers. Besides this, several promising lines of betelvine for commercial cultivation were also developed.

**Hi-tech horticulture**

*Improved high yielding varieties*

Several high yielding varieties in horticultural crops have been developed and released in fruits, vegetables, flowers and many other crops for various regions. The tapping hybrid vigor or heterosis in vegetable crops has revolutionized vegetable farming both in self and cross pollinated crops. Further, the development of male sterile lines and their commercial exploitation economized the hybrid seed production, which led to the emergence of private sector catering to hybrid seeds of vegetables. Last five decades the main focus was given for the development of varieties and hybrids for high yields, quality and resistance to various biotic and abiotic stresses. Research work is being carried out for improvement and production aspects of various horticultural crops such as fruits, vegetables, ornamental crops, medicinal and aromatic plants and mushroom. In fruit crops, a total of 40 hybrids/varieties in fruit crops have been developed and released for commercial cultivation of which the varieties such as Arka Udaya (mango), Arka Kiran and Arka Mridula (guava), Arka Surya and Arka Prabhat (papaya), Arka Sahan (custard apple) are being popular among the farmers. In vegetable crops, improvement and production work is being carried out in 30 different vegetable crops, and more 136 hybrids were released of which the hybrids/varieties such as Arka Samrat and Arka Rakshak (tomato), Arka Anand (brinjal), Arka Anamika (okra), Arka Khyati and Arka Meghan (chilli), Arka Manik (water melon), Arka Suvidha, Arka Komal and Arka Anoop (French Bean), Garden Pea (Arka Ajit), Arka Garima (cowpea), Arka Jay and Arka Vijay (dolichos bean), Arka Bahar (bottle gourd), Arka Harit (bitter gourd) and Arka Sujat and Arka Sumeet (ridge gourd) are very popular among vegetable growers. Besides, research on improvement and production techniques are being carried out in 19 ornamental crops, 6 medicinal plants and 2 aromatic crops. A total of 75 hybrids/varieties in ornamental crops, 9 hybrids/varieties in medicinal plants and 3 varieties in aromatic crops have been released of which the varieties such as Arka Prajwal (tube rose), Arka Bangara and Arka Agni (marigold), Violet Cushions and Poornima (China aster) and Arka Alankar (crossandra) are being popular among farmers. Besides this, several promising lines of betelvine for commercial cultivation were also developed.

**Protected cultivation of flowers and vegetables**

Protected cultivation is a cropping technique for growing horticultural crops under protective structures to shield them from pests and weather for assured, climate-resilient and enhanced production of quality products. India has a long tradition of cultivating flowers mainly for use in religious and social functions apart from making floral ornaments for personal adornment. The area under floriculture in India is only 0.76% of the global area. The area under protected cultivation is very low in India as compared to many flower producing countries. In between 1991 and 1996, about 170 export-oriented floriculture units with 1,545 million stems capacity (small and big) were started in various parts of the country involving more than 1,500 crore for growing 40 varieties of roses in an area of 500 ha, of which 70 units are operational. Indian
floriculture is constrained by lack of awareness, weak infrastructural support, lack of quality planting material, post-harvest facilities, exploitation by middlemen, lack of organized markets and weak database. There are more than 300 export-oriented units in India. More than 50% of the floriculture units are based in Karnataka, Andhra Pradesh and Tamil Nadu. With the technical collaborations from foreign companies, the Indian floriculture industry is poised to increase its share in world trade.

Drip fertigation

The new technologies of micro-irrigation now include drip/trickle systems, surface and sub-surface drip tapes, micro-sprinklers, sprayers, micro-jets, spinners, rotors, bubblers, etc. Micro-irrigation is popularly practised in about 30 crops, and is more popular in horticultural crops which allow relatively wide spacing. It is however critical that micro-irrigation is popularised and facilitated in field crops grown in rainfed cultivation systems. This will benefit the small and marginal farmers, who are predominant practitioners of field crops and rainfed farming systems. Studies have revealed that water savings ranging between 25 and 50% are possible by drip irrigation compared with surface irrigation. Micro-irrigation also facilitates application of controlled quantity of water and nutrients in the vicinity of each plant, such that the crop, water and nutrient needs are almost matched with irrigation water supplies.

High-density planting

High density means to increase the plant population per unit area for increasing the production of fruit crops or HDP is one of the novel methods to achieve high productivity per unit area both in short duration and perennial horticultural crops. In mango, HDP at 1111 trees/ha on ‘Olour’ rootstock with Paclobutrazol application from 4th year at 0.125g/tree/year of age, stabilized by the 10th year resulted in 6-fold increase in productivity. Similarly, cv. Amrapali at 2.5 x 2.5 m in triangular system accommodation of 1600 and cv. Dashehari at 3.0 x 2.5 m in square system–1333 plants/ha. Increase in yield per ha was 2.5 times in Amrapali than that of the low density orchards of vigorous cultivar. In cv. Dashehari, the average yield in high density is reportedly 9.6 tonnes compared to 0.2 tonnes in low density planting. In citrus, kinnow on Troyer Citrange and Karnakhatta rootstocks could be planted at 1.8 x 1.8 m and 3 x 3 m to accommodate 3,000 and 1,088 plants/ha, respectively. In pineapple, population density of 63,758/ha coupled with improved package of agrotechniques resulted in increase in yield from 15-20 to 70-80 t/ha.

In banana, the following HDP methods are being commercially practiced:

<table>
<thead>
<tr>
<th>Variety</th>
<th>Plant Density (No. of plants/ha)</th>
<th>Yield (t/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Robusta</td>
<td>4400 (1.5 m x 1.5 m spacing)</td>
<td>-- 120</td>
</tr>
<tr>
<td>Dwarf Cavendish</td>
<td>4400 (1.5 m x 1.5 m spacing)</td>
<td>--100</td>
</tr>
<tr>
<td>Ney Poovan</td>
<td>5120 (1.5 m x 1.5 m triangle planting)</td>
<td>recommended, which is 16% more than 4440 plants/ha (1.5 m x 1.5 m planting).</td>
</tr>
</tbody>
</table>

The concept of HDP and UHDP or meadow orcharding is very successful in apple (Table 1) and it is being commercially practiced by many growers.
Canopy management

Canopy management is the manipulation of tree canopies to optimize the production of quality fruits. The canopy management, particularly its components like tree training and pruning, affects the quantity of sunlight intercepted by trees, as tree shape determines the presentation of leaf area to incoming radiation. An ideal training strategy centers around the arrangement of plant parts, especially, to develop a better plant architecture that optimizes the utilization of sunlight and promotes productivity. Light is critical to growth and development of trees and their fruits. Strong bearing branches tend to produce larger fruits. The problem of a fruit grower is initially to build up a strong and balanced framework of the trees, then equip them with the appropriate fruiting. Obviously, pruning in the early years has to be of a training type to provide strong and stocky framework with well spaced limbs or any other desired shape.

Soilless culture

Soilless culture is one of the best techniques to overcome local water shortages, while also producing high quality produce, even in areas with poor soil structure and problematic conditions. Soilless culture is a method of growing plants without soil. The application of these systems is likely to increase close to existing cities as well as in mega-cities worldwide in the near future.

In order to meet out the growing demand for soilless culture technology, ICAR-IIHR has initiated a project on development and standardization of soilless cultivation of vegetables on Arka Fermented Cocopeat under open and protected conditions during the year 2015. Under this project, the production technology including nutrient formulations for open and polyhouse soilless cultivation of most commonly consumed vegetables, viz. tomato, chilli, cabbage, cucumber, brinjal, cow pea, dolichos, French bean, garden peas, ridge gourd and leafy vegetables and few exotic vegetables like zucchini, broccoli and colour cabbage using Arka Fermented Cocopeat as substrate has been standardized. The results of most of the experiments conducted with different vegetable crops in grow bags under open-field and polyhouse soilless culture indicated that the plants grown in soilless culture recorded higher yield and better quality particularly in mineral nutrient content compared to soil grown plants.

Vertical farming

Vertical farming is the practice of growing crops on a smaller land area, by the utilization of vertical space, which is usually left unutilized in traditional agriculture. Though vertical farming has been in vogue since ancient times as evinced by the Hanging Gardens of Babylon, the modern concept of vertical farming involves the union of plant biology and suitable engineering know-how. It can be considered as an extension of indoor farming that evolved in the 1700s with the advent of greenhouses, with the primary objective of harnessing the off-season crop cultivation potential during unfavourable seasons. This involves the stacking of crops growing platforms in a vertical fashion and providing the necessary nutrition and lighting by artificial means in order to cultivate crops all-round the year. Most commercial vertical farm ventures in developed countries operate from existing warehouses or abandoned factories/buildings that have been suitably converted to hydroponic/aeroponic facilities with LED based illumination systems. Further, utilizing vertical space, is highly energy intensive since artificial illumination needs to be provided for crop production in multi-tiered structures. Therefore, uninterrupted power supply would be a limiting factor for vertical farming under Indian conditions. Apart from this, the high initial costs of the infrastructure and the operating costs may act as deterrents for large scale vertical farming, therefore, there is a need to develop country specific infrastructure and technology before vertical farming can be adopted on a large scale in India. Other limitations of the vertical farming include the cultivation of crops without sufficient scientific validation, lack of varieties/hybrids that have been exclusively bred for the purpose of vertical farming, lack of Good Agricultural Practices for vertical farming situations and the design of existing high-rise structures that are not amenable for vertical farming. The above limitations could be taken up as researchable issues to promote vertical farming in India.

Quality planting material production

Availability of planting material (Table 2) of good quality is one of the most important elements of successful horticultural production. Planting material available to small-scale farmers in different areas is often of insufficient quality, which undermines potential yield

<table>
<thead>
<tr>
<th>Canopy management system</th>
<th>Number of plants/ha</th>
<th>Recommended rootstock</th>
<th>Average yield (t/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertical axis</td>
<td>8888 (1.5 x 0.75 m)</td>
<td>M-9</td>
<td>62-66 (5 yrs)</td>
</tr>
<tr>
<td>Espalier</td>
<td>2222 (1.5 x 3.0 m)</td>
<td>M-9</td>
<td>55-60 (4 yrs)</td>
</tr>
<tr>
<td>Cordon system</td>
<td>8888 (1.5 x 0.75 m)</td>
<td>M-9</td>
<td>40-50 (7-8 yrs)</td>
</tr>
<tr>
<td>Head and spread</td>
<td>2222 (1.5 x 3.0 m)</td>
<td>M-9</td>
<td>35-45 (7-8 yrs)</td>
</tr>
<tr>
<td>Spindle bush</td>
<td>2222 (1.5 x 3.0 m)</td>
<td>M-9</td>
<td>25-40 (10-12 yrs)</td>
</tr>
<tr>
<td>Modified central leader system</td>
<td>1600 (2.5 x 2.5)</td>
<td>M-106</td>
<td>40-45 (8-10 yrs)</td>
</tr>
<tr>
<td></td>
<td>2222 (3.0 x 1.5)</td>
<td>M-9</td>
<td>30-35 (7-8 yrs)</td>
</tr>
<tr>
<td>Modified central leader system</td>
<td>625 (4 x 4 m)</td>
<td>Seedling</td>
<td></td>
</tr>
</tbody>
</table>
and performance of crop production. There has been a significant increase in the production of horticultural crops in recent years in India. At present in India more than 4,409 fruit nurseries including 1,575 under government sector and 2,834 under private sector are functioning which have an annual target of producing 1,387 million fruit plants. This accounts for 30-40% of the demand of planting materials of fruit sector.

In order to produce true to type planting materials, most of the fruit crops are propagated by asexual or vegetatively except the crops like papaya, phalsa and mangosteen.

Climate smart horticulture

The world has been experiencing a dramatic change, especially in the last few decades. Although the nature and extent of the changes cannot be accurately quantified, the experts of the Inter governmental Panel on Climate Change (IPCC) are unanimous on the impact of this phenomenon which is nowadays perceptible in all regions of the world. A significant change in climate at global and national level is certainly impacting horticulture and affecting the production and quality. The understanding of impact of climate change on horticultural crops production system and its potential effects have drawn a little attention of researchers. Due to severe cold wave, horticultural crops suffer a yield loss of 10-100% depending upon crop and varieties. The issue of climate change has thrown up greater uncertainties and risks, further imposing constraints on production systems. As per the estimate, India’s total population will be more than 1.5 billion, the largest in the world, with the urban population of around 600 million by 2030. The influx of population from rural to urban areas in search of jobs has been increasing in the recent past due to growth in

### Table 2. Planting material requirements in fruit crops

<table>
<thead>
<tr>
<th>Crop</th>
<th>Annual growth rate (%)</th>
<th>Area (ha)</th>
<th>No of plants / ha</th>
<th>Total requirement of plant materials (crore)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mango</td>
<td>4.0</td>
<td>92,000</td>
<td>156</td>
<td>1.43</td>
</tr>
<tr>
<td>Banana</td>
<td>6.0</td>
<td>48,000</td>
<td>3086</td>
<td>14.81</td>
</tr>
<tr>
<td>Citrus</td>
<td>6.0</td>
<td>38,000</td>
<td>300</td>
<td>1.14</td>
</tr>
<tr>
<td>Sapota</td>
<td>4.0</td>
<td>6,400</td>
<td>100</td>
<td>0.64</td>
</tr>
<tr>
<td>Guava</td>
<td>6.0</td>
<td>13,800</td>
<td>400</td>
<td>0.55</td>
</tr>
<tr>
<td>Grape</td>
<td>4.0</td>
<td>4,000</td>
<td>2400</td>
<td>0.96</td>
</tr>
<tr>
<td>Papaya</td>
<td>5.0</td>
<td>5,000</td>
<td>3086</td>
<td>1.54</td>
</tr>
<tr>
<td>Pomegranate</td>
<td>8.0</td>
<td>12,000</td>
<td>400</td>
<td>0.48</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td></td>
<td><strong>21.55</strong></td>
</tr>
</tbody>
</table>

### Aeroponics for mini-tuber production

- Plant are grown in troughs, tubes or other type of chambers
- Roots are hung in air and are sprayed with nutrient mist
- Easily absorb nutrients
- Easily absorb oxygen
- Less chance of root diseases
Micro rhizomes – disease free plants and germplasm exchange

In crops like potato, ginger, turmeric and a few tuber crops, micro rhizome technology is very efficient in production of disease free clonal planting material of elite genotypes.

services and manufacturing sector as a result ensuring the adequate food supply, environmental pollution reduction, employment and income generation are real challenges which may be addressed through urban and peri-urban horticulture.

Farmers' friendly production technologies in horticulture

There are several farmers’ friendly technologies for enhancing the yield and quality of various horticultural crops. The details are as follows:

- Methyl eugenol pheromone traps for mango and guava fruit fly.
- Cuelure pheromone trap for cucurbit fruit fly.
- Neem soap for agricultural use.
- Pongamia soap for agricultural use.
- Use of neem cake for the management of insect pests of vegetables.
- IPM modules for major pests of fruits, vegetables and flower crops.
- IDM modules for major diseases of fruits, vegetables and flower crops.
- Dogridge a salt and drought tolerant root stock for grapes recommended.
- Salt tolerant variety of acid lime Tenali recommended for saline areas.
- Crop specific micronutrient formulations for banana, citrus, mango and vegetables developed and commercialized.
- Nutrient feeding of banana bunches by denavelling through nutrient blended cow dung.
- Arka microbial consortium for fruits and vegetable productions.
- Arka cocopeat for nursery raising of fruits and vegetable seedlings.
- Seed pelleting of onion and tomato.
- Technologies for protected cultivation of tomato, capsicum, cucumber and lettuce have been standardized and transferred to State Agri/Hort. Departments of many states.
- Production of RTS beverages and flavoured wine from Muscat grapes to Coimbatore grape growers association, Coimbatore.
- Long term preservation of raw mango slices for pickling to MTR Ltd., Bengaluru.
- Short term preservation of vegetable baby corn to M/s Kevina Foods Ltd., Bengaluru.
- Production of osmotically dehydrated fruits like mango, pineapple, papaya and aonla and mango fruit bar to M/s PEE PEE Industries, Chennai.
- Preparation of beverages of mango, pineapple and aonla was transferred to M/s PEE PEE Industries, Chennai.
- Hot water treatment of mango for uniform ripening to Kisan products, Bengaluru.
- Low temperature storage of pineapples for long distance transport by ship to M/s TEDMAG, Bengaluru.
- Ready-to-pluck (RTP) mushroom packs are being commercialized to two private companies.

Conclusion

The horticulture sector in India possesses unique advantage because of availability of varied climatic conditions for production of various horticultural crops and several ICAR institutes and SAUs are working for the benefit of farmers and other stakeholders. Besides, there is a huge varietal diversity in most of the cultivated fruits, vegetables, flowers, plantation and spices, which increase the harvesting season and more revenues to the farmers. The production and supply of quality planting materials, implementation of INM, IDM and IPM, multi cropping system, integrated farming system (IFS), pollinators, pre- and post-harvest management, forward and backward linkages in marketing are very important for successful cultivation of horticultural crops. In spite of higher production, the quantity of processed products from the raw materials are poor and very low in quantity produce, which is due to the lack of GAP for most of the horticultural crops and poor post-harvest handling. Several prediction models have suggested that the area under horticultural crops are going to increase and
Cereal crops will be decreasing, hence, it is time to breed the climate resilient varieties to withstand the climatic aberrations. Hence, a comprehensive plan covering R&D aspects for all horticultural crops is must and convergence of scientists, policy makers and public is the need of the hour for marching ahead and to take the horticulture to newer heights. However, there are certain causes of concern like horticulture does not enjoy a safety net like the Minimum Support Price (MSP) for foodgrains; lack of good cold chain storage and transport networks to extend the life of perishable products; very less or limited input by machinery and equipment so it is tough to minimise the time restraints; higher input costs than foodgrains make it a difficult set up, especially when there is no support from the local governments to the smaller farmers; and limited availability of market intelligence, mainly for exports—make it a tougher option to choose.

For further interaction, please write to:
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Flowers always make people better, happier, and more helpful; they are sunshine, food and medicine for the soul.

– Luther Burbank
Vegetables for better nutrition and safe environment

Vegetable crops are a vital component of agriculture for ensuring food and livelihood security owing to their higher yield potential and better nutrient contents. Enormous diversity in vegetables cater to the dietary nutrient requirements of humans and therefore vegetables make a very important constituent of food for fulfilling nutritional security as well. Most of the vegetables are short duration crop easily adjusted in crop diversification, provide higher biomass and return leading to nutritional and economic security to resource-poor farmers. Vegetables are also economic engines for productive, profitable agricultural economies. Intensified vegetable production has the potential to generate more income and employment than other segments of the agricultural economy, making vegetables an important element of any agricultural growth strategy. Vegetable production provides a promising economic opportunity for reducing rural poverty and unemployment in rural areas, and is a key component of farm diversification strategies.

Prospects

India ranks second after China in vegetable production in the world and India’s contribution to the total vegetable production of the world is 14%. Vegetable cultivation in India is done from the mountainous regions of the Himalayas in the north to the coastal parts of the sea located in the south. Due to more income from vegetables throughout the year, the more number of growers are adopting vegetable farming. Carbohydrates, proteins, mineral salts, amino acids and many vitamins are found in vegetables, which not only make our food tasty but also make the body active by giving it the strength to fight diseases. According to the Indian Council of Medical Research, 300 g of vegetable is necessary per person per day in which 100 g of leafy vegetables, 100 g of root vegetables and 100 g of other vegetables should be included, but at present this prescribed quantity is not available to everyone. On one hand, vegetables are being wasted in India due to lack of storage and processing while on the other hand, the problem of malnutrition is widespread in the country. The recently published National Family Health Survey data showed that 79.2% of the 6-35 months old children in our country are suffering from anaemia. The problem of malnutrition in our country can be tackled by including more vegetables in the diet. According to an estimate, by the year 2030, the population of the country will be around 145 crore and more than 263 million tonnes of vegetable production will be required to cater the demands of growing population. With more production of vegetables, we will be able to consume more vegetables to fulfill the requirements of essential nutrients in our food, and also get more foreign exchange than ever before by selling the surplus produce abroad. Therefore, to ensure the nutritional and income security of the growing population of the country, it is very necessary to increase the production of vegetables.

Current status

India’s diverse climate ensures availability of a wide variety of vegetables. It ranks second in vegetables production in the world, after China. India produced 191.77 million metric tonnes of vegetables from 10.35 million ha area as per National Horticulture Database 2019-20 (Second Advance Estimates). Besides, India is the largest producer of ginger and okra amongst vegetables and ranks second in production of potatoes, onions, cauliflowers, brinjal, cabbages, etc.

India has achieved enormous growth in terms of area,
production, productivity and consumption of vegetables from last decade. The production of vegetables has increased from 133.73 MT in 2009-10 to 184.39 MT in the year 2017-18. Similarly, the productivity has also increased from 16.75 t/ha to 17.97 t/ha (Fig. 1).

Uttar Pradesh is the largest vegetable producing state in India, where 283 lakh metric tonnes of vegetables were produced from a total area of 14 lakh ha during the year 2017-18. According to the latest estimates, West Bengal will become the largest vegetable producing state in the country in 2019-20 (Fig. 2).

Although more than 50 types of vegetables are grown in India, potato, onion, tomato, brinjal, chilli etc. are the main vegetable crops here (Table 1). If we look at the global level, India ranked at second place in the world in the production of brinjal, cabbage and cauliflower, while India ranked first in both the area and production of lady finger. But when it comes to productivity, we are ranked third, sixth, eighth and ninth in the world in okra, cauliflower, brinjal and cabbage respectively. India is also an exporter of fresh vegetables in the world. The country has exported 682,085.85 MT of fresh vegetables other than onion to the world for the worth of ₹ 2,143.21 crore/ 289.09 USD millions during the year 2020-21. The major importing countries are United Arab Emirates, Nepal, Bangladesh, UK and Qatar. However, compared to countries like USA, Korea, Spain, the productivity of vegetables in our country is very low and serious policy efforts need to be implemented to overcome this situation.

Table 1. All India area and production of horticulture crops

<table>
<thead>
<tr>
<th>Vegetable</th>
<th>2017-18</th>
<th>2018-19</th>
<th>2019-20</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Area ('000 ha)</td>
<td>Production ('000 MT)</td>
<td>Area ('000 ha)</td>
</tr>
<tr>
<td>Beans</td>
<td>228</td>
<td>2277</td>
<td>236</td>
</tr>
<tr>
<td>Bitter gourd</td>
<td>97</td>
<td>1137</td>
<td>99</td>
</tr>
<tr>
<td>Bottle gourd</td>
<td>157</td>
<td>2683</td>
<td>187</td>
</tr>
<tr>
<td>Brinjal</td>
<td>730</td>
<td>12801</td>
<td>727</td>
</tr>
<tr>
<td>Cabbage</td>
<td>399</td>
<td>9037</td>
<td>400</td>
</tr>
<tr>
<td>Capsicum</td>
<td>24</td>
<td>326</td>
<td>34</td>
</tr>
<tr>
<td>Carrot</td>
<td>97</td>
<td>1648</td>
<td>109</td>
</tr>
<tr>
<td>Cauliflower</td>
<td>453</td>
<td>8668</td>
<td>465</td>
</tr>
<tr>
<td>Cucumber</td>
<td>82</td>
<td>1260</td>
<td>105</td>
</tr>
<tr>
<td>Chillies (green)</td>
<td>309</td>
<td>3592</td>
<td>377</td>
</tr>
<tr>
<td>Elephant foot yam</td>
<td>30</td>
<td>774</td>
<td>33</td>
</tr>
<tr>
<td>Mushroom</td>
<td>198</td>
<td>487</td>
<td>0</td>
</tr>
<tr>
<td>Okra</td>
<td>509</td>
<td>6095</td>
<td>513</td>
</tr>
<tr>
<td>Onion</td>
<td>1285</td>
<td>23262</td>
<td>1220</td>
</tr>
<tr>
<td>Pointed gourd</td>
<td>20</td>
<td>310</td>
<td>55</td>
</tr>
<tr>
<td>Pea</td>
<td>540</td>
<td>5422</td>
<td>552</td>
</tr>
<tr>
<td>Potato</td>
<td>2142</td>
<td>51310</td>
<td>2173</td>
</tr>
<tr>
<td>Radish</td>
<td>209</td>
<td>3061</td>
<td>200</td>
</tr>
<tr>
<td>Pumpkin</td>
<td>78</td>
<td>1714</td>
<td>94</td>
</tr>
<tr>
<td>Sweet potato</td>
<td>131</td>
<td>1500</td>
<td>110</td>
</tr>
<tr>
<td>Tapioca</td>
<td>173</td>
<td>4950</td>
<td>163</td>
</tr>
<tr>
<td>Tomato</td>
<td>789</td>
<td>19759</td>
<td>781</td>
</tr>
<tr>
<td>Others</td>
<td>1580</td>
<td>22320</td>
<td>1441</td>
</tr>
<tr>
<td>Total vegetables</td>
<td>10259</td>
<td>184394</td>
<td>10073</td>
</tr>
</tbody>
</table>

Source: Ministry of Agriculture and Farmers Welfare, GoI
If we look at the export of vegetables, then it contributes only 5% to the total agriculture and 0.23% to the total national export. Similarly, at the international level, India is ranked 24th in vegetable exports.

**Vegetable production: problems and solutions**

Vegetable based industry is developing rapidly in India. In this decade, work has been done on many dimensions of vegetable variety improvement and production techniques, but to fight the challenges of the future, it is absolutely necessary to make efforts in this area. There are many challenges before the vegetable farmers in India, some of which are as follows:

- Non-availability of quality seed
- Lack of multi-stress resistant varieties to deal with climate change
- Lack of location-specific technical recommendations related to production
- Lack of awareness about modern methods of vegetable farming like protected farming and non-seasonal farming
- Lack of special varieties for processing
- Lack of market facilities for marketing of vegetables
- Lack of facilities for storage, packing and transportation for export
- Lack of targeted extension and training programs for vegetable growers.

At present, climate change due to increase in the concentration of greenhouse gases and high temperature, increase in drought, flood, cyclone etc. is a reality and the effect of climate change is clearly visible on various ecosystems, especially, vegetable production. Various strategies for mitigation and adaptation have been suggested like development of vegetable crop varieties which are tolerant to high temperature, low rainfall, drought, submergence etc., conservation of natural resources (water, energy etc.) through adoption of drip and sprinkler irrigation method, suitable cropping system modules, balanced use of organic manures and chemical fertilizers etc. Adaptation can be accomplished by adopting crop rotation and suitable vegetable crop production practices. There is also a need to give priority to specific under-exploited vegetable crops in varietal development programmes. In addition, it will be necessary to strengthen training programs on various aspects of vegetable and its seed production and postharvest technologies for members of cooperatives, government officials and farmers.

**Major accomplishments in vegetable production**

**Biofortified varieties**

Biofortification of different vegetable varieties offers a sustainable and long-term solution in providing nutritionally-rich crops to people. Intensive breeding efforts have resulted in development of some exceptionally nutrient-rich vegetable varieties. Some of the biofortified vegetable varieties, developed in India, and their characteristics are presented in Table 2. Breeding for such varieties in other crops are also underway at ICAR-IIHR, Bengaluru and ICAR-IIVR, Varanasi.

**Hybrid varieties**

Recognizing the prospects of heterosis breeding in development of improved vegetable hybrids, Indian Council of Agricultural Research (ICAR) initiated a network project on Promotion of Hybrids in Vegetable Crops in 1995-96. At present, heterosis breeding is being taken up in crops like tomato, brinjal, chilli, capsicum (bell pepper), sweet pepper, okra, cauliflower, cabbage, carrot, cucumber, bitter gourd, bottle gourd, muskmelon, and watermelon etc. with the aim to (i) promote hybrid research in order to increase productivity per se of the country, (ii) incorporate biotic stress resistance in the hybrids, and (iii) to strengthen hybrid seed research and hybrid seed production technology. Screening and development of vegetable varieties resistant to specific pathogen has been an integral component of research programmes. The impacts of vegetable breeding programmes made major strides in the development of varieties resistant to leaf curl virus and bacterial wilt in tomato, YVMV in okra, powdery mildew in pea, bacterial wilt in brinjal, downy mildew and CGMV resistant in muskmelon.

**Development of off-season varieties**

Past few years have witnessed large scale adoption of off-season varieties, especially, of radish, tomato, onion,

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**Table 2. Biofortified varieties of vegetable crops developed by ICAR institutions**

<table>
<thead>
<tr>
<th>Crop</th>
<th>Variety</th>
<th>Special features</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cauliflower</td>
<td>Pusa Beta Kesari 1</td>
<td>Developed by ICAR-IARI, New Delhi in 2015; country’s first biofortified cauliflower; contains high β-carotene (8.0-10.0 ppm) in comparison to negligible β-carotene content in popular varieties; curd yield: 40.0-50.0 t/ha.</td>
</tr>
<tr>
<td>Potato</td>
<td>Bhu Sona</td>
<td>Developed by ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala in 2017; high β-carotene (14.0 mg/100 g) content as compared to 2.0-3.0 mg/100 g β-carotene in popular varieties; tuber yield: 19.8 t/ha; dry matter: 27.0-29.0%; starch: 20.0%; total sugar: 2.0-2.4%.</td>
</tr>
<tr>
<td>Sweet Potato</td>
<td>Bhu Krishna</td>
<td>Developed by ICAR-Central Tuber Crops Research Institute in 2017; high anthocyanin (90.0 mg/100g) content in comparison to popular varieties which have negligible anthocyanin content; tuber yield: 18.0 t/ha; dry matter: 24.0-25.5%; starch: 19.5%; total sugar: 1.9-2.2%; salinity stress tolerant.</td>
</tr>
<tr>
<td>Radish</td>
<td>Pusa Jamuni</td>
<td>Developed by ICAR-IARI, New Delhi in 2012; first purple fleshed unique trait nutritionally rich radish variety. Distinct advantage in root size, shape, yield and consumer preference over the existing varieties. Higher anthocyanins and ascorbic acid.</td>
</tr>
<tr>
<td>Radish</td>
<td>Pusa Gulabi</td>
<td>Developed by ICAR-IARI, New Delhi in 2012; first entire pink fleshed unique trait nutritional rich radish variety. Medium root size, cylindrical shape, optimal yield and consumer preference over the existing varieties. High total carotenoids, anthocyanins and optimal ascorbic acid.</td>
</tr>
</tbody>
</table>
cabbage and carrot amongst the growers that has resulted in ever-higher vegetable production. Tomato cvs. Pusa Sheetal and Pusa Hybrid 1 have been identified for fruit set at low and high temperature, respectively. Likewise, development of cvs. like Pusa Chetki and Pusa Desi in radish has made it possible to grow it throughout the year. Onion, which is a rabi season crop, traditionally, can now be grown in kharif as well with the advent of cvs. like N-53, Agrifound Dark Red, Arka Kalyan and Baswant 780. Furthermore, rescheduling the planting season has also extended the availability period of carrot. For instances, carrot cv. Pusa Vrishi and Pusa Meghali can be sown during July-August and made available during October-December. On the other hand, cv. Pusa Yamdagini can be sown during December-February to make roots available during March-May. Similarly, cv. like Pusa Nayanjyoti can be sown in March-April and roots are available for harvest in June-July.

**Protected cultivation**

India being a country blessed with diverse agro-climatic regions has displayed an overall growth of around 2.15 lakh ha area under protected cultivation in different forms in the last two decades. Protected cultivation is rendering opportunities for improving quality, productivity and remunerative prices to the vegetable growers by protecting crop from the vagaries of nature. Insect proof net houses can be used to reduce pest and pesticide levels in addition to virus-free cultivation of tomato, chilli, sweet pepper and other vegetables during the rainy season. Parthenocarpic cucumber production under protected cultivation gives very high yield with quality fruit. Low cost greenhouses can be used for high quality vegetable cultivation for long duration (6-10 months) to obtain appropriate price of produces. Basically the growth of protected cultivation technology in the country happened mainly due to government policies providing handsome subsidies under various schemes launched by government of India under MIDH [NHM], TM, NHB, RKVY etc., but merely due to the technical beauty of the technology. Initially, most of the varieties suitable for protected cultivation were from private sector; however, at present many varieties developed by public sector research organizations, such as tomato – Pusa Rakshit, Arka Meghali, Arka Saurav, Pant Poly House Tomato-1, Pant Poly House Tomato Hybrid-1; cucumber - Pant Parthenocarpic Cucumber-2, Pusa Parthenocarp Cucumber 6 and 3; capsicum - Arka Gaurav, Arka Basant etc. have shown promise for cultivation under protected environment. Pusa Seedless cucumber-6 first extra early variety has been developed which is a parthenocarpic, gynoeocious cucumber and suitable for protected conditions. Likewise, Swarna and Shonima have been developed by crossing a stable tetraploid line of watermelon KAU-CL-TETRA-1(4x) with diploid males (2x) namely, CL-4 (red fleshed) and CL-5 (yellow fleshed), respectively.

**Vegetable grafting**

Grafting is the union of two or more pieces of living plant tissue, which grow as a single unified plant. Grafting vegetable scion plant onto desirable rootstocks is an effective tool to mitigate targeted soil-borne diseases, environmental stresses (moisture imbalances; extremes of temperatures; salt stress) and enhancing yield and quality of vegetable. In India, researches on vegetable grafting to combat abiotic stresses, particularly moisture imbalance, are underway at ICAR-IIHR, Bengaluru; ICAR-CAZRI, Jodhpur, and ICAR-IIVR, Varanasi, in solanaceous and cucurbitaceous crops. NBPGR regional station, Thrisur, Kerala have done work on *Momordica cochinchinensis*. The female plants were grafted on to the male plants to increase its production. CSKHPKV, Palampur, initiated work on grafting and identified more than 22 rootstocks of brinjal, chilli, tomato and cucurbits for importing resistance to bacterial wilt and nematodes. Amongst private sector, some companies are producing grafted vegetable seedlings resistant to bacterial wilt for farmers.

**Vertical farming**

Soilless hydroponic/aeroponic vertical vegetable production is mainly adopted under the controlled environment or greenhouse conditions and offers appropriate alternatives to traditional soil-based vegetable culture. Ideal management of plant growth gives higher yield and better quality produce in comparison to conventional greenhouse production in soil. Vertical farming in India is still in infancy stage. Very few research institutions are working on this area of future farming. Researchers at the Bidhan Chandra Krishi Viswavidyalaya, Nadia had initial success in working on vertical farming hydroponically on a small scale. Likewise in Himachal Pradesh and Punjab, scientists have attained initial success in growing potato tubers in soilless conditions. The micro-tubers production through aeroponics have been developed by ICAR-CPCRI and the technology of the same has been licenced to more than two-dozen private companies. At commercial level, a project ‘Nature Fit’, Panchgaon, Manesar commissioned by the Haryana Department of Horticulture is supplying safe, chemical-free fruit and vegetables to residents of Delhi and Gurugram, and encouraging a new generation of urban farmers in India. Indo-Israel Centre of Excellence for Vegetables, Gharaunda, Haryana and Uttarang, Uttar Pradesh are also imparting training to interested farmers on vertical farming. Similarly many students from various fields, especially, of engineering has successfully ventured in the area of vertical farming and leading their companies successfully. However at present, the private sectors are leading and have developed significant expertise. For instance, leading Lab Consumable manufacturer HiMedia is dealing vertical farming by hydroponics. Other big players are based in Ahemdabad, Chennai etc.

**Promotion of indigenous vegetables**

Indigenous plant species provide a variety of products like food, medicines and raw materials, and are also an important source of renewable energy. The Indian subcontinent has been one of the rich emporia of 2,500 plant species used in indigenous treatments and utilized as food sources. The Indian subcontinent represents one of the richest diverse genetic resources.
Of the estimated 250,000 species of flowering plants at global level, about 3,000 are regarded as food source, in which only 200 species have been domesticated. Global diversity in vegetable crops is estimated at about 400 species, with about 80 species of major and minor vegetables are reported to have originated in India. The UN Food and Agriculture Organization (FAO) reports that approximately 75% of the Earth’s genetic resources are now extinct, and another third of plant biodiversity is predicted to disappear by the year 2050.

Indigenous (‘traditional’) vegetables are best defined as species that are locally important for the sustainability of economies, human nutrition and health, and social systems - but which have yet to attain global recognition to the same extent as major vegetable commodities. In general, vegetables are the key component of balanced human diet and are also the main drivers in achieving nutritional security by providing essential micronutrients, vitamins and minerals such as potassium, vitamin C, vitamin B<sub>1</sub>. In addition to this, vegetables are important sources of an array of phytochemicals that play important role as antioxidants, phytoestrogens and anti-inflammatory agents, and through various protective mechanisms protects the human body from a number of lifestyle diseases. Spectacular growth in vegetable production has been achieved, which was possible due to development of improved varieties/hybrids/production and protection technologies through systematic research coupled with large scale adoption by the farmers. However, this remarkable production was contributed by only few major vegetables. Endowed with a wide diversity of agro-climatic conditions, India is virtually a herbarium of the world. This diverse agro-climate in the country permits to grow more than 60 cultivated and about 30 lesser known vegetable crops which are not all indigenous. Many rural households including people residing in the tribal areas still depend on the traditional leafy vegetables to a great extent for their food security strategies. Traditional leafy crops are important fresh crops during the rainy season and are especially important in dried form during winter and spring seasons as a source of low cost protein. Bitter gourd, despite its distinctive appearance and bitter taste, originally from the Indian subcontinent, is popular in a number of Asian countries. The triterpenoid momordicin, responsible for the bitterness of this vegetable, has been demonstrated to have anti-diabetic activities. Another triterpenoid from wild bitter gourd has been shown to inhibit breast cancer cells.

Although, some of these indigenous vegetables are widely harvested and consumed, but there is an increasing concern that their use is declining in the rural areas. The importance of these indigenous vegetables in the food security strategies is being limited due to loss of the biodiversity and the associated indigenous knowledge. Their potential contribution to food security, nutrition, health, income generation, and ecosystem services for the wellbeing of mankind is still largely under-exploited.

Indigenous vegetables are primary candidates for greater use of crop biodiversity in horticulture as they are already consumed and enjoyed locally, and can be produced profitably in both rural and urban environments. Conservation and sustainable use of the genetic resources of indigenous vegetable crops offer a tremendous tool for addressing the problem of food security - both inadequate quality and quantity - at both national and household levels. The food base for the rural population, especially in the marginal and semi-arid areas, has become narrower, leaving communities more vulnerable to food shortages and nutrient-deficiency diseases. Wild and weedy species, commonly used as vegetables in the past, are disappearing as a result of changes in customs and land use. Local knowledge about the cultivation and management of these species is on decline as well. At the same time, producers lack knowledge of more efficient, intensive production and management techniques. There is also a lack of knowledge about nutritive value and cooking methods that minimize nutrient leaching during food preparation.

Thus there is a need to promote the use of indigenous vegetables, and hence their production, by carrying out research on nutritive value, agronomy and value addition, in particular focusing on the role of vegetables in alleviating malnutrition among certain vulnerable groups in the community.

**Promotion of underutilized aquatic vegetables**

Integrated approach to diversify aquatic underutilized resources need thorough and systematic exploration to harness multifunctional benefits to the growers of Eastern India. Aquatic vegetables are predominantly grown in water bodies like lakes, ponds, ditches and marshy wet places. Present food habits indicate that most of consumers are fond of rhizomes (Kamal kakdi) of lotus, fruits of Singhara (water chestnut), and young leaves and stem of Kalmi saag (water spinach) are eaten, as common vegetable. Singhara is one of the submersed plants, used as edible nut. In general, yield of fresh nut range between 2,500-3,800 kg/ha area of water pond. The integration of water chestnut with mangur fish could offer a surface cover protection besides adding income. This shallow waterlogged areas of eastern Uttar Pradesh and Bihar, where surface drainage is not possible, and water stagnates with depth of more than 50 cm for about six months, this technology is farmer-friendly and a cost-effective option. The successful implementation of the technology has led to the spread of water chestnut cultivation technology in the tribal areas. Top of Form Fruits of water chestnut are usually sold in the market at the rate of ₹50-200/kg and an amount of ₹125,000 to 190,000 could be generated from 1 ha pond with minimal input cost. Lotus is a well-known flower, for which there is a good business opportunity, Rhizome (Kamal-Kakadi) of lotus is edible. Rhizomes yield potential varies from 50-70 q/ha pond. Kamal kakdi sold as vegetable in the market at the rate of ₹150-180/kg. On an average ₹ 825,000-1,155,000 could be obtained from 1 ha area pond of lotus with least cost of cultivation. Kalmi Saag (Water spinach) is commonly used as a food plant. The leaves are a good source of minerals and vitamins especially carotene. The plant serves as a green fodder of high nutritive value. It is also used as feed of fish and broilers. Upland field water spinach is an excellent vegetable, worth promoting in lowland areas. The popularization of improved line
VRWS-1 developed by ICAR-Indian Institute of Vegetable Research, Varanasi, of upland water spinach might be successful especially in areas where sweet potato leaves are traditionally consumed. Locally, conditions are suitable for seed production. Crop becomes ready for harvest 25-30 days after planting. Two to three harvests per month can be taken if shoots are cut above ground level, allowing secondary shoots to grow from nodes below the cut. About 130-140 t/ha can be harvested from two or more cuttings in a year. Leaves are usually sold in 500 g bunches in the markets at the rate of ₹ 35-40/kg. Income of ₹ 12-15 lakh could be generated from 1 ha area of water spinach with minimum crop care and input cost.

Safe and sustainable pest management

Farmers often identify crop pests and diseases as their main sources of risk because they reduce yields and negatively affect the marketability of the produce. Indications are that the intensity of pest and disease pressures may increase due to climate change so methods of mitigation will assume even greater importance. Interventions like use of biocontrol methods, grafting high-yielding seedlings on to resistant rootstocks, and investing in protected cultivation systems can be taken up. Bio-control methods (i.e. the use of living organisms such as predator insects or parasites to control pests) have much potential to replace chemical pesticides, thereby improving food safety and lowering production risks.

Reducing post-harvest losses and improving market access

Post-harvest losses in vegetable value chains are typically large, estimated to be in the range of 15-30%. Reduction of these losses begins on-farm with appropriate selection of varieties and the use of good agricultural practices. Simple on-farm innovations such as harvesting at the right time of the day and sorting and grading of produce, combined with the use of appropriate packaging near the farm, can reduce economic losses. However, investments in logistics, like pack houses, refrigerated vehicles for transport, cold storage, and market information systems are needed to improve market functioning for high-value perishable vegetables. Increased access to domestic, regional and international markets for vegetables can provide important income incentives for farmers to enter vegetable production.

The expansion in the vegetable area and use of improved inputs are expected to lead to qualitative improvement in the production of these crops thereby restoring the processing industry to its competitive levels. This institute has developed a number of value addition technologies in vegetables including ready-to-eat convenience vegetables, easy-to-cook leafy vegetables, steeping preservation of vegetables with hurdle concept, protein rich instant vegetable soup mix, instant mushroom whey soup powder, protein rich instant moringa soup mix, protein rich instant corn vegetable soup mix, instant moringa-jaljeera drink mix, low calorie instant moringa drink, instant bottle gourd kheer mix and dry chilli powder. ICAR-IIVR have patented some of these technologies and sharing them same through FPO’s for their commercialization.

Home garden/ kitchen garden and school meals

Studies across countries suggest home/kitchen gardens as an option to enhance food security and nutritional status of households. Home garden interventions have been successful in delivering positive nutritional outcomes in Asia. Nutrition gardens are a micro-solution and an affordable way of ensuring healthy food and balanced nutrition. Vegetables from the kitchen gardens are good source of micronutrients especially in the poor households. Rural areas have ample space and establishing a kitchen garden is far simpler as farm families are involved in agriculture. Such interventions simultaneously address vegetable availability, access, demand and utilization. This multipronged approach is especially effective at increasing vegetable consumption among poor rural households vulnerable to micronutrient deficiencies. Home garden interventions are often targeted at women as they are typically in control of meal choice and preparation. School meals provide a good entry point for influencing children’s diets; recent studies provide sound evidence for their nutritional impact. Nutritional benefits can be increased when school meal programs include fresh vegetables alongside food staples, pulses, vegetable oil, dairy and meat. School garden programs-involving a combination of nutrition and health education with hands-on experience in vegetable gardening, is one such integrated approach to influence children’s food behaviour toward healthier food choices, including vegetables. School garden interventions aim to expose children at a young age to vegetables and to develop eating habits and food attitudes during childhood that may persist through to adulthood.

Transforming young vegetable farmers into entrepreneurs

A vegetable selling business is an excellent business opportunity as it deals with commodities that are essential for survival and needed on a daily basis. Also, the increased awareness regarding healthy eating, consuming fresh foods and preferably eating local produce has risen and so has the demand for freshly sourced farm produce. Vegetable business hubs bring young farmers together in a community and focuses on three major components—training youth on improved vegetable production practices; connecting young farmer groups to markets to increase household incomes; and strengthening the cohesion within and between the farmer groups. Their skills and confidence grow as they learn new vegetable production and postharvest methods, find ways to solve problems together and learn collective saving methods to enable group investments.

For further interaction, please write to:
Viticulture for better prospects

Grape, a temperate crop, has been adopted to tropical conditions in India, and most of the area under grape cultivation is in peninsular Indian states, viz. Maharashtra, Karnataka, and Tamil Nadu. The viticultural practices involve double pruning (foundation and fruit pruning) and single cropping to make the grapevines yield under tropical conditions. The area under grapes in India has increased from 52.1 thousand ha (2002-03) to 139 thousand ha (2018-19) (NHB Database), a 2.6 folds increase in 15 years. The production during the corresponding period has increased by 2.38 times. The grape is highly skilled, heavy investment prone and high-value crop. However, in recent years, extreme weather events like hail, unseasonal rainfall, frost, delayed rainfall and temperature stress during the productive period are playing havoc with the grapevine production in India. These factors pose challenges to researchers to develop technologies and/or strategies for sustainable grape cultivation.

Prospects

Protected cultivation for better yield

Plastic cover is used to grow table grapes in many parts of the world. Spain, where table grape is extensively grown under plastic cover, supplies table grapes to European Union for at least 4-5 months in a year. The intent is to grow crop in otherwise unfavourable conditions by modifying the natural environment to increase yield, improve quality, enhance the stability of production, extend harvesting period and expand the area for production. In grape, like other horticultural crops, climate is the most determinant factor. Though plastic cover helps circumvent the negative effects like rain and diseases during grapevine growing season but it also results in early ripening or delay harvest.

Studies at ICAR-National Research Centre for Grapes for three years conclusively demonstrated the favourable impact of plastic cover on vine growth and productivity. Analysis of three years pooled data showed significant increase in yield from 8.34 MT/ha under open conditions to 18.59 MT/ha under plastic cover. The use of plastic cover was validated in 2017, when rainfall occurred during early growth stage after fruit pruning. The vines in the open and under hailnet experienced severe downy mildew infestation leading to very low productivity whereas, the vines under plastic cover were not affected. The vines under plastic cover recorded significantly higher yield of 18 MT/ha as compared to 7.1 MT/ha, and 3.6 MT/ha in vines under hailnet and open conditions respectively. Considering ₹ 40/kg as farm gate price, the price realization was ₹ 6 lakh/ha more than the income earned from vines raised in the open. Further, another ₹ 69,100 was saved on account of reduction in six sprays for downy mildew disease.

Plastic cover also protects against the damage to vine parts and bunches from hails, reduces berry cracking due to unseasonal rains, reduces impact of temperature on vine growth and productivity besides reducing irrigation water requirement by 20% and provides opportunity for risk free early pruning to avoid glut in the market and improves profitability.

The plastic cover should be woven laminated film, UV stabilised to 580 kLy (Indian conditions) with anti-thermic properties (25% thermicity). It should have 85 to 90% light transmission with 65±5% light diffusion with cloth weight of 140±5% gsm/sqm. It should also have anti-sulphur, anti-drip and anti-dust properties. The life of the plastic cover could range from 3 to 5 years depending upon quality of plastic. The cost of plastic cover ranges between ₹ 2.75 – 4.5 lakh/acre depending upon the source and the cost of structure ranges from ₹ 2.5 – 3.5 lakh/acre for erecting on existing training system. However, considering the price realisation and input saving, this cost can be recovered within 1-2 years.

Decision support system for improved input use efficiency

Grape is high-skilled crop and expert advice is required on day-to-day basis. Most of the viticultural operations are dependent on phenology, weather and soil factors. These factors are site-specific and vary from farm-to-farm. Therefore, the problems are site-specific and the expert advice also varies from farm-to-farm. To provide farm-specific advisory to the farmers, decision support systems (DSS) were developed for irrigation and nutrition management, pest and disease risk assessment, and advisory for their management.

The research on the use of weather forecasting and crop stage based advisory for management of diseases
and insect pests on grapes have been carried out at ICAR-National Research Centre for Grapes, Pune. During 2009-13, plant protection practices using location-specific weather-forecasting based online advisory for disease and pest management in grapes in growers’ vineyards was demonstrated at 49 locations in four districts of Maharashtra. It was observed that in demonstration plots, an average of 9.03 pesticide sprays per plot were saved in comparison with farmer practice plots. Fifteen demonstration plots whose yield data were analyzed, recorded average yield of 13.68 MT/acre as compared to 9.59 MT/acre in the growers’ practice plots. In all demonstration plots, residues of recommended pesticides were lower than maximum residue limit (MRL) prescribed in Annexure 5 of Residue Monitoring Plan.

Subsequently, to provide farm-specific advisory to the farmers, decision support systems (DSS) were developed for pest and disease management as well as for nutrient and water management based on weather forecast and crop phenology. The models for pests, diseases, nutrient and water were integrated into integrated system. The integrated decision support system helps to improve the grape grower’s ability to take crucial management decisions on time. It provides recommendations to the grower based on his/her crop data, farm data, and prevailing weather conditions that will support or assist growers’ decision making capacity in terms of water, irrigation, pest and disease management. It also helps in guiding growers on pest and disease risks, and nutrient use based upon soil and petiole test. On an average, there is 15% saving of input use namely pesticides, water and nutrients. Considering the saving of labour cost due to reduced number of applications of pesticides and fertilizers, the total cost of production has reduced by 14-17%.

Application programming interface (API) has been developed which processes inputs given by mobile or web application and gives outputs for use in the application. The access to this API is provided to licensed mobile or web application service providers who give access of DSS to farmers via his web/mobile application. The service provider is given license for API access for fixed duration.

Grape for nutritional security

The grape berries are known for their high nutritive value. Sugars are major content in berries and these have up to 30% of easily digestible sugars viz. glucose and fructose, viz. The berries also contain a large range of organic acids namely malic, tartaric, citric, succinic, gallic, formic, oxalic, salicylic, and others. Grapes are rich source of mineral salts also. Among them, potassium (235 mg), calcium (45 mg), sodium (26 mg), phosphorus (22 mg), manganese, cobalt and iron are available in berries. Fresh grapes (100g) provides 4% of daily intake of calcium, 1.6% of magnesium, 0.12% of phosphorus, 16.4% of iron, 2.7% of copper, and 16.6% of manganese. Same time grapes are rich source of vitamins such as A, B (B₁, B₂, B₃, B₆, B₁₂, etc.), C, E and K. Vitamin E is found specifically in grape seeds.

The grapes are packed with polyphenols which have well established antioxidant activities. Polyphenols are mainly found in grape skin and seeds, and coloured grapes have higher polyphenols. Antioxidants are molecules that safely interact with free radicals to stop the condition of oxidative stress. Resveratrol, a polyphenol found in high quantity in grapes, has ability to reduce the risk of heart disease through antioxidant and anti-inflammatory activities. Flavonoids can help protect the heart against blood clots and may reduce the damage of high cholesterol. Grapes and grape-based products are excellent sources of various anticancer agents also. The grapes have possible ability to help prevent breast, colon and prostate cancers. Anthocyanins are another class of polyphenolic antioxidants, which are widely present in coloured grapes. These phytochemicals have an anti-allergic, anti-inflammatory, anti-microbial, as well as anti-cancer activity.

Wealth from Waste: A grape perspective

Industrial processing of grapes generates large quantities of solid residues that consist of a mixture of grape skins, pulp, stalks and seed together named as grape pomace. These by-products are an important source of dietary fibre and phenolic compounds, with antimicrobial
and antioxidant properties. The grape pomace contains lots of bioactive phytochemicals such as phenols, flavonoids, anthocyanins, stilbenes etc. having various health benefits. Considering the immense nutritional and nutraceutical values, utilization of these wastes in food products, and development of new high value products not only saves soil and water from pollution, but sustains this industry by earning additional income.

The juice of Manjari Medika, a grape variety developed by ICAR-National Research Centre for Grapes, is attractive red colour and contains high anthocyanin content. One kg grapes contains 4-6 mg anthocyanins. The Centre has developed Zero Waste concept of grape processing for this variety. Zero waste concept is the conservation of all resources by means of responsible production, consumption, reuse, and recovery of all products, packaging, and materials, without burning them, more than 70% is recorded in this variety. TSS content in the juice is achieved more than 20°B easily. The juice is very dark in colour and found with higher anthocyanins and polyphenolic content. Due to higher anthocyanins and phenolic content, higher antioxidant activities were recorded in the juice of Manjari Medika. Besides the nutritional and functional properties, the juice has higher level of acceptance based on sensory properties.

Because of its attractive colour, Manjari Medika juice can be used for enriching and giving colour to juices of other grape varieties. The blending with Manjari Medika will not only give attractiveness but also enrich other grape juices with additional functional properties.

Grape pomace is a rich source of bioactive phytochemicals. Technologies have been developed for the production of high value bakery products like cookies, bread etc. Up to 15% of maida can be replaced with grape pomace and such cookies were attractive in colour with higher nutritional, functional and sensory properties. Similarly, breads and muffins prepared after replacing maida by pomace powder of Manjari Medika were highly attractive in colour, had higher nutritional, functional properties and dietary fibre.

A juice recovery of more than 70% is recorded in this variety. TSS content in the juice is achieved more than 20°B easily. The juice is very dark in colour and found with higher anthocyanins and polyphenolic content. Due to higher anthocyanins and phenolic content, higher antioxidant activities were recorded in the juice of Manjari Medika. Besides the nutritional and functional properties, the juice has higher level of acceptance based on sensory properties.

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The Manjari Medika grapes are rich in phenolic compounds, especially anthocyanins. ICAR-NRCG developed a technology for the extraction, isolation and purification of anthocyanins from Manjari Medika. The extracted anthocyanin was formulated to microencapsulated capsules (10%) (meet the 50% dietary requirement of anthocyanins) through spray drying technology. Our collaborative study with CSIR-Indian Institute of Chemical Biology, Kolkata established the in-vitro and in vivo anticancer activities of these anthocyanins against colon cancer. Combination of IC50 dosage of IR radiation and anthocyanin treatment resulted in more than 50% cell death in human colorectal carcinoma cell, suggesting radio sensitizing effect of anthocyanin indicating relevance for the treatment of cancer radio therapy.

A technology has been developed for extraction of phenolic compound and vitamin-E enriched grape seed oil from Manjari Medika seeds through super critical fluid extraction. Significantly higher levels of total vitamin E, gamma tocotrienol and phenolic compounds especially resveratrol were found in SFE extracted GSO as compared to cold-pressed oil. The anticipated bioactive potential was estimated through in vivo animal studies to evaluate the radioprotective effect of GSO on the modulation of IR-induced intestinal injury.

The cost: benefit (CB) ratio of grape cultivation approximately ranges from 1.03 in table grape to 1.34 and 1.46 in raisin and wine/juice grape cultivation. In all these, no waste/bi-product utilizations were considered in CB ratio calculation. Our internal estimate of CB ratio for the Zero waste processing technology of Manjari Medika suggests a CB ration of 2.3 to 3.5 if we utilize judiciously all the wastes or bi-products generated out of the juice industry. This CB ratio is highly encouraging in our future target of doubling the farmers’ income by 2030.

For further interaction, please write to:
Spices technologies for maximum nutraceutical, environmental and social benefits

Spices are high value and low volume, export-oriented commodities, commonly used for flavouring and seasoning of food and beverages. India is the world’s largest producer, consumer, and exporter of spices; the country produces about 75 of the 109 varieties listed by the International Organization for Standardization (ISO) and accounts for half of the global trading in spices. The consumption of spices is growing in the country with increase in purchasing power. It is envisaged that everyone in India would be consuming one spice or the other with a high per capita consumption. This may increase further due to rapid urbanization which needs spices as natural food preservatives. Growing demand from the emerging segment of nutraceuticals is driving the global consumption of Indian spices further at a time when the country is straining to meet the needs of the traditional food sector. Though spices contain diverse array of phytochemicals, the nutraceutical preparation often revolve around few major bioactive metabolites. Non-traditional use of spices including nutraceuticals now accounts for nearly 15% of spice production in India, estimated at 50 lakh tonne a year.

Prospects

The enhanced productivity witnessed across spice crops is a result of adoption of improved cost-effective technologies which can improve the competitiveness of Indian spices in the global markets. India’s spice industry has been one of the Nation’s great horticultural success stories. Developing new innovative technologies for commercial release that open new markets, is essential to build a stronger Indian Spice sector. Researchers are working to develop new spice technologies with desirable production qualities and industrial use that will help capture the market and revitalize this industry.

Industrial use
The demand of spice oils and oleoresins is increasing mostly due to enhanced use in food and beverage industries. Spice oils are the volatile components present in most spices and provide the characteristic aroma of the spices. Spice oleoresins represent the complete flavour profile of the spice. It contains the volatile as well as non-volatile constituents of spices. The standard of quality expected in a spice oil or oleoresin will differ depending on its end uses. Therefore, these oils are custom-made to meet the exact requirement of the user. India is a leading exporter of spice oils to West Europe, USA and the Far East.

Nutraceuticals in spices
In addition to nutrients such as vitamins, minerals, amino acids, peptides, and some fatty acids, there are other specific bioactive compounds that can be considered as nutraceuticals: enzymes, pre- and pro-biotics, coenzyme Q10, glucosamine, chondroitin, etc., as well as many phytochemicals (polyphenols, sulphur-containing compounds, alkaloids, terpenoids, etc.). Additionally, nutraceuticals can be classified into potential and/or established nutraceuticals according to their proven beneficial effects as demonstrated in either preclinical or clinical studies. In addition to their sensory properties, the spices in our diet are rich sources of different phytochemicals with putative beneficial effects e.g. antioxidative, anti-inflammatory, chemopreventive, antimutagenic, immune-modulatory properties.

Spices like turmeric, ginger, black pepper, fenugreek, coriander, etc., contain considerable quantity of biologically active specific metabolites with numerous biological functions. Curcumin in turmeric; capsaicin in red pepper; piperine in black pepper; [6]-gingerol in ginger; saponin in fenugreek are immensely valuable in health care with their multiple physiological effects.

Better varieties
Over the past few decades, ICAR-Indian Institute of Spices Research and ICAR-All India Co-ordinated Research Project on Spices (involving State Agricultural Universities) have released several spices with focus on spice industry, greater resilience to Indian conditions, and improved attributes and performance.

Varieties for industrial extraction
Spice oleoresins are largely used for food processing and flavouring industries like meat canning, sauces, soft
drinks, pharmaceutical preparations, perfumery and soap, tobacco, confectionery, and bakery. Most of the released varieties are aimed for higher yield and disease tolerance. Some of the varieties released in India with specific quality attributes with high essential oil and oleoresins are as follows:

<table>
<thead>
<tr>
<th>Crop</th>
<th>Industrial extraction</th>
<th>Variety</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black pepper</td>
<td>High essential oil</td>
<td>Sreekara (7%), Subakara (6%), Panniyur 9 (5%)</td>
</tr>
<tr>
<td></td>
<td>High oleoresin</td>
<td>PLD 2 (15.45%)</td>
</tr>
<tr>
<td>Small cardamom</td>
<td>High essential oil</td>
<td>Appangala 1 (8.7%)</td>
</tr>
<tr>
<td>Turmeric</td>
<td>High essential oil</td>
<td>Sudarsana, Suvarna (7.0 %)</td>
</tr>
<tr>
<td>Ginger</td>
<td>High essential oil</td>
<td>KAU Athira, KAU Karthika (3%)</td>
</tr>
</tbody>
</table>

**Varieties for natural colour**

The colours that originate from any edible sources like flowers, fruits, vegetables and plants are called natural food colourants. They impart colour when added to food or drink. The natural colourant is obtained by physical and/or chemical extraction resulting in a selective extraction of the pigments relative to the nutritive or aromatic constituents. Some spices are also used as natural colourants.

**Anthocyanins**

Anthocyanins are water soluble pigments responsible for the attractive red, purple and blue colours of many flowers, fruits and vegetables. The colour varies with respect to the pH, it is reddest in strongly acidic conditions and become bluer as the pH rises. Used in drinks, jams and sugar confectionery. Anthocyanins are present in kokum (Garcinia indica), which is a potential source of a natural food colourant. The ripe kokum fruit is coloured either dark purple or red tinged with yellow. It is widely available and has been traditionally used as a food ingredient without apparent toxic effects; it could be a potential source of anthocyanins.

**Curcumin**

Turmeric is a well-known spice, used widely in cookery. Its pigment, curcumin, is oil soluble and sensitive to light, but has good heat stability. It gives a lemon-yellow shade in food systems. Its applications include pickles, soups and confectionery.

**Spices varieties rich in flavour compounds**

Spices were always valued exclusively for their aroma and flavour. The flavour of each spices is contributed by secondary metabolites. The flavour compounds responsible for distinct aroma in different spices are:

**Varieties for nutraceuticals**

Though spices contains diverse array of phytochemicals, the nutraceutical preparation often revolve around few major bioactive metabolites. In addition to their sensory properties, the spices in our diet are rich sources of different phytochemicals with putative beneficial effects e.g. antioxidative, anti-inflammatory, chemopreventive, antimutagenic, immune-modulatory properties. Spices like turmeric, ginger and black pepper contains considerable quantity of biologically active specific metabolites with numerous biological functions—curcumin in turmeric; piperine in black pepper; [6]-gingerol in ginger.

<table>
<thead>
<tr>
<th>Crop</th>
<th>Nutraceutical attribute</th>
<th>Variety</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black pepper</td>
<td>High piperine (&gt; 5%)</td>
<td>IISR Malabar Excel, Panniyur 2, Panniyur 9</td>
</tr>
<tr>
<td>Turmeric</td>
<td>High curcumin (&gt; 5%)</td>
<td>IISR Prathiba, IISR Pragati, Megha Turmeric, Rajendra Sonia</td>
</tr>
<tr>
<td>Ginger</td>
<td>High gingerol</td>
<td>KAU Karthika</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Crop</th>
<th>Variety</th>
<th>Flavour compounds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black pepper</td>
<td>IISR Malabar Excel, Panniyur 2, Panniyur 9</td>
<td>&gt; 5% piperine</td>
</tr>
<tr>
<td>Cardamom</td>
<td>PV1, ICRI 6, ICRI 7, Appangala 1</td>
<td>&gt; 25% 1, 8-cineole, 45% alpha-terpinyl acetate</td>
</tr>
</tbody>
</table>
Varieties for processing industries

Spices are value added by different types of processing, where black pepper is processed to white pepper, fresh ginger as ginger candy and nutmeg seed for nutmeg butter. The following are some of the varieties suitable for processing:

<table>
<thead>
<tr>
<th>Crop</th>
<th>Variety</th>
<th>Flavour compounds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ginger</td>
<td>IISR Vajra, Suprabha</td>
<td>Zingiberene content (&gt;30%)</td>
</tr>
<tr>
<td>Turmeric</td>
<td>IISR Prathiba, IISR Pragati and Duggirala Red</td>
<td>&gt;35% Turmerone</td>
</tr>
<tr>
<td></td>
<td>Narendra Haldi 98, Megha Turmeric 1</td>
<td>&gt;19% Zingiberene</td>
</tr>
<tr>
<td>Nutmeg</td>
<td>IISR Keralashree, IISR Vishwasree</td>
<td>Myristicin (&gt;9%), Sabinene (&gt;35%)</td>
</tr>
<tr>
<td>Cinnamon</td>
<td>IISR Navashree, IISR Nithya shree</td>
<td>Cinnamaldehyde (&gt;50%)</td>
</tr>
</tbody>
</table>

Better technologies

Quality planting material

Protocols for micro-propagation, micro-rhizome production and improved vegetative propagation methods of spice crops were standardized, popularized for disease free production of nucleus planting materials of improved varieties throughout the country. The pro-tray based transplanting technique in turmeric and ginger by using single bud sprouts (5 g) raised in soil-less nursery mixture, reduces the seed rhizome requirement by one-fourth and saves considerably the cost on seed which otherwise contributes to 60% of production cost. This technology can address some of the serious concerns of diseases in the seedling stage and same method can be followed in black pepper also for production of disease-free planting materials.

The continuous demand for quality planting material in black pepper created a novel idea of producing more orthotropic shoots on vertical mesh columns filled with composted cocopeat and vermicompost mixture fortified with bio-control agents under protected conditions. In this method, three types of planting material i.e. single node cuttings, top shoots with lateral branch (use of top shoots for field planting is having advantage of producing fruit bearing branch from the base of the support and start yielding early) and laterals or plagiotropes, which are used for production of bush pepper can be produced simultaneously in large numbers.

Soil health management

Majority of soils in the spice growing areas are encountering fertility issues due to acidity, nutrient imbalances, and deficiencies of secondary and micronutrients that becomes yield limiting. Crop specific, soil pH based micronutrient mixtures for foliar application in spice crops offer a way out from the production limiting factor induced by micronutrient deficiency. The application of micronutrient guarantees 10 to 25% increase in yield besides improvement in product quality. An innate advantage of these mixtures is that they can also be used in organic agriculture and therefore are benign and environment friendly. Institute has also developed mixed and intercropping system models for doubling farmers’ income; integrated site-specific nutrient management for sustainable soil health for spice based cropping systems; organic production packages; and demonstrated the same in major spice tracts for increasing productivity.

Irrigation of black pepper vines around the basin from March to May @ 50-80 litre/vine at an interval of 15 days can markedly enhance spike length, number of spikes, oleoresin content and berry yield. This technology promotes uniform spike initiation and reduces the spike shedding due to late monsoon and guarantees good crop. A simple technique of hormone treatment was developed to split open nutmeg fruits without exposure to soil to prevent aflatoxin contamination in nutmeg.

Plant health management

IPM technologies involving spraying of low-risk green labelled insecticides such as chlorantraniliprole, flubendiamide, spinosad for effective control of shoot borer in ginger, and turmeric and cardamom thrips reduces the risk to the environment. IDM protocols involving CaCl₂ for the control of bacterial wilt of Black pepper.
ginger was standardized and demonstrated across India.

Development of diagnostics for virus infecting spices by loop-mediated isothermal amplification (LAMP) and real-time LAMP based assays have been developed and deployed for quick and sensitive detection of virus diseases of black pepper, cardamom and ginger. The technology can be used for certification of mother plants/planting materials of black pepper for freedom from viruses. A strain specific and sensitive technique based on Real Time Loop Mediated Isothermal Amplification (Real Time- LAMP) was developed for detecting race 4 strain of *Ralstonia solanacearum* causing bacterial wilt in ginger.

Technologies like, *Pochonia chlamydosporia*, a biocontrol agent against nematodes, use of an entomopathogenic fungus, *Leconicilium psalliotae*, for controlling the cardamom thrips etc., offers immense scope for reducing the pesticide use in spice based cropping systems. PGPR formulations for spices identified across several spice crops are gaining attention in the wake of the persistent and strong demand for effective environment friendly strategies for enhancing crop health. For ginger, the formulation consists of *Bacillus amyloliquefaciens*, a PGPR specific to ginger, and for black pepper, the PGPR is a consortium of three PGPR specific to black pepper, namely *Micrococcus luteus*, *Enterobacter aerogenes* and *Micrococcus* sp. The major advantages of the ecologically safe PGPR formulations include enhanced nutrient mobilization and nutrient use efficiency, increased growth, yield, and better tolerance to specific biotic stresses.

Seed coating using PGPR is a novel approach of coating efficient strains of PGPR on seeds/ seed rhizomes. The components consist of live PGPR, inert material and a binding agent. The coated seeds can be stored at room temperature. Constraints like low germination, slow initial growth and high susceptibility to diseases can be addressed through this technology and can be easily adopted in spices like ginger, turmeric, tuber crops and seed spices.

**Bio-agent input delivery**

World’s first encapsulation technology for smart delivery of beneficial microorganisms to crops developed and patented by the institute is expected to replace the conventional talc and liquid bio-fertilizers formulations. Any agriculturally important microorganism like N fixers, phosphorus solubilizers can be encapsulated and delivered to crops for enhanced growth promotion, soil nutrient solubilization/ mobilization and biocontrol. The capsules can be stored at normal temperature and has enhanced shelf life. The licensing of this technology on smart delivery of bio-agents (bio-control/ PGPRs) has helped in easy and effective reach of bio-agents reaching targeted crops in about 10% of spice growing areas.

**Post-harvest technology**

Post-harvest technologies for processing and value addition of spices were developed and adopted by farmers/ entrepreneurs for increasing income. Spices extracts were established as the most potent antioxidant and exploiting the same as a nutraceutical and anti-cancerous agent. ICAR-IISR has developed turmeric milk preparations, viz. ready-to-serve sterilized flavoured turmeric milk turmeric milk, instant mix powder with rich flavour and antioxidant properties, in collaboration with MILMA, Kozhikode, Kerala. The export of value-added products has happened across spice commodities and this development is favourable for strengthening value chain in spices, and realizing the profit margins from organizing production activities along the value chain.

DNA barcoding has been put into use to detect the plant-based adulterants in traded spices such as black pepper powder, cinnamon, nutmeg, and turmeric at ICAR-IISR. DNA barcoding method could detect chilli as an adulterant in traded black pepper for the first time. At a time when food safety and quality of spices in the value chain is garnering more importance, this technology offers a tool for quality control along the value chain.

**Conclusion**

Our capability to address the challenges faced by spice sector directly depend on the technological options developed in response that are to be simple, cost-effective and farmer friendly. There is a great scope to improve the productivity of major spices by adopting technologies that will help to bridge the gap between potential yields realized in the research stations/progressive farmers’ plots. Nurturing and improving sound techniques, technologies and innovations in the entire spices sector can help in surmounting the challenges posed by competing countries, and help in meeting the global market demands while ensuring a sustainable and equitable production model.

For further interaction, please write to:
High density plantation in apple – A highly remunerative enterprise

High density planting (HDP) refers to increasing the plant population per unit area of land to increase the fruit production, overcome low productivity and long gestation period for early returns, which is achieved by using suitable scion varieties grafted on dwarfing/semi dwarfing rootstocks. High density orchards were first planted in Europe at the end of the 19th century and since then there is decline in traditional orchards with low densities. The underlying principle of HDP is to make the best use of vertical and horizontal space per unit time and to harness maximum possible return per unit of output. Standard apple plants raised on seedling rootstocks are planted at a spacing of $6 \times 6$ m to $7 \times 7$ m with a planting density of 204-278 trees/ha and spur varieties on seedling rootstocks are planted at a spacing of $5.0 \times 5.0$ m with a planting density of 400 plants/ha. The average productivity of these orchards is approximately 10 to 12 MT/ha, which is much below the productivity obtained in high-density orchards (60-80 MT/ha). High-density planting of apple varieties grafted on dwarf/semi-dwarf clonal rootstocks can accommodate approximately 3,333 plants/ha to improve productivity without affecting the quality of the produce.

HIGH-DENSITY orchards can be laid on flat and fertile lands with assured irrigation are trained to modern methods of training systems, viz.espalier, vertical axis, slender spindle, tall spindle etc. The technology is helpful in best utilization of land resources, ease in orchard inter-culture operations, plant protection, harvesting and to obtain export quality of the produce. Canopy management has paramount importance in high-density planting to control vigour of trees and harvest of quality fruits. Apple is an important temperate fruit crop and is currently grown in Jammu and Kashmir, Himachal Pradesh and Uttarakhand. Apple cultivation is also extended to Nagaland, Sikkim, Arunachal Pradesh and Meghalaya. In Himachal Pradesh, farmers are currently in a fight to save their apple orchards that have been hit by climate change. They are adopting the new method of high density apple plantation being promoted by the state government. In Jammu and Kashmir, government is promoting high density apple plantation by phasing out old orchards that have completed their economic life, giving farmers a subsidy on re-plantation with new varieties grafted on dwarfing rootstock like M9. The commonly used apple varieties in high density planting are Jeromine, King Roat, Scarlet Spur-II, Super Chief, Red Velox, Gala’s, Mema Master, Golden Delicious Reinders, Granny Smith, Adams and Gala Redlum.
Advantages of HDP
- High density planting facilitates better utilization of available resources i.e. solar radiation, land, water, labour, dwarf rootstocks, spur cultivars, human skill etc.
- High density orchards are more precocious thus result in earlier return on investment, which is key for investment.
- High density planting results in higher productivity and harvest index due to increase in bearing surface per unit area.
- High density planting produce better quality fruits due to high light interception and distribution of light within plant canopy.
- High density planting facilitate easy picking with less injury to fruit which result in better post-harvest life during storage.
- High density orchards have better acceptance to modern input saving fruit production technique such as drip irrigation, fertigation, mechanical harvesting, mechanical pruning etc.
- High density orchards increase effectiveness and reduce cost involved in horticultural operation like inter-cultural operation, pruning, plant protection measures etc.

Limitation/constraints
- High initial establishment costs, mainly due to the increased tree cost per unit area and tree support structure.
- Need more professional and scientific approach in management.

Recommended HDP models in apple by ICAR-CITH, Srinagar
High density planting system recommended in apple by ICAR-CITH, Srinagar (Model 1 and Model 2) having potential for enhancing productivity from 10-15 t/ha under traditional orcharding to 50-60 t/ha under HDP system. Under this system, varieties have been identified with better fruit quality and thus having more consumer acceptability and market value. Since this technology has been standardized on M-9 rootstock, which needs support and assured irrigation, therefore drip irrigation for assured irrigation and trellis system for proper support is being recommended. This support system provides the scope for development of designer tress using suitable canopy architectures like Espalier or/and Tall Spindle systems. Both these canopy architectural systems provide the scope for proper light penetration and diffusion responsible for optimum colour development and secondary metabolism in apple. Apples harvested through this technology are of better quality with optimum size, colour, secondary metabolites and uniformity in quality.

Recommended Model 1
- Planting spacing: 3.0 × 1.5 m (Plant to plant 3.0 m and row to row spacing 1.5 m)
- Planting density: 2222 plants/ha
- Canopy architecture: Espalier system
- Yield/productivity: Approx. 60 t/ha
- Varieties evaluated and recommended: Oregon Spur, Gala Mast, Coe Red Fuji, Granny Smith, Silver Spur, Spartan and Red Chief
- Rootstock: M-9.

Recommended Model 2
- Planting spacing: 3.0 × 1.5 m or 3.0 × 1.0 m (row to row spacing 3.0 m and plant to plant distance 1.5 m)
- Planting density: 2222 plants/ha (3 m × 1.5 m spacing) or/and 3333 plants/ha (3 m × 1 m spacing)
- Canopy architecture: Tall Spindle System
- Yield/productivity: Approx. 50-60 t/ha
- Varieties evaluated and recommended: Super Chief, Red Velox, Gala Redlum, Golden Delicious Reindeers, Golden Delicious Clone-B etc
- Rootstock: M-9.

In apple, high density plantation with modern canopy management system has been developed by the

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Traditional orcharding</th>
<th>HDP (Recommended)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planting density</td>
<td>100-278 plants</td>
<td>2222-3333 plants</td>
</tr>
<tr>
<td>Training system</td>
<td>Centre leader, open centre, modified central leader system</td>
<td>Tall Spindle and Espalier</td>
</tr>
<tr>
<td>Precocity</td>
<td>Bearing starts after 6-8 years of plantation</td>
<td>Highly precocious (bearing starts after second year of plantation)</td>
</tr>
<tr>
<td>Productivity</td>
<td>Low (&lt;20 t/ha)</td>
<td>High (&gt;60 t/ha)</td>
</tr>
<tr>
<td>Yield potential</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Fruit quality</td>
<td>Low; due to low photosynthetic photon flux density (PPFD) and less penetration and diffusion of photosynthetically active radiation (PAR)</td>
<td>High; due to high photosynthetic photon flux density (PPFD) and more penetration and diffusion of photosynthetically active radiation (PAR)</td>
</tr>
<tr>
<td>Input use efficiency</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Disease incidence</td>
<td>High; this is due to dense canopy and low air circulation through canopy</td>
<td>Low; which is due to sparse canopy and more leaf area index</td>
</tr>
<tr>
<td>Mechanization</td>
<td>Difficult</td>
<td>Easy and cost effective</td>
</tr>
</tbody>
</table>
Institute which increases the productivity of apple from 15 t/ha to 60 t/ha. This technology was taken as the base during 2016-17 and 2017-18 by the Government of India for initiating the High Density Mission of apple in Jammu and Kashmir. The spur and standard type cultivars like Oregon Spur, Super Chief, Silver Spur, Well Spur, Starkrimson, Scarlet Spur, Red Velox etc have potential to yield up to 60 t/ha under HDP on M-9 rootstock against the existing productivity of 15 t/ha on traditional orchards. Use of clonal rootstocks like M-9 induces precocity and plants bear fruits 2 years after plantation. Thus use of spur type apple cultivars grafted on clonal rootstocks like M-9 not only increases the productivity and quality but also induces precocity. Increase in productivity from 15 t/ha to 60 t/ha can increase the returns from 6 lakh/ha to 24 lakh/ha (₹ Rs 40/kg). Under HDP, total planting density is about 2222 plants/ha and therefore requirements of planting material is huge. ICAR-CITH, Srinagar in addition to development of HDP technology in apple has also commercialized the identified elite apple varieties in the region. Institute is multiplying approximately 20,000 plants of elite varieties covering an area of about 10 ha annually. Entrepreneurship and employment generation has increased manifolds after the introduction of HDP in apple and other crops. At present, most of the youth are involved in HDP in apple due to better returns and quality produce. ICAR-CITH, Srinagar has identified new spur type and coloured varieties in apple which have been recommended for HDP in the regions. Due to better yield and quality, these varieties have better market value and consumer acceptance and hence play important role in enhancing employment generation and entrepreneurship. The varieties identified and technology developed can be commercialized in other states for enhancing the income of the farmers in the region.

Economic advantages of HDP (Per ha)

Economic return
- Input cost per year ₹ 1.20 – 1.50 lakh/year/ha and returns on 60 t/ha at ₹ 50/kg are ₹ 30 lakh/ha/year. Therefore two-year return after commercial bearing (₹ 60 lakh) will cover establishment cost in addition to significant benefit to the farmer. Thereafter benefit of more than ₹ 28 lakh/ha/year is assured up to the age of at least 25 years.
- If we compare traditional orcharding system where productivity is about 10 t/ha with HDP orchard where productivity can go up-to 60 t/ha and therefore can increase the economic returns from existing (10,000 × 50 = ₹ 5 lakh /ha) to (60,000 × 50 = ₹ 30 lakh/ha).
- The quality of fruit under HDP is better (Grade A) due to proper canopy management system which leads to good fruit size and colour.
- The varieties which are being recommended for HDP are better in quality and have higher consumer acceptability.
- Orchards come into commercial bearing early due to better precocity.


For further interaction, please write to:

<table>
<thead>
<tr>
<th>Component</th>
<th>Estimated estab. cost (Approx.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost of plant material (5 feathered and above) for 3333 trees (1×3 m)</td>
<td>16.00</td>
</tr>
<tr>
<td>Cost of 4-wire trellis system (with 12.00 installation)</td>
<td>12.00</td>
</tr>
<tr>
<td>Cost of micro-irrigation system</td>
<td>2.00</td>
</tr>
<tr>
<td>Annual maintenance including nutrition and plant protection</td>
<td>1.20</td>
</tr>
<tr>
<td>Total</td>
<td>31.2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Additional cost may be incurred on anti hail net, land development etc., based on location.</th>
</tr>
</thead>
</table>

Indian Horticulture
Coconut based cropping systems for enhancing profitability, ensuring sustainability and transcending towards nutritional security

Coconut is considered as one of the most important crops for the Asia and Pacific region, providing food, nutrition and livelihood to millions of coconut farmers in the region. Despite the economic importance of the coconut palm, coconut production continued to show stagnancy in production, productivity and trade in the recent decade. The coconut sector in the past has been dominated by copra and coconut oil, and the international coconut trade used to be driven by the demand for coconut oil. However, demand for coconut oil has witnessed a sharp decline during the last decades due to increased competition from other edible oils, such as palm oil and soybean. Furthermore, there is a changing trend wherein coconut is increasingly being processed into diversified value-added products in recent times. This emerging trend has influenced the current production, processing and trading system in coconut. To take advantage of these newfound opportunities in the world market, coconut growers must look into the trade patterns, performance and global competitiveness of coconut and coconut products. At present, the market trends indicate consumer choice and acceptance of the various products of coconut.

Growth rates in export volumes continue to increase each year for Virgin Coconut Oil (VCO) by 30%, Coconut Water by 150%, Coconut Milk/Cream/Powder by 50%, Desiccated Coconut by 30%, Coconut Flour by 115% and similar trends for other emerging products. Taking a cue from the changed scenario in the coconut sector, the Kalpa Agri-Business Incubator functioning under ICAR-CPCRI provides much-needed handholding to the startup entrepreneurs in the sector.

**Production scenario**

According to the latest production statistics brought out by the ICC, the coconut production in the world is estimated at 68,833 million nuts from an area of 12.08 million ha. The world productivity of coconut stands at 5,777 nuts/ha (Table 1). Notably, the world’s area and production of coconuts are skewed by and large, wherein 70% of the total area and production is concentrated in India, Indonesia, and the Philippines. India is the largest producer of coconuts, with a share of 31% of the total production. India is much ahead of the major coconut producers’ with an average yield of 9,897 nuts/ha.

In India, coconut contributed about ₹10,707 crore in crop output in 2019-20, and the coconut industry directly or indirectly employs about 12 million people. Coconut is a major plantation crop of coastal regions of Kerala, Tamil Nadu, Karnataka, and Andhra Pradesh. These top-four producers accounted for 90% of total production and about 89.5% of total production acreage in the country in the year 2019-20 (Table 2). Other important coconut producing States in the country include West Bengal, Odisha, Gujarat, Maharashtra, Assam and Bihar, which account for nearly 8% of production. Among the four major coconut growing States, Andhra Pradesh had the highest productivity (14,019 nuts/ha), followed by Tamil Nadu with 12,291 nuts/ha. While Kerala, which accounts for the largest share in production in the country, had average productivity of 10,097/ha in 2019-20, marginally higher than the all-India yield of 9,897 nuts/ha. The productivity level in Karnataka (7,983 nuts/ha) was significantly lower than the all India average and other major producers.

The area under coconut has remained stagnant at around 2.1 million ha since 2011-12, with minor inter-year fluctuations. Coconut production and yield have been fluctuating in cycles of two years due to climatic and biological reasons. Overall, coconut production has increased at an annual growth rate of 3.3% during 2001-2020. The growth in coconut production was largely attributed to improvement in yield, reflecting the concerted efforts on coconut research, especially the popularization of improved varieties (Fig. 1 a,b).
Demand and supply scenario

The projected coconut demand for 2050 is predicted to be about 45,000 million nuts. With the projected supply of around 36,000 million nuts, there would be a demand-supply gap of 9,000 million nuts by 2050. To meet the projected demand, the annual growth rate in production should be 3.20%. As a matter of fact, coconut in future may experience a paradigm shift from the oilseed label if promoted as food for nutrition, healthcare and environmental services to support the farming community. Moreover, the recent surge in the export of coconut products and the rising demand for tender coconut in the country is noteworthy. In such a scenario, by 2050, the demand for coconut would be certainly more than the estimated figure. Therefore, it would be a challenge to meet the futuristic coconut demand, especially because of the scarce land, labour, water and energy resources at disposal. An appreciable growth in total factor productivity and appropriate capital substitution are the possible alternatives. To achieve these, strengthening the traditional coconut-based farming system through modern research tools would be the starting point.

Table 1. Area, production and productivity of coconut in the world

<table>
<thead>
<tr>
<th>Country</th>
<th>Area ('000 ha)</th>
<th>% share</th>
<th>Production (million nuts)</th>
<th>% share</th>
<th>Productivity (nuts/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indonesia</td>
<td>3544</td>
<td>29.3</td>
<td>14356</td>
<td>20.9</td>
<td>4530</td>
</tr>
<tr>
<td>The Philippines</td>
<td>3612</td>
<td>29.9</td>
<td>14049</td>
<td>20.4</td>
<td>4196</td>
</tr>
<tr>
<td>India</td>
<td>2151</td>
<td>17.8</td>
<td>21288</td>
<td>30.9</td>
<td>9897</td>
</tr>
<tr>
<td>Sri Lanka</td>
<td>440</td>
<td>3.6</td>
<td>2450</td>
<td>3.6</td>
<td>6623</td>
</tr>
<tr>
<td>Brazil</td>
<td>216</td>
<td>1.8</td>
<td>2343</td>
<td>3.4</td>
<td>11923</td>
</tr>
<tr>
<td>Papua New Guinea</td>
<td>221</td>
<td>1.8</td>
<td>1483</td>
<td>2.2</td>
<td>6709</td>
</tr>
<tr>
<td>Thailand</td>
<td>179</td>
<td>1.5</td>
<td>666</td>
<td>1.0</td>
<td>4859</td>
</tr>
<tr>
<td>Others</td>
<td>1725</td>
<td>14.3</td>
<td>12198</td>
<td>17.6</td>
<td>5662</td>
</tr>
<tr>
<td>Total</td>
<td>12053</td>
<td>100</td>
<td>68737</td>
<td>100</td>
<td>5777</td>
</tr>
</tbody>
</table>


Table 2. State-wise statistics: Coconut

<table>
<thead>
<tr>
<th>State/UTS</th>
<th>Area ('000 ha)</th>
<th>% share</th>
<th>Production (million nuts)</th>
<th>% share</th>
<th>Productivity (nuts/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tamil Nadu</td>
<td>436.94</td>
<td>20.31</td>
<td>5370.39</td>
<td>25.23</td>
<td>12291</td>
</tr>
<tr>
<td>Karnataka</td>
<td>619.78</td>
<td>28.82</td>
<td>4947.74</td>
<td>23.24</td>
<td>7983</td>
</tr>
<tr>
<td>Kerala</td>
<td>760.95</td>
<td>35.38</td>
<td>7683.55</td>
<td>36.09</td>
<td>10097</td>
</tr>
<tr>
<td>Andhra Pradesh</td>
<td>111.82</td>
<td>5.20</td>
<td>1567.6</td>
<td>7.36</td>
<td>14019</td>
</tr>
<tr>
<td>Others</td>
<td>221.40</td>
<td>10.29</td>
<td>1718.96</td>
<td>8.08</td>
<td>---</td>
</tr>
<tr>
<td>All India</td>
<td>2150.89</td>
<td>100.00</td>
<td>21288.24</td>
<td>100.00</td>
<td>9897</td>
</tr>
</tbody>
</table>


Coconut products

Coconut palm is often called ‘tree of life’ as it ensures vibrant living, vitality, health and prosperity. Mature coconut fruit (nearly 10 to 12 months after fertilization) has solid and liquid endosperm referred to as the kernel (meat) and coconut water.

Kernel-based products: Fresh coconut kernel (i.e. gratings) is used for various culinary preparations. It has more fat (33%) than carbohydrate (15%) and is a rich source of dietary fibre (9%), potassium (355 mg) and manganese (1.5 mg). More than half the fat in coconut gratings is in the medium-chain category, absorbed directly at the
small intestine and rapidly used for energy. Some studies suggest that medium-chain fats promote loss of weight in people with obesity.

Fresh coconut kernel will have 50 to 55% moisture; on dehydrating, the desiccated coconut (DC) is obtained. It can be stored for more than six months. It may be noted here that the brown coloured testa, the thin layer separating the white coconut kernel from the shell, is removed while making the DC.

Another way of preserving coconut fruit is in the form of copra. The ball copra is obtained by allowing the whole fruit to dry (without removing its husk, i.e. exocarp) over 4 to 8 months; it will take a few months to obtain the ball copra. Once fully dried, there will be no water inside the fruit, and the entire kernel will be detached inside the shell. The milling copra (for oil) is produced by drying the split-opened nut (after removing the husk) to detach the kernel from the shell. The nutrient profile of copra is more or less similar to dried coconut gratings except for the constituents of testa, which is nearly 2% of copra weight. Testa has 40 to 50% fat.

In India, the milling copra is used for the extraction of edible oil, whereas in other countries, edible oil is obtained from the processing of coconut milk (extracted from fresh coconut kernel) or from instantly dried gratings. The nutrient profiles of coconut oil obtained in different ways show some variation. It has 92% saturated fats and 8% unsaturated fats. Because of the high concentration of saturated fats, many recommend avoiding or restricting coconut oil intake. But when examined critically, one can see that more than 80% of fat in coconut oil is of medium-chain fatty acids (Sl. No. 1 to 4 in Table 3). Further, 50% of the fat is in the form of lauric acid, making it the highest source among edible oils. As mentioned earlier, medium-chain fatty acids are easily absorbed and converted to energy instantly, unlike long-chain fatty acids. This advantage makes coconut fats a preferred choice for infant and sports person food recipes.

For direct consumption and culinary purposes, the Virgin Coconut Oil is most recommended. The VCO can be obtained by processing the coconut milk in three different ways: Centrifuge, hot processing or fermentation. ICAR-CPCRI has commercialized the protocol for hot and fermentation processing of VCO.

Coconut milk and milk powder are also used for many culinary purposes. While extraction of milk, 60 to 65% fat is removed from the kernel. These technologies are available with ICAR-CPCRI.

**Beverages:** More and more people now prefer natural drinks over soft drinks, which made the tender coconut a premium product across India in recent years. More than 15% of the production is consumed as tender coconut in India.

Another beverage from coconut is the inflorescence sap, popularly known as ‘neera’. Technology for the collection of unfermented coconut sap has been developed by ICAR-CPCRI (Fig. 2a) and is referred to be Kalparasa®. The nutrient profile of coconut water, tender coconut water and Kalparasa® is provided in Table 4.

One of the value-added products from Kalparasa® is coconut sugar (Fig. 2b). As it is processed without adding any chemicals, it is most recommended for infants. Another product getting attention from the public is the vegan coconut delicacy with constituents as tender coconut pulp, coconut milk and coconut sugar.

**Biodiversity support through system approach**

By and large, the coconut lands in India are conducive to producing various annuals, biennials, and perennials. Secondly, since coconut is planted at a wider spacing due to its characteristic morphological features, the inter- and intra-row spaces in coconut gardens are adequate to provide the best forms of cropping system without adversely affecting the productivity of the palms. Several inter/mixed crops yield reasonably well because of their ability to tolerate coconut shade. On these accounts, the returns from the system offset the costs and ensure profits.

Crops identified as compatible ones with coconut include many tuber crops (cassava, elephant foot yam, yams, colocasia), rhizome-spices (ginger, turmeric), pulses (cowpea), oilseeds (groundnut, soybean), upland rice, fruit crops (banana, pineapple) and vegetables among the annuals and cocoa, black pepper, clove and nutmeg among perennials. Many intensive crop combinations

### Table 3. Fatty acid profiles of different types of coconut oil

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Fatty acid</th>
<th>Oil from copra</th>
<th>Hot processing of coconut milk (VCO)</th>
<th>Fermentation of coconut milk (VCO)</th>
<th>Oil from dried gratings</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Saturated</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>C12-lauric acid</td>
<td>50.44</td>
<td>50.39</td>
<td>51.09</td>
<td>51.35</td>
</tr>
<tr>
<td>2</td>
<td>C14-myristic acid</td>
<td>20.94</td>
<td>20.91</td>
<td>20.89</td>
<td>19.74</td>
</tr>
<tr>
<td>3</td>
<td>C8-caprylic acid</td>
<td>4.85</td>
<td>4.9</td>
<td>4.6</td>
<td>5.45</td>
</tr>
<tr>
<td>4</td>
<td>C10-capric acid</td>
<td>4.99</td>
<td>4.96</td>
<td>4.54</td>
<td>5.42</td>
</tr>
<tr>
<td>5</td>
<td>C16-palmitic acid</td>
<td>8.15</td>
<td>8.54</td>
<td>8.7</td>
<td>8.09</td>
</tr>
<tr>
<td>6</td>
<td>C18:0-stearic acid</td>
<td>3.01</td>
<td>2.53</td>
<td>2.64</td>
<td>2.49</td>
</tr>
<tr>
<td></td>
<td>Unsaturated</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>C18:1-oleic acid</td>
<td>5.83</td>
<td>6.1</td>
<td>6.12</td>
<td>5.62</td>
</tr>
<tr>
<td>8</td>
<td>C18:2-linoleic acid</td>
<td>1.45</td>
<td>1.15</td>
<td>1.15</td>
<td>1.11</td>
</tr>
</tbody>
</table>

that involve different annuals and perennials over time, such as multistoried cropping systems and high-density multi-species crop models (HDMSCs), have also been developed (Fig. 3a). Perennial intercrops such as cocoa (Fig. 3b), nutmeg, cinnamon and fruit trees are most compatible for commercial production under coconut. Mixed farming systems, which integrate other enterprises like dairying, provide higher employment and enhanced net income.

The comparative economic analysis of coconut monocropping, coconut-based compact cropping system and coconut-based mixed farming system (CMFS) categorically proved the advantages of the system approach. The system using multi-species cropping of coconut with pepper, banana, nutmeg, pineapple, ginger, turmeric and elephant foot yam generated a net income of ₹ 362,595/ha, which is 150% higher than that of coconut monocrop (₹ 141,505), while the CMFS wherein the components are coconut, pepper, banana, crossbred cows, poultry birds, goat, and pisciculture generated a net return of ₹ 550,214, which is 288% higher than that of coconut monocrop. However, there are cases of farmers who are highly successful in implementing multiple cropping/integrated farming in coconut. Similarly, some grama panchayats have successfully implemented the coconut-based farming system interventions under the peoples’ campaign for decentralized planning programme. The potential to strengthen food and nutritional security by adopting appropriate coconut-based intercropping/mixed farming also needs to be effectively utilized.

Cocoa as a component crop

Cocoa is one of the most compatible intercrops in the coconut garden, evidenced from field experiments conducted in ICAR-CPCRI. The coconut-cocoa cropping system is one of the widely adopted cropping systems across coconut growing tracts in India.

Cocoa is grown in 58 countries on around 10 million ha with an estimated production of 4.7 million tonnes. Among the major countries, Côte d’Ivoire has the highest productivity of 660 kg/ha, while the world productivity is 504 kg/ha. The four West African countries viz. Côte d’Ivoire, Ghana, Cameroon and Nigeria contributed to 73.6% of worldwide cocoa production. India is a very small player with a production share of meagre 0.31%. In India, cocoa is cultivated mainly in Tamil Nadu, Andhra Pradesh, Kerala, and Karnataka. India produced 19,866t of cocoa from 88,515 ha with a 580 kg/ha productivity in the year 2020. Tamil Nadu has the highest area under cocoa (33%), followed by Andhra Pradesh (32%), and in cocoa production, Andhra Pradesh has the major share (41%), followed by Kerala (38%). The contribution of cocoa to the national income amounts to ₹ 2,000 million. The cocoa industry in the country has expanded to a considerable extent in recent years. At present more than

### Table 4. The nutrient profile of mature- and tender- coconut water and Kalparasa®

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Mature coconut water</th>
<th>Tender coconut water</th>
<th>Kalparasa®</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total sugar, %</td>
<td>3.3</td>
<td>4.8</td>
<td>14</td>
</tr>
<tr>
<td>Reducing sugars, %</td>
<td>0.2</td>
<td>4.4</td>
<td>1.5</td>
</tr>
<tr>
<td>Minerals, %</td>
<td>0.5</td>
<td>0.6</td>
<td>0.32</td>
</tr>
<tr>
<td>Protein, %</td>
<td>0.1</td>
<td>0.01</td>
<td>0.17</td>
</tr>
<tr>
<td>Fat, %</td>
<td>0.1</td>
<td>0.01</td>
<td>0</td>
</tr>
<tr>
<td>pH</td>
<td>5.2</td>
<td>4.5</td>
<td>7.0</td>
</tr>
<tr>
<td>Potassium, mg%</td>
<td>247</td>
<td>290</td>
<td>175</td>
</tr>
<tr>
<td>Sodium, mg%</td>
<td>48</td>
<td>42</td>
<td>45</td>
</tr>
<tr>
<td>Calcium, mg%</td>
<td>40</td>
<td>44</td>
<td>4.5</td>
</tr>
<tr>
<td>Magnesium, mg %</td>
<td>15</td>
<td>10</td>
<td>0.5</td>
</tr>
<tr>
<td>Phosphorus, mg%</td>
<td>6.3</td>
<td>9.2</td>
<td>3.0</td>
</tr>
<tr>
<td>Iron, mg%</td>
<td>79</td>
<td>106</td>
<td>75.0</td>
</tr>
</tbody>
</table>

15 industrial entrepreneurs and firms existing in the field demanding nearly 40,000 t of cocoa beans, of which the present domestic availability is only about 42%.

Considering the present-day food consumption patterns and growth of the confectionery industry in India at around 20%, the demand for cocoa is likely to increase in the coming years. The import of cocoa and cocoa products to India has increased at a compound growth rate of 17% during the 10 years period (2009-19), which shows a surging domestic demand for cocoa and cocoa products and surplus processing capacity existing in the country. It is noteworthy that the import of cocoa in the year 2019 was 63,613 t while the export was meagre 25,700 t accounting for a negative trade balance of 37,913 t.

The projected demand for cocoa in India by 2050 is 212 thousand tonnes against the estimated supply of 121 thousand tonnes. With the projected supply, there would be a demand-supply gap of 90 thousand tonnes of cocoa beans in 2050. To achieve this target, production should increase at an annual growth rate of 7.68%. There is a need to chalk out a logical and pragmatic strategy to achieve the desirable projected demand-supply equation. Growth in per capita consumption of cocoa in India is the motivating factor behind the projection of an optimistic supply-demand scenario. We have about 26 lakh ha area available in India under coconut, arecanut and oil palm gardens to cultivate cocoa plants (new area expansion), and around 35% of this land is under irrigation. Thereby, the total potential area for cocoa planting comes to around nine lakh ha. Availability of such areas in Kerala, Karnataka, Tamil Nadu, Andhra Pradesh and Odisha will therefore offer ample scope for new area expansion of cocoa.

There are potentials and possibilities in the form of massive acreage wherein cocoa can be comfortably accommodated as an intercrop, an internal market with accelerated annual growth of the confectionery industry, and well-established research and development back up. In case of cocoa, the development of exclusive market yards and assembling places for cocoa beans and the adoption of high-quality food safety standards would be a proactive step for better realization of bean prices. Assured buy-back systems developed in the frame of contract farming under the government’s stake (tripartite arrangement) can help in the sector’s growth.

**Recycling for sustainability**

Recycling crop wastes in coconut and cocoa through vermicomposting and mushroom production helps in disposing of wastes, improving soil fertility, reduction in use of chemical fertilizers and sustaining the yield besides enhancing nutritional security. Coconut gardens of 1 ha area can generate up to 8 t of leaf biomass residues every year. Technology has been developed to utilize these wastes for the production of vermicompost, vermiwash, compost and mushrooms. From about 8 t of leaf residues, 3-4 t of vermicompost could be produced annually using the local isolate of *Eudrilus* sp. The coconut leaf vermicompost can also meet 50% of the nitrogen requirement of coconut palms grown in 1 ha, saving expenditure on inorganic fertilizers.

**Coconut based ancillary industries**

An off-shoot from the mainstay coconut sector, the coir industry in India contributes significantly to employment creation and the economy at large, mainly in Kerala and Tamil Nadu but also in other major coconut growing States and Union Territories, including Andhra Pradesh, Karnataka, Maharashtra, Goa, Odisha, Assam, Andaman and Nicobar, Lakshadweep and Puducherry. In the country, approximately seven lakh persons find employment, both direct and indirect, in this industry. The industry is also significant in terms of exports. In 2019-20, India exported 9.9 lakh MT of coir and coir products, earning ₹2,758 crore in export revenues. It is also noteworthy that, the exports of coir and coir products have increased at an annual growth rate of 11.1% during the last five years (2016-2020).

The domestic revenue earned is double the export revenue. India accounts for more than two-thirds of the global production of coir and coir products, including 60% of the total global supply of white fibre. Sri Lanka is the second-largest producer accounting for 30% of the total global supply of golden fiber. Currently, the global annual production of coir fiber is about 3.5 lakh metric tonnes.

The coir industry assumes significance because it
is agro-based, has a large presence in rural areas, and involves a large proportion of women workers (80%) and workers belonging to the economically and socially disadvantaged sections. India currently exports about 14 coir products, including coir pith, coir fiber, tufted mats, handloom mats, geotextiles, coir yarn, curled coir, handloom matting and rubberised coir. Currently, only 40% of the coconut husk is utilised by the coir industry, and there is potential for further development.

**Coir pith:** It is a by-product separated from the husk while extracting the fibre. Its capacity to hold moisture eight times its weight makes coir pith an excellent soil conditioner. With the ban on peat mining, the horticulture industry was in search of an alternative material from a renewable resource, and coir pith fits exactly into the slot. Coir pith has amazing water-retaining capacity. Thus, the fibre acts like mini-sponges, yielding astounding plant growth, which eventually makes it a great product. It is striking that coir pith contributes up to 49% of the value share in coir products exports from India.

**Shell charcoal:** India is amongst the top five exporters of coconut shell charcoal and activated carbon. Coconut based activated carbon is produced using coconut shell and coconut husks. Hardness required in coconut shells for manufacturing activated carbon, which are in high demand, is a rare feature in the shells sourced from southern India, therefore activated carbon from India has a high demand in international markets. Coconut shell-based activated carbon accounted for 67.2% of total exports of coconut products and stands as a promising and profitable enterprise for the aspirants.

In India, the coconut sector has been inextricably linked to coconut oil, the most dominant product from the palm, from time immemorial. Such a strong dependency on a single product had indubitably made the sector vulnerable to supply and price shocks. It is also noteworthy that trade and market prices are increasingly playing a key role in sustaining the livelihood of those dependent on this sector. Hence, it is imperative to think beyond production and productivity, especially when many other issues plague the coconut sector. The potential area of the coconut sector is the agri-business, based on value-added products of coconuts.

Further, many rural youths from the country are interested in utilizing coconut value addition technologies such as virgin coconut oil, coconut chips, Kalparasa® and coconut sugar to start business ventures. The breakthrough products developed from the coconuts have export potential, and thereby in the long run, price stabilization in the domestic coconut sector is also possible. Further, to ensure the livelihood security of those dependent on the sector, it is of paramount importance to strengthen the value chain of the coconut through appropriate forward and backward integration of the chain.
Mushroom, a super food suitable for all age groups, contains all the vital nutrients required for human body in desired proportion. The production of mushrooms in India has increased by an average growth rate of 8.3% in last 25 years. Different types of mushrooms viz. white button (Agaricus bisporus), oyster (Pleurotus spp.), paddy straw (Volvariella volvacea), milky (Calocybe indica) and shiitake (Lentinula edodes) mushroom with a total production of about 2.43 lakh tonnes are being cultivated on commercial scale in India because of its diversified agro-climatic conditions. Mushrooms have been recognized to contain highest and quality protein per unit area from agro-wastes generating employment, improving economic status of growers, checking pollution and earning foreign exchange. They also restore the environment by playing a role in degrading the pesticides and persisting chemicals. The spent mushroom substrate after cropping, remain as a good source of protein and other nutrients for animal feed. Mushrooms with their good nutritional, medicinal and functional properties are considered as a health food as they contain low calories, high protein, dietary fibre, vitamins, and minerals with high antioxidant capacity. Hence, mushroom cultivation is an effective way for resource poor farmers to generate wealth from waste using a limited space within a short duration. It also provides an opportunity to produce a highly tradable commodity, thereby contributing to income generation and improved socio-economic status.

Mushrooms

Appearing with their attractive and spectacular shapes and structures, mushrooms have always been intriguing to human beings since ancient times. Mushrooms belong to a group of organisms called fungi. Fungi have always been found growing on the dead organic matter helping to decompose and utilize it for production of nutrition rich food. The thread like structures (mycelium) spread in the substrate help absorb the nutrition with formation of fruiting body called mushroom. Very often, people associate appearance and growth of the mushrooms with thunder and lightning.

As per the reports, about 14,000-16,000 species of mushroom have been recorded worldwide out of which about 3,000 species are primarily considered edible. Throughout the world, about 200 mushroom species have been grown successfully, 100 are economically cultivated, about 60 have commercial importance and 10 have industrial application in different countries. As far as vital bioactive compounds are concerned, 2,000 species have shown health attributes addressing a number of disorders and diseases and 30 species were reported lethal if consumed. Because of nutritious components, mushrooms have phenomenal contribution in combating malnutrition among women and children. Supplementing Indian diets with mushroom thus will help in bridging the protein gap among general population while improving the socio-economic status of resource poor farmers. At present, out of total 43 million tonnes of world mushroom production, China is leading producer and India ranks Sixth in terms of total mushroom production in the world. It is reported that average world mushroom consumption is 5-6 kg/person/year, whereas it is 22-23 kg in China and about 175 g in India. Presently, shiitake (Lentinula edodes) has become the most cultivated mushroom in the world followed by oyster (Pleurotus spp.) and wood ear (Auricularia spp.) mushrooms. In India, about 70% mushroom production is contributed by button mushroom, though there is a great scope for others including speciality mushrooms. Now with people becoming more and more aware about healthy foods, which are complete in all respect, the demand for mushrooms is increasing every year.

India is blessed with varied agro-climatic conditions, abundant availability of agricultural wastes and human resource and thus is most suitable for the cultivation of all the types of mushrooms. In India, commercial cultivation started in 1960s, in 1970 total mushroom production was 3,000 tonnes, which rose to 40,000 tonnes in 1997, and
126,000 tonnes in 2016. In the last five years country has witnessed exponential growth and presently India is producing 242,000 tonnes of mushrooms per annum. White button mushroom is still the most commonly grown mushroom and oyster (Pleurotus sp.), milky (Calocybe indica), paddy straw (Volvariella volvacea) and shiitake (Lentinula edodes) are the other commercially cultivated mushrooms in India (Fig. 1). Fig. 2 provides the growth of mushroom production in India which shows exponential growth over last two decades. When compared, yield of food grains have increased at a very low rate (1.96%) than mushroom production (8.30%) over the last 25 years. This can be attributed to more recent inclination of Indians towards healthy and functional foods and hence setting up of more commercial seasonal and round the year mushroom cultivation units.

Mushrooms for better resource utilization

Mushroom production not only provides diversification and improves nutritional security but also address the alarming issues related to dwindling natural resources like land and water. Mushroom cultivation is typical example of vertical farming and can easily be taken up by the resource poor farmers in the country. Mushroom utilizes agricultural residues, can be cultivated vertically, highest protein producer per unit area per unit time. Mushrooms have high nutritive value and being a labour intensive industry provides ample opportunities for the employment. The land requirement for mushroom cultivation is almost negligible owing to vertical farming; water requirement for mushroom cultivation is also very less (25-30 litre/kg production of mushroom). Hence, mushroom cultivation is helping in the judicious use of fast depleting natural resources and can pave the path towards sustainable agriculture.

Mushrooms for better environment

Cleaning up of agricultural waste: Pollution is an important threat for sustainability of environment. Leading environmental pollutants are automobile emission, industrial wastes, agricultural wastes and municipal waste. According to an estimate around 700 million tons of crop residues are generated per year and most of it is left unutilized which creates environmental pollution. A huge amount of paddy straw and stubbles are burnt in the fields every year especially in north India. This practice of burning paddy straw and dumping of other agricultural wastes affect the quality of air, soil and water in addition to the life of farm animals and the microclimate of the crop. Mushroom farms can utilize this agricultural waste for growing mushrooms. Mushroom mycelium produces extracellular enzymes such as ligninases, cellulases, and laccases, which can degrade and utilize diverse crop residues and reduce pollution. Mushrooms also play an important role in synthesizing non-toxic nanoparticles of metals from their salts. Hence, mushroom farming is an eco-friendly sustainable technology, which produces nutritive and medicinal fruiting bodies utilizing agricultural waste.
Removal of environmental pollutants: Mushrooms also play a significant role in the restoration of damaged environments. Bioremediation involving the use of mushroom mycelia to remove or neutralize a wide variety of pollutants is an effective way of reducing soil and water pollution. The injudicious use of pesticides has caused accumulation of a lot of pesticide residue in agricultural products and in soil. Many insecticides have been reported to be mineralized by the mushrooms. Pleurotus ostreatus degrades DDT as well as malathion. Spent oyster mushroom substrate can also perform denaturation and removal of biocide pentachlorophenol in water systems.

Spent mushroom substrates for animal feed: Agricultural crop residue is used as one of the important animal feed for increasing milk production and for improving body mass of animals. But the nutritional quality of these crop residues is poor many a times. Hence, animal feeds need to be supplemented with enriched nutrient sources. Oyster mushroom spent mushroom substrate (SMS) is one of the suitable nutrient rich supplements for animals. The spent substrate remained after cropping of mushrooms, is a very good source of protein for livestock and poultry. It contains a number of beneficial microorganisms, extracellular enzymes and relatively high level of proteins and macronutrients like nitrogen, potassium, phosphorus, calcium and trace elements such as iron and silicon. Spent straw or compost also have good digestibility in animals. SMS also contains good amount of polysaccharides and vitamins, which are beneficial for animals. Mushroom also have positive effect on health of animals and poultry. Since mushrooms are rich in antioxidants and have antibacterial properties, they may also act as probiotics for poultry feed. SMS can also be given in diet of pigs to improve their body weight. The SMS mixed with barley powder can also be used as fish feed, and have shown increased fish production with reduced feed cost.

Mushrooms for better nutrition and health

Nutritional value of mushrooms: Mushrooms are rich in protein, vitamins, minerals and are low in fat and sugar because of which it is considered a super food. Mushrooms contain a good amount of quality proteins (30-40% of dried mass) rich in essential amino acids required for good health. Mushrooms are rich in leucine and lysine amino acids, which are commonly lacking in many staple cereal foods. Mushrooms are low in sugar and fat and thus are very useful for the people suffering from diabetes and heart related problems. Being rich in fibres, they help to overcome the acute constipation problem. Mushrooms provide several groups of vitamins, particularly vitamin D, thiamine, riboflavin, niacin, biotin, pantothenic acid and ascorbic acid. Being the only vegetarian source of vitamin D, mushrooms can be very helpful in alleviating the prevalent vitamin D deficiency among masses. Moreover, mushrooms are also rich in various minerals like phosphorus, zinc, manganese, potassium, copper, selenium [an antioxidant], iron, magnesium, etc. (Fig. 3).

Mushroom: A functional food: Mushrooms also provide many added health benefits apart from their rich nutritional values and thus can be categorized under functional foods. Mushrooms have a lot of functional food ingredients such as dietary fibre, poly-unsaturated fatty acids (PUFA), proteins, peptides, amino acids, keto acids, minerals and other antioxidants (glutathione, selenium, etc.), which make them a health food. The high proteins, sterols, macro-elements and low calorie content make mushroom ideal for prevention of cardiovascular diseases. Thus they are an ideal food for patients, old people, pregnant women and children. Mushroom also contains bioactive compounds like β-1-3-glucans, which have an ability to control the blood cholesterol level preventing cardiovascular diseases. Besides, β-glucans also have immuno-modulatory properties and have been used clinically as part of a combination therapy for a variety of cancers (Fig. 4).

Medicinal value of mushrooms: Some mushrooms are also classified as medicinal mushrooms, as they contain some bioactive compounds that are Host Defense Potentiators (HDP) and can have immune system regulating properties. These compounds include polysaccharides (β-glucans), polysaccharide-peptides, nucleosides, triterpenoids,
complex starches, and other metabolites. Shiitake mushroom (*Lentinula edodes*) possesses antitumor, antihypertensive, hypocholesterolemic, and antibacterial activities. Reishi mushroom (*Ganoderma lucidum*) has been proven to have antimicrobial and anti-HIV effects, while the β-glucan polysaccharide and the ganoderic acid of this mushroom have shown anti-tumorogenic effects. Oyster mushrooms (*Pleurotus* species) also contain cholesterol lowering and immune-stimulatory properties.

**Conclusion**

Mushroom production is indoor activity, hence, does not need agricultural land thus suited to small farmers and landless labourers. Many agricultural wastes can be utilized to produce quality food and organic manure for field crops. Besides mushroom have high bio-efficiency i.e. conversion of dry substrate into fresh mushroom. Spent mushroom substrate can be used to produce organic manure and animal feed. It can generate self-employment and can improve socio-economic status. It can provide nutritional security particularly to poor people through incorporating mushrooms in their diets. Thus, mushroom production is a vocation that should be encouraged in the country vigorously.

*For further interaction, please write to:*

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**Handbook of Agriculture**

The Handbook of Agriculture is one of the most popular publication of the ICAR with a wider readership. The present edition presents science-led developments in Indian agriculture, the ongoing research efforts at the national level and with some ideas on the shape of future agriculture. While information in some chapters such as Soil and water, Land utilization, field and forage crops has been updated with latest developments, many new topics such as the Environment, agrobiodiversity, Resource conservation technologies, IPM, Pesticides residues, Seed production technologies, Energy in agriculture, informatics, Biotechnology, Intellectual Property Rights, Agricultural marketing and trading and Indigenous Technical Knowledge have been included in the present edition. For those who take intelligent interest in agriculture – and their number is increasing fast – the present edition would serve as a useful book.

**TECHNICAL SPECIFICATIONS**

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Horticulture and nutrition: Two sides of the coin

‘There is a horticultural remedy for every nutritional malady’ says Prof. M.S. Swaminathan, the Father of Green Revolution in India. Horticulture forms an integral and important component in the economy of a nation. Horticultural crops constitute a significant segment of the total agricultural production of a country. The importance of horticulture can be substantiated by its benefits like high export value, high per unit area yield, high returns per unit area, best utilization of wasteland, provision of raw materials for industries, whole engagement by a grower/labourer, production of more food energy per unit area than that of field crops, better use of undulating lands, and stabilization of women’s empowerment by providing employment opportunities through processing, floriculture, seed production, mushroom cultivation, nursery preparation, etc. In addition, fruits and vegetables constitute the important energy-giving material to the human body. It also improves the economic condition of many farmers, and it has become a means of improving livelihood for many unprivileged classes too. Flower harvesting, nursery maintenance, hybrid seed production and tissue culture, propagation of fruits and flowers, and food processing are highly remunerative employment options for women in rural areas.

Prospects

Wide range of horticulture

India has been bestowed with wide range of climate and physio-geographical conditions and as such is most suitable for growing various kinds of horticultural crops such as fruits, vegetables, flowers, nuts, spices, medicinal plants, orchids and plantation crops (coconut, cashew nut and cocoa). Horticulture production has increased by 13% in the last five years. This has placed India among the foremost countries in horticulture production, just behind China. During 2015-16, its contribution in the world production of fruits and vegetables was 12.6 and 14%, respectively. Total horticulture production during 2015-16 was 283.3 million tonnes which increased to 320.77 million tonnes in 2019-20 (Table 1). It is projected to be 330 million tonnes by 2021-22. The increased production was because of the farmer-friendly policies of the government, tireless efforts of farmers and research of scientists.

Dietary benefits of fruits and vegetables

How many food groups a person routinely eats can be used as a proxy for the nutritional adequacy of a diet. Eating a variety of fruits and vegetables (Figs. 1 and 2) is key to achieving dietary diversity and meeting daily micronutrient needs.

Eating fruits and vegetables is part of a healthy diet. Fruits and vegetables are not only sources of many vitamins and minerals, but eating them reduces the risk of diseases. In fact, the World Health Organization has identified low fruit and vegetable intake as a top risk factor for global mortality. Specific fruits or vegetables can be used to target particular nutrient deficiencies, for example, orange-fleshed sweet potatoes have been proven effective for alleviating vitamin A deficiencies. Perhaps more importantly, these whole foods also provide an array of phytonutrients and antioxidants that have a variety of beneficial health impacts. A diet rich in fruits and vegetables provides necessary micronutrients that cannot be found in staple grains, meat or dairy.

Fruits and vegetables, especially, are a good source of fibre, selected minerals, vitamins and antioxidants. Most fruits and vegetables are available almost year-round in a wide variety and they not only taste good, but they also have favourable attributes of texture, colour, flavour and ease of use. They can be fresh, cooked, hot or cold, canned, pickled, frozen or dried. Fruits and vegetables are consumed at all times, and due to their convenient size; they are an excellent between-meal snack. They are relatively low in calories and fat (avocado and olives being the exceptions), they have no cholesterol, they are rich in carbohydrates and fibre, they contain vitamin C and carotene, and some are a good source of vitamin B6. Fruits and vegetables are relatively low in sodium and high in potassium. Ascorbic acid in fruits and vegetables enhances.
the bioavailability of iron in the diet. Because of all these characteristics, fruits and vegetables have a unique role in a healthy diet. A growing body of research has shown that fruits and vegetable consumption is associated with reduced risk of major diseases, and possibly delayed onset of age-related disorders, promoting good health. However, in many cases fruit and vegetable consumption is still below the dietary guideline goal of consuming 5–10 servings each day. The nutritional value of fruits and vegetables depends on their composition, which shows a wide range of variation depending on the species, cultivar and maturity stage. The composition of fruits, vegetables, leafy green leaves and medicinal herbs (Fig. 2, 3 and 4) includes a great number of metabolites however, it could be predicted that no single commodity might be rich in all these constituents.

**Trends in horticulture production and present status**

The production of fruits has touched at 100 MT, while that of vegetables at about 197 MT (2020-21). It is indeed a matter of accomplishment that horticulture production of the Country has crossed 320 million MT during 2019-20 continuously outpacing food grain production which is 3.7% higher than the previous year and 13% higher than the past five years’ average production (Fig. 1). The spices production has touched at 10 MT (2019-20) and plantation crops at 16.0 MT. India retains its position as the second largest producer of fruits and vegetables globally. The current production of fruits (101 Million MT) and vegetables (197 million MT) not only meet the ICMR EAC 2008 recommended dietary allowance for the country with respect to fruits and vegetables (400 g/person/day) but also the current production is near achievement of projected demand of fruits and vegetable by ICAR in its vision 2030 (110 million MT of fruits and 180 Million MT of vegetables) much in advance. This demonstrates willingness and risk taking entrepreneurship of Indian farmers to accomplish task of production to meet food and nutritional security of the nation. Over a period, it is heartening to note that horticulture sectors’ contribution to overall agriculture sector is growing very sharply.

**How horticultural crops can improve nutrition**

There is no doubt that horticultural crops can improve nutrition. Farmers who grow fruits and vegetables often eat some of what they are growing and they may also have more money to buy food. A tremendous sense has prevailed over a period of time to consume fruits and vegetables to accomplish the dietary requirement. Because fruits and vegetables are high-value crops, farmers who grow them can earn significant income even from small plots and consistently higher prices than those growing cereal crops. That additional income can allow farmers to spend more on food purchases.

Women make up a majority of horticultural farmers in many countries. Because they are often responsible for feeding their households and making nutritional choices, reducing women’s workload including time and energy spent growing and selling crops can increase their capacity to provide for their households’ nutritional needs. Women are also more likely to spend their available income on improving their families’ health. Regions and communities where farmers grow and sell horticultural crops have greater access to fruits and vegetables for purchase. As more fruits and vegetables enter the market, prices may decrease which can make these nutritious crops more available and more enticing to shoppers.

**Double burden of malnutrition**

As diets shift in developing countries, malnutrition can include both people who are undernourished and people who are overweight. Undernutrition and overnutrition can co-exist, even in the same household. Increasing fruit and vegetable consumption is one of the few dietary strategies that can help improve both situations.

A nutritious and varied diet is a critical means by which good health can be maintained. Consumption of less than 200 g of vegetables per person per day in many countries today is common and this low amount, often in conjunction with poverty and poor medical services, is associated with unacceptable levels of mortality and malnutrition in preschool children and other vulnerable groups. An increase in the availability, affordability and consumption of nutrient-dense vegetables and pulses is one way malnutrition which may be substantially reversed yet nutritional security appears to be less valued than food security by key decision makers, and vegetable crops thus receive inadequate research investment. Opportunities exist for the poor to improve their access to vegetables, particularly if they are willing to grow home gardens. Research continues on defining appropriate nutrient-dense vegetables for such activities, but these efforts may be compromised by failure to adopt good agricultural practices, resulting in contamination and unhealthy produce for producers and consumers. The scientific community is ready to play its role in battling malnutrition and hunger, but unless the political resolve can be found to support the causes of both food and nutritional security together, it is unlikely that the Millennium Development Goals will be achieved in a timely fashion. Redressing the current imbalance in agricultural investment can improve efficiency in food production and ensured-nutritious diets can be a reality for all people.

**Food groups**

‘My Plate for the Day’ developed by ICMR-NIN illustrates the proportion of foods from different food groups to be sourced for a 2000 Kcal Indian
diet. It recommends sourcing of macronutrients and micronutrients from minimum of eight food groups per day with vegetables, fruits, green leafy vegetables (Fig. 4), tubers forming essentially half the plate of the recommended foods per day. The other major portion consists of cereals and millets, followed by pulses and milk/curd. Vegetables/tubers (excluding potato) intake should be 350 g, while ideal consumption of fruit and nuts should be 150 g and 20 g per day, respectively.

Diet rich in fruits and vegetables have been shown to reduce the incidence of cardiovascular disease and some chronic and degenerative diseases associated with oxidative stress. The incorporation of fruits and vegetables in the diet may also help eliminate certain toxins. The protective effects have been associated with the presence of antioxidant compounds. Antioxidants are present in all horticultural crops and include ascorbic acid, carotenoids, vitamin E and phenolic compounds, among others.

Food safety

Food safety and quality are also becoming important considerations for consumers. A study done indicates that one-third of food expenditure towards 2050 will be for quality traits. Food safety, especially before sale of produce by the farmers, is not monitored and inspected effectively. Food Safety and Standard Authority of India (FSSAI) which is entrusted with the responsibility of food safety, covers only post-harvest stage of food chain. The need for quality and safety monitoring is equally important in pre-harvest stage.

Transformation to nutrition-sensitive investment

We must look throughout the food system to address the factors that are driving up the cost of nutritious foods. This means supporting food producers especially small-scale producers to get nutritious foods to markets at low cost, making sure people have access to these food markets, and making food supply chains work for vulnerable people from small-scale producers to the billions of consumers whose income is simply insufficient to afford healthy diets.

Whatever recommendations we make or made, once tailored to our context, will help government to reduce the cost of nutritious foods, make healthy diets affordable for everyone and enable vulnerable people working in food systems to earn decent incomes that enhance their own food security. This will set in motion a transformation of existing food systems that makes them resilient and sustainable. Areas of policy emphasis should include following:

- Rebalancing of agricultural policies,
- Incentives towards more nutrition-sensitive investment,
- Policy actions all along food supply chains, with a focus on nutritious foods for healthy diets, to reduce food losses,
- Create opportunities for vulnerable small-scale producers and others working in food systems, and
- Enhance efficiencies.

There should be nutrition-sensitive social protection policies to increase the purchasing power and affordability of healthy diets including fruits and vegetables by the most vulnerable populations. An enabling environment should also be promoted by policies that, more generally, improve the nutritional quality of the food produced and available on the market, support the marketing of diverse and nutritious food, and provide education and information for fostering individual and social behaviour change towards healthy diets.

Way forward

- A continuous effort to promote research and development structures and alliances to enable innovation within the fruit and vegetable sector, which could reduce food loss and waste.
- Coupling research with conservation of indigenous fruit and vegetables to contribute to improving diet quality by providing nutrient dense foods while supporting climate-change adaptation.
- Encouraging public–private sector collaboration for systematic market approach and consumption, generating new knowledge on fruits and vegetables, and promoting absolute change.
- Adequate distribution and utilization of fresh fruits and vegetables by making supply chain a viable component for furthering dietary control.
- Formulation of food-based dietary guidelines that promote the consumption of fruits and vegetables as part of a diverse and healthy diet.
- Encouraging innovation and investments in the sector to transform fruit and vegetable food systems in ways that could sustainably boost productivity and enable more equitable consumption.
- Use of public procurement policies that promote healthy diets.
Conclusion

The fruit and vegetable sector plays an important role in providing fresh and nutritious food to consumers around the world, especially in growing towns and cities. The sector generates income not only for producers but also for the actors along the value chain that links farms to consumers. Fruits and vegetables can generate high returns per hectare, making it possible to reduce poverty if the right investment, capacities and services are in place. Improving nutrition across many regions of the globe hinges upon increasing fruits and vegetable intake as key constituents of healthy diets. Increasing consumption could lead to a win–win scenario for the health of both people and the planet if it is accompanied by concerted efforts and investments to increase production and productivity in the sector. At the same time, however, such efforts need to decrease the environmental footprint, improve harvesting, handling, storage and distribution to reduce loss and waste, maintain quality (particularly nutritive) and increase shelf-life, and educate consumers on the health benefits to be derived from increased consumption of fruits and vegetables.

For further interaction, please write to: Manish Das and A K Singh, Horticultural Science Division, Indian Council of Agricultural Research, Krishi Anusandhan Bhawan-II, New Delhi 110 012, India.
Tuber crops: Treasure of soil for better production, better nutrition and better life

Tropical tuber crops like cassava, sweet potato, yams, elephant foot yam, taro, tannia, arrowroot and Chinese potato are ethnic starchy vegetables with high production potential, photosynthetic efficiency, nutritive value, cooking quality and grown throughout India ensuring food and nutritional security to the marginalised population of the country. They have higher biological efficiency, can tolerate drought and shade, withstand flood and salinity to some extent and adapted to marginal environments with low soil fertility. These crops are comparatively free from pests and disease and can be grown with less inputs including water. Hence, these crops are known as ‘climate resilient’ and ‘climate smart future crops’. They have immense industrial uses in the production of starch, sago, alcohol, liquid glucose, vitamin C, as a raw material for poultry and animal feed besides medicinal properties.

Nutritional value of tropical tuber crops

These crops provide 6% of world’s dietary energy and good source of dietary fibre, β-carotene, antioxidants, flavonoids, mucilage, omega 3 fatty acid, minerals, nutraceuticals and resistant starch, which can play an important role in mitigating hidden hunger through diet diversification. The nutritional profile of important tropical tuber crops is presented in Table 1.

Tropical tuber crops varieties for better nutrition

Natural antioxidants are recently getting much attention and being extensively studied for their capacity to protect organisms and cells from damage caused by oxidative stress, which is considered a cause of degenerative diseases such as cancer. Anthocyanins both in fresh and processed forms in natural products such as vegetables and tubers not only improve the overall appearance of the food products but also contribute to scavenging of free radicals. β-carotene is the precursor of vitamin-A and the β-carotene rich tubers are expected to solve the vitamin-A deficiency in tribal and marginal communities. Tropical tuber crops such as sweet potato...
Table 1. Nutritional profile of tropical tuber crops

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<td>1.0-1.6</td>
<td>1.12-2.70</td>
<td>0.56-3.10</td>
<td>1.10-3.05</td>
</tr>
<tr>
<td>Starch (%)</td>
<td>28.0-33.2</td>
<td>11.8-20.1</td>
<td>24.5-26.5</td>
<td>6.72-16.60</td>
<td>15.9-28.0</td>
</tr>
<tr>
<td>Sugar (%)</td>
<td>0.34-1.14</td>
<td>2.38-9.70</td>
<td>1.00-1.01</td>
<td>0.14</td>
<td>0.50-1.39</td>
</tr>
<tr>
<td>Dietary fibre (%)</td>
<td>1.43-1.57</td>
<td>1.64-2.50</td>
<td>1.46-3.80</td>
<td>1.45</td>
<td>1.19-2.36</td>
</tr>
<tr>
<td>Crude fibre (%)</td>
<td>0.9-2.0</td>
<td>0.80-1.50</td>
<td>0.61-0.70</td>
<td>0.74</td>
<td>0.6-1.4</td>
</tr>
<tr>
<td>Fat (%)</td>
<td>0.1-0.3</td>
<td>0.12-0.70</td>
<td>0.10-0.30</td>
<td>0.06-0.74</td>
<td>0.03-0.27</td>
</tr>
<tr>
<td>Ash (%)</td>
<td>0.5-1.7</td>
<td>0.74-1.10</td>
<td>0.80-1.20</td>
<td>0.31-1.36</td>
<td>0.7-2.1</td>
</tr>
<tr>
<td>Nutrient and minerals (DW)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N (%)</td>
<td>0.4-0.8</td>
<td>0.6-1.0</td>
<td>0.23-3.61</td>
<td>0.34</td>
<td>0.57</td>
</tr>
<tr>
<td>P (ppm)</td>
<td>1,000-1,400</td>
<td>1,050-1,750</td>
<td>1,500-4,500</td>
<td>32.0-67.0</td>
<td>4.8-58.0</td>
</tr>
<tr>
<td>K (ppm)</td>
<td>7,000-10,000</td>
<td>9,000-13,000</td>
<td>10,000-17,000</td>
<td>416-622</td>
<td>224-329</td>
</tr>
<tr>
<td>Ca (ppm)</td>
<td>1,300-1,600</td>
<td>750-1,000</td>
<td>400-1,200</td>
<td>26.0-127.0</td>
<td>4.4-14.0</td>
</tr>
<tr>
<td>Mg (ppm)</td>
<td>600</td>
<td>400-900</td>
<td>650-3,800</td>
<td>22.0-47.0</td>
<td>6.6-17.8</td>
</tr>
<tr>
<td>S (ppm)</td>
<td>500</td>
<td>450</td>
<td>280</td>
<td>11.8</td>
<td>9.8-14.4</td>
</tr>
<tr>
<td>Fe (ppm)</td>
<td>127</td>
<td>14-34</td>
<td>15-55</td>
<td>0.51-2.4</td>
<td>0.14-1.15</td>
</tr>
<tr>
<td>Mn (ppm)</td>
<td>10-15</td>
<td>4-9</td>
<td>10-15</td>
<td>0.31</td>
<td>0.01-0.64</td>
</tr>
<tr>
<td>Zn (ppm)</td>
<td>15-16</td>
<td>7-20</td>
<td>40-120</td>
<td>1.05</td>
<td>0.24-0.49</td>
</tr>
<tr>
<td>Cu (ppm)</td>
<td>3-3.9</td>
<td>5-6</td>
<td>6.5-8</td>
<td>0.18</td>
<td>0.05-0.21</td>
</tr>
<tr>
<td>B (ppm)</td>
<td>4</td>
<td>3.4</td>
<td>3</td>
<td>0.17</td>
<td>0.08-0.09</td>
</tr>
<tr>
<td>Al (ppm)</td>
<td>1.06-2.60</td>
<td>28</td>
<td>13</td>
<td>0.41</td>
<td>0.10-1.18</td>
</tr>
<tr>
<td>Na (ppm)</td>
<td>6.2-8.1</td>
<td>34-1,800</td>
<td>23-400</td>
<td>4.1-5.8</td>
<td>2.2-108.0</td>
</tr>
<tr>
<td>Vitamins (mg/100 g) (FW)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vitamin A</td>
<td>5-35</td>
<td>0.01-0.67</td>
<td>0-0.02</td>
<td>0-0.15</td>
<td>0.018</td>
</tr>
<tr>
<td>Thiamine</td>
<td>0.03-0.28</td>
<td>0.08-0.10</td>
<td>0.03-0.13</td>
<td>0.05-0.06</td>
<td>0.031-0.10</td>
</tr>
<tr>
<td>Riboflavin</td>
<td>0.03-0.06</td>
<td>0.02-0.7</td>
<td>0.02-0.03</td>
<td>0.02-0.07</td>
<td>0.02-0.04</td>
</tr>
<tr>
<td>Nicotinic acid</td>
<td>0.6</td>
<td>0.45-0.80</td>
<td>0.44-1.38</td>
<td>0.7-1.7</td>
<td>0.07-0.47</td>
</tr>
<tr>
<td>Ascorbic acid</td>
<td>15-50</td>
<td></td>
<td></td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Dehydroascorbic acid</td>
<td>5.2</td>
<td></td>
<td></td>
<td>17.6</td>
<td></td>
</tr>
<tr>
<td>Vitamin C</td>
<td>14.9-36.0</td>
<td>15-30</td>
<td>0-15.0</td>
<td>1.5-6.0</td>
<td>5.0-27.6</td>
</tr>
</tbody>
</table>

Table 2. Nutrient rich varieties developed by ICAR-CTCRI

<table>
<thead>
<tr>
<th>Sweet potato</th>
<th>Sree Kanaka</th>
<th>β-carotene content (8.8-10.0 mg/100 g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bhu Sona</td>
<td>Orange fleshed sweet potato with carotene (13.2-14.4 mg/100 g)</td>
<td></td>
</tr>
<tr>
<td>Bhu Krishna</td>
<td>Purple flesh variety with high anthocyanin (85-90 mg/100 g)</td>
<td></td>
</tr>
<tr>
<td>Bhu Kanti</td>
<td>Orange fleshed variety with β-carotene (6.5 mg/100 g)</td>
<td></td>
</tr>
<tr>
<td>Bhu Ja</td>
<td>Orange fleshed variety with β-carotene content (5.5-6.4 mg/100 g)</td>
<td></td>
</tr>
<tr>
<td>Greater yam</td>
<td>Sree Neelima</td>
<td>Purple flesh variety with anthocyanin (15 mg/100/ HPLC)</td>
</tr>
<tr>
<td>Da 340</td>
<td>Purple flesh genotype with anthocyanin (37.69±2.21 mg/100 g)</td>
<td></td>
</tr>
<tr>
<td>Cassava</td>
<td>17S325</td>
<td>Yellow flesh genotype with higher carotene (6.01 mg/100 g)</td>
</tr>
</tbody>
</table>
and yams offer immense scope as health protectants, therapeutics and biocolourants because of the presence of compounds like carotenes and flavonoids. ICAR-Central Tuber Crops Research Institute (ICAR-CTCRI) released nutrient rich varieties in sweet potato, greater yam and cassava (Table 2).

**Tuber crops technologies for better environment**

Nutrient use efficient varieties make the best use of available nutrients in limited quantity. Hence, they reduce the need for artificial application of fertilizers thereby indirectly promoting the soil health. The cassava variety Sree Pavitra comes under such category. It is a potassium use efficient variety.

**Features of potassium efficient cassava variety, Sree Pavithra**

- The cassava variety, Sree Pavithra is the first potassium use efficient variety released by ICAR-CTCRI.
- It reduces the requirement of potassium by 50%.
- Yields about 35 t/ha under optimum conditions.

Site specific nutrient management (SSNM) is an important component of precision farming, which includes the soil test based and need based application of fertilizers thereby reducing the excess use of fertilizers and cost involved in production besides reducing the impact of indiscriminate use of fertilizers on environment. Site specific nutrient management recommendations using calibrated QUEFTS model were developed for cassava, sweet potato, elephant foot yam, yams and taro, which resulted in 13-28% yield increase in these crops, higher nutrient use efficiency, reduction in the use of fertilizer inputs, higher B:C ratio and better soil health. Nutrient management zones were delineated based on agro-ecological zones/units and separate nutrient recommendations were developed for each zone/unit and validated. Six nutrient decision support tools were developed for need based soil test based application of fertilizers. A stand-alone decision support tool, a newer version CASSNUM version 1.1 was released as CD. A mobile app, Sree Poshini, for site specific nutrient management of tropical tuber crops was also developed (Fig. 1).

Besides chemical fertilizers, indiscriminate use of pesticides also imposes harmful effects on environment and human health. Use of botanicals is highly encouraged in this context for the management of insect pest. The cyanogenic glucosides present in the leaves of cassava are used against insect pests of banana and other vegetable crops. ICAR-CTCRI has formulated three bio-formulations namely Nanna, Menma and Shreya from cassava leaves.

**Features of cassava based bio-formulations**

- Nanna is found to be very effective against different types of sucking pests like whiteflies, thrips, aphids etc (7-10 ml/l). The bioformulation was also effective as prophylactic spray against pseudostem weevil in banana.
- Menma is effective against different borer pests and found very promising against pseudostem weevil of banana as stem injection.
- Shreya was very effective for the management of mealybugs.

**Tuber crops technologies for better production**

Climate change is a real phenomenon and its effects are being evidenced in the form of cyclones, drought, heat and cold waves etc. So, monitoring the climate during crop production is much essential and weather based agro-advisory is crucial for protecting the crops from climate adversaries. In this context, an automatic devise called e-crop is developed to simulate the crop growth real-time in the field.

**Features of e-crop device**

- E-crop, an electronic device to simulate crop growth in real time.
- This device collects weather data from the field and generates agro advisory for the crop using the simulation model.
- The generated advisory sent as SMS to the mobile of the concerned farmer.

Water is an important resource for agriculture, scarcity of which affects all forms of life. Agriculture is one of the industries dependent on the supply of water. Under climate change scenario, droughts are becoming common due to abnormal monsoon patterns and prolonged dry spells. Hence, water management has utmost importance in crop production. Tropical tuber crops like cassava and yams are said to be drought tolerant when compared with other cereal, vegetable, legume and oil seed crops, but at the cost of tuber yield. Other tropical tuber crops like taro and elephant foot yam require enough water for sprouting, establishment and optimum yields. ICAR-CTCRI has developed a set of best water management technologies for cultivation of tropical tuber crops (Table 3).
Table 3. Various water management technologies developed

- Developed drip fertigation schedule in cassava raised through minisets.
- Standardized drip fertigation schedule (on alternate days at 80% CPE with fertigation of N-P₂O₅-K₂O@120-60-120 kg/ha in 40 splits [4-day interval]) with higher water and nutrient use efficiency in elephant foot yam.
- Developed water saving techniques in elephant foot yam to reduce the water requirement of elephant foot yam to 50%.
- Standardized drip irrigation schedule and water requirement in upland taro.

Table 4. Impact of organic farming of major tropical tuber crops

<table>
<thead>
<tr>
<th>Crop</th>
<th>Sustainable yield</th>
<th>Higher soil quality index</th>
<th>Higher energy use efficiency</th>
<th>Better net income</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cassava</td>
<td>26.19 t/ha</td>
<td>0.94</td>
<td>+ 72.61%</td>
<td>₹ 286,664/ha</td>
</tr>
<tr>
<td>Elephant foot yam</td>
<td>20% increase in yield</td>
<td>1.93</td>
<td></td>
<td>₹ 215,776/ha</td>
</tr>
<tr>
<td>Yam</td>
<td>9% increase in yield</td>
<td>High organic carbon (14%) and water holding capacity (14.78%)</td>
<td>₹ 498,940/ha for greater yam</td>
<td></td>
</tr>
<tr>
<td>Taro</td>
<td>10.61 t/ha</td>
<td>High organic carbon (39%)</td>
<td></td>
<td>₹ 174,160/ha</td>
</tr>
</tbody>
</table>

Table 5. Various food products prepared from tropical tuber crops

<table>
<thead>
<tr>
<th>Crop</th>
<th>Food Products</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sweet potato</td>
<td>Gluten-free spaghetti, nutriose fortified noodles, high protein starch noodles, spaghetti enriched pasta with various leguminous flours</td>
</tr>
<tr>
<td></td>
<td>Ready-to-use paratha mix, vacuum fried orange/purple fleshed sweet potato chips, ready-to-eat-energy dense nutri bars, sweet potato flour-based gluten free cookies, and extruded products from purple fleshed sweet potato flour</td>
</tr>
<tr>
<td>Cassava</td>
<td>Functional sago with high protein content, functional sago with high calcium content, sago from the reconstituted dry cassava starch, functional sago with high antioxidant potential</td>
</tr>
<tr>
<td></td>
<td>Solid dough technology to prepare papads from cassava, rice analogue from cassava flour</td>
</tr>
<tr>
<td>Other tuber crops</td>
<td>Purple yam flour based anthocyanins-rich pasta, Papad from elephant foot yam flour, ready-to-fry Jimikand short snack foods, Multi-grain functional cookies using Curcuma angustifolia starch, Taro flour based gluten-free cookies and bread, Probiotic enriched lacto pickles from EFY, yam bean and yams</td>
</tr>
<tr>
<td>High value compounds</td>
<td>Microencapsulation of sweet potato and greater yam anthocyanins by spray drying technique was used to develop stable natural colours with extended shelf-life and antioxidant potential</td>
</tr>
<tr>
<td></td>
<td>Gelatin capsules were prepared as nutrient supplement using purified anthocyanins from purple yam tubers, purple sweet potato leaves and tubers</td>
</tr>
</tbody>
</table>
Tuber crops technologies for better life

Organic farming is not only a production technology; it is a way of life. It is an age old farming practice and part of Indian rural life. Under the view of day-by-day gaining importance of organically produced food commodities, ICAR-CTCRI has developed organic production packages for major tropical tuber crops such as cassava, yam, taro, elephant foot yam, arrowroot and Chinese potato (Table 4). Besides, being free from agrochemicals, organically produced products fetch high market price thereby helps farmers to achieve more income.

Small scale value addition and food processing industries in rural and semi-urban areas provide livelihood, employment and attractive income opportunities to the rural youth. A good number of value addition and food processing technologies are developed by ICAR-CTCRI and made available to stakeholders (Table 5; Fig. 2).

A techno-incubation centre was established at ICAR-CTCRI which houses all the machineries required for the preparation of processed products. Trainings are being given to the interested women and youth on the preparation of various food products from tropical tuber crops.

It can be understood that tropical tuber crops are undoubtedly going to play an important role in eliminating malnutrition, overcoming hidden hunger, providing balanced diet, alternate production systems under climate change conditions, sustainable development and providing livelihood and employment to the rural and semi-urban youth. ICAR-Central Tuber Crops Research Institute stands in forefront in achieving these goals by developing and disseminating the technologies related to varieties, production, protection and value addition of tropical tuber crops.

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Kerala 695 017, India.

Availability of high-yielding varieties/hybrids and increased irrigated facilities have resulted in the development of production-intensive cropping systems in several parts of India, and this has catalyzed further agronomic research based on the cropping-system approach. Many changes have also taken place in the crop-production technologies. And this necessitated the revision of the earlier publication brought out in 2002. The revised textbook is in two volumes: First is covering Foodgrains and second is on Commercial Crops.

The discipline of Agronomy has no longer remained mere field trials without application of discoveries emanating from the related disciplines of Genetics, Soil Science and Agricultural Chemistry, Plant Biochemistry, etc. The future Agronomy Landscape will face challenges of climate change, transboundary issues, TRIPS and other trade-related barriers, biotic and abiotic stresses, consequences of biotechnology and genetic engineering and increased market demands in terms of quality assurance, customized food crops, global competition, ecosystem services on land and social equities etc. The Agronomy must measure up to these futuristic challenges with well-defined metrics and methodologies for performance. The advent of hydroponics, precision farming, bio-sensors, fertigation, landscaping, application of ICT, GPS and GIS tools and micro-irrigation is in the horizon. This revised edition in two volumes covers fundamentals of the subject and at the same time will inspire and prepare teachers and students for the emerging frontiers.

For obtaining copies, please contact:
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Ashwagandha: Most of desired COVID-19 immunobooster medicinal plant

Ashwagandha (Withania somnifera (L.) Dunal) belongs to family Solanaceae, and is one of the popular and highly valued medicinal herbs in Ayurveda, classified as a rasayana (rejuvenator) in various Ayurvedic classical texts. Various parts of the plant are used in the preparation of different Ayurvedic formulations and home remedy recipes to increase health and longevity. This herb is always on demand, however, demand has risen further due to its immunoboosting capacity which would be a great therapy for fighting COVID-19 like situation. The word Ashwagandha has been derived from Sanskrit name “Ashwa” meaning horse and “gandha” meaning smell and thus given to this plant due to the smell of the roots resembling a sweating horse. Root is the economic part of this crop. The roots are frequently used for therapeutic purposes and is a constituent of over 200 formulations in Ayurveda, Siddha and Unani medicines. There are several reports to establish its immune-modulatory, anti-inflammatory, anti-stress, memory enhancing, anti-parkinsonian, hypolipidemic, antibacterial, cardiovascular, antioxidant, antitumor and adaptogenic properties. Ashwagandha plants are multiplied through seeds. Some significant work has been carried out by ICAR-DMAPR, Anand on seed germination and crop improvement including developing chemotypes.

Withania species

Ashwagandha belongs to the genus Withania, family Solanaceae. Considering all the medicinal properties, the species of genus ‘Withania’ are also of great medicinal value. The Solanaceae family comprises 84 genera that include about 3,000 species, scattered throughout the world. Members of this family are generally annual shrubs. The genera Withania and Physalis play an important role in the indigenous medicine of South East Asia, e.g. in the Unani and Ayurvedic systems. The 23 known species of genus Withania are widely distributed in the drier parts of tropical and sub-tropical zones, ranging from the Canary Islands, the Mediterranean region and northern Africa to Southwest Asia. Among them, only two species, W. coagulans Dunal and W. somnifera Dunal are found in India and are economically and medicinally significant, as being used in medicine. It is cultivated in several regions of India.

Area and production

India is one of the few countries where almost all the known medicinal plants can be cultivated in one or the other part of the country. India has about 2,000 species of medicinal plants and a vast geographical area with high production potential under the varied agro-climatic conditions.

Withania somnifera (L.) Dunal is known as Winter Cherry or Indian Ginseng in English and Ashwagandha in Hindi by which it is commonly known in India. Ashwagandha is indigenous to the Middle-East Asia and North Africa. It is widely distributed in India, Pakistan, Sri Lanka, South Africa, Iraq, Iran, Syria and Turkey. It is also grown in North America and other temperate climate including dry parts in sub-tropical regions.

Ashwagandha is cultivated over an area of 10,780 ha with a production of 8,429 tonnes in India. Based on the current trend, the demand of Ashwagandha would be around 12,500 tonnes. It is cultivated in many states in India, but Madhya Pradesh, Gujarat, Haryana, Maharashtra, Punjab, Rajasthan and Uttar Pradesh are the major Ashwagandha producing states. In Madhya Pradesh alone it is cultivated in more than 5,000 ha in Manasa, Neemuch and Jawad talukas of Mandasaur district. Neemuch and Mandasaur markets of Madhya Pradesh are popular for Ashwagandha.

Being hardy and drought tolerant species with enormous bio-compounds, the use of Ashwagandha has enjoyed monopoly in many parts of India. The herb has been identified by the National Medicinal Plants Board of India as one of the 32 selected priority medicinal plants, which are in great demand in domestic and international markets. Since the production is lesser than its consumption, there is a need necessitating the increase in its cultivation and higher production.
Medicinal uses

Ayurveda, the traditional system of medicine practised in India can be traced back to 6000 BC (Charak Samhita). Ashwagandha is one of the most important medicinal plants required in allopathic, ayurvedic and unani system of medicines. It is considered to be one of the best rejuvenating agents. Withanine and somniferine are the two important alkaloids of Ashwagandha. The total alkaloid content of its roots has been reported to vary from 0.13 to 0.31%. Its root drug boosts immune system and finds an important place in treatment of rheumatic pain, inflammation of joints, nervous disorders and epilepsy. Dried roots are used as a tonic for hiccup, cold, cough; as a sedative; in care of senile debility; ulcers; etc. It is a drug used as anti-cancer, anti-stress, anti-depressant, in endocrine and cardiovascular activities. It is also used to control Parkinson and Alzheimer. The fresh leaves are applied for the treatment of carbuncles, inflammation and swellings. Leaf juice of Ashwagandha is useful in treating conjunctivitis and bark decoction is taken to control asthma and applied locally to bed sores. Green berries are used for treating ringworm infection, animal sores and horse’s girth galls. Different parts of the plant possess activities such as amoebicide, anodyne, abortifacient, bactercide, contraceptive, diuretic, emmenagogue, fungicide, narcotic, pediculicide, sedative, spasmylytic, adaptogenetic and tonic. Ashwagandha and its extracts are used in preparation of herbal tea and are available in the form of powders, tablets and syrups as herbal tonic. The leaves are bitter and are recommended in fever and painful swellings. The flowers are astringent, deputative, diuretic and aphrodisiac. The seeds are anthelmintic and combined with astringent and rock salt to remove white spots from the cornea. Ashwagandharishta prepared from seed is used in hysteria, anxiety, memory loss, syncope; etc. It also acts as a stimulant and increases the sperm count.

The different formulations involving Ashwagandha available in market are Ashwagandhadi Churna, Ashwagandha Rasayana, Ashwagandha Ghrit, Ashwagandharishta, Ashwagandha Powder, Ashwagandha Capsule.

Botanical description

Ashwagandha is an erect, branching undershrub growing in dry and sub-tropical regions. It grows up to 150-170 cm height. The roots are stout, fleshy and whitish brown. Leaves are dull green; simple, petiolate, elliptic-ovate to broadly ovate, entire, ex-stipulate, opposite and up to 10 cm long, those in the floral region are smaller. Flowers are bisexual, inconspicuous, greenish or lбыrid-yellow, pedicellate, 4-6 mm in diameter, axillary, umbellate cymes occurring in 5-25 clusters. Berries are small, globose, bright orange-red when mature, 5 mm in diameter, enclosed in the persistent calyx and contain numerous seeds. Seeds are small, smooth, yellow, reiform, 2 mm long, 1.5-2.0 mm wide and 0.5 mm thick.

Chemical compositions

The plant roots consist of 0.13 – 0.31% alkaloids, 40-65% starch, and minor quantity of oil. The major chemical constituents in Ashwagandha are:

- **Alkaloids** – Withanine, withananine, somniferine, etc.
- **Steroidal lactones** – Withaferin A, withanolides A-Y, withasomniferin A, withanine, withasomniferols A-C, etc.
- **Saponins** – Additional acyl group - Sitoindoside VII and VIII.
- **Withanolides** – with a glucose at carbon 27 - Sitoindoside IX and X.
- **Withanolide glycosides** – Withanosides I, II, III, IV, V, VI and VII.
- **Pyrazole derivatives** – Pseudo withanine and ashwagandhine.

Apart from these contents, plant also contains chemical constituents like withanisol, acylsteryl glucosiodes, starch, reducing sugar, variety of amino acids and high amount of iron.

Cultivation

In India, cultivation of Ashwagandha is distributed from 23°N -33°N, from 600-1500 m altitudes. The plant grows well in sandy loam or light red soil having pH 7.5-8.0 with good drainage. Black soils or such heavy soils are suitable for cultivation. The semi-arid tropical areas receiving 500-750 mm rainfall are suitable for its cultivation as rain-fed crop. It requires relatively dry season during its growing period. Temperature between 20° and 35°C is most suitable for cultivation. One or two late winter rains are conducive for the proper development of roots.

Ashwagandha is propagated by seeds. The crop can be sown by broadcasting or in lines in well ploughed and pulverized land. Line to line method of sowing is preferred for performing intercultural operations properly. The seeds are usually sown in late kharif about 1-3 cm deep and should be covered with light soil. The distance between plants is 10-15 cm and that in between the row is 30 – 45 cm. Two weeding are required to keep the field free from weeds. The first weeding is done within 25-30 DAS and the second weeding is done after 60 DAS. The crop does not require heavy doses of manures and fertilizers. It responds well to organic manures. Addition of 10 t FYM or 1 vermicompost/ha is recommended. Application of 15 kg of nitrogen and 15 kg of phosphorous per hectare.
Ashwagandha: Ashwagandha is beneficial for higher production. Excessive rainfall or water is harmful for the crop. Life-saving irrigation is given as and when required. Under irrigated conditions, the crop can be irrigated once in 15-20 days to encourage good crop growth and to produce high root yield.

Flowering and bearing of fruits start from December onwards. The crop is ready for harvest in January–March at 150-180 DAS. The maturity of the crop is judged by drying out of leaves and yellow-red berries. There should be moisture in soil at the time of digging of roots. The tap root should be carefully pulled out not damaging even the small lateral roots. The entire plant is uprooted and the roots are separated from the aerial portion by cutting the stem 1-2 cm above the crown. The roots are washed, either cut transversely into 7-10 cm small pieces or dried as such in the sun to 10–12% moisture content. The dried roots are beaten to remove soil and to break off thin, brittle, rootlets. Lateral branches, root crown and stem remains are carefully trimmed with a knife. About 650–800 kg roots can be obtained from 1 ha and on drying it becomes 350-435 kg. Berries are hand plucked separately. They are dried and crushed to take out the seeds. The crop produces 200-500 kg seeds/ha.

Roots of ashwagandha are sorted out into the following grades, as per its length and thickness (Table 1).

Table 1. Ashwagandha root grades

<table>
<thead>
<tr>
<th>Grade</th>
<th>Root properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>A grade</td>
<td>Root pieces up to 7 cm in length, 1-1.5 cm in diameter, solid cylindrical with smooth external surface and pure white from inside.</td>
</tr>
<tr>
<td>B grade</td>
<td>Root pieces up to 5 cm in length, 1 cm or less in diameter, solid, brittle and white from inside.</td>
</tr>
<tr>
<td>C grade</td>
<td>Solid root pieces up to 3-4 cm in length, 1 cm or less in diameter.</td>
</tr>
<tr>
<td>D grade</td>
<td>Small root pieces, semi-solid or hollow, very thin, yellowish inside and less than 1 cm in diameter.</td>
</tr>
</tbody>
</table>

Varieties developed

**Arka Ashwagandha:** Arka Ashwagandha was developed by ICAR-IIHR, Bengaluru in 2012. It is a high yielding variety developed from pure line selection with double the dry root yield (1,195 kg/ha) and total withanolide content (0.580%) compared to check Jawahar Ashwagandh-20 (527 kg/ha and 0.320%). The other significant features of the variety are good establishment, early vigour, field tolerance to bacterial wilt, late blight diseases and pests viz. *Epilachna* beetle, mites and aphids. Variety matures in 180 days and is characterized by pencil thickness roots and desired root depth of around 30 cm. The variety Arka Ashwagandha is also recommended for release in Zone 6 and 7 by AICRP on MAP and Betelvine. This variety is licensed to the pharmaceutical company Natural Remedies Pvt. Ltd, Bengaluru.

**Jawahar Asgand-134:** Jawahar Ashwagandha-134 was developed and released through ICAR-AICRP on medicinal and aromatic plants (ICAR-AICRPMAP) from the College of Horticulture, Mandsaur, JNKVV, Jabalpur, Madhya Pradesh, in 1998. It is a selection from JA-20 and wild types of Ashwagandha. JA-134 is erect, tall and leaf are chordates, dark green colour, surface is hairy, berries are yellow or yellowish brown. It takes about 150-175 days for maturity and average dry root yield is about 4 to 6 q/ha.

**Jawahar Asgand-20:** Jawahar Ashgand-20 (JA-20) has been developed and released through ICAR-AICRP on Medicinal and Aromatic Plants (ICAR-AICRPMAP) from the College of Horticulture, Mandsaur, JNKVV, Jabalpur, Madhya Pradesh in 1989. It is a pure line selection. JA-20 is a spreading type, medium and leaves are ovate yellow green, surface non-hairy, berries colour are yellow. It takes about 135-150 days for maturity and average dry root yield is about 6 to 7 q/ha.

**Gujarat Anand Ashwagandha-1:** This variety was released by All India Coordinated Research Project on Medicinal and Aromatic Plants, Anand Agricultural University centre. It is resistant to *Alternaria* leaf blight. The root cortex is white and thick. The calyx is bigger. The variety is tall and has dark green foliage colour. The branches possess profusely stellate tomentose. The roots are dark brown and comparatively thick, long and having more girth. Average yield is 650 kg/ha.

**NMITLI-118:** The variety NMITLI-118 was developed jointly by CSIR-CIMAP and NBRI and was released in September 2009. The variety has uniform crop canopy, non-spreading plant architecture (more plant/unit area), high root yield and high withanolide yield per unit biomass, and phytochemically uniform and is the first pharmacologically validated variety. It has withanolide A and withanone in roots and high content of withaferin A (up to 2%) and no withanone in leaves. The variety is reported to give dry root yield of about 15 q/ha.

**Poshita:** The variety Poshita of Ashwagandha developed by CSIR-CIMAP has the potential of producing dry root yield of 14 q/ha with total alkaloids and withanolide content (steroidal lactones) which are the major group of secondary metabolites of medicinal interest containing 1.292 and 3.469 kg/ha, respectively. The fresh and dry leaf yields are also high up to 2.83 and 0.50 q/ha with high withaferin content in dry leave 0.528%.
Rakshita: This variety was developed by CSIR-CIMAP. It was selection from wild. The berry colour is red and total alkaloid content: 0.5%. It takes about 180-200 days for maturity. The total yield of root is 800-1000 kg/ha.

Vallabh Ashwagandha: Vallabh Ashwagandha was recommended for release in 2017 through ICAR-AICRP MAP for cultivation in all Ashwagandha growing areas of the country. The variety has 589.4 kg/ha dry root yield which is significantly higher than JA-20, JA-134 and RVA100. Higher root yield with marker character orange coloured berries are its special characters for easy identification.

Contributions of ICAR-AICRP-MAP&B
All India Co-ordinated Research Project on Medicinal and Aromatic Plants & Betelvine (AICRP-MAP&B) is an important research program of ICAR for location specific research. There are 26 centres under AICRP-MAP&B working on more than 40 species. The research on Ashwagandha is being taken up in Mandsaur, Anand, Udaipur and Raipur centres and supported by other centres for MLT experiments. A total of 390 accessions of Ashwagandha are being maintained at ICAR-DMAPR, Anand and 658 at its different AICRP centres.

Seed germination
Seed germination is erratic at times in Ashwagandha. Under laboratory condition carried out at ICAR-DMAPR, Anand, a temperature of 25°C recorded the mean lowest days of germination initiation in 4.8 days and complete germination was achievable in 10.2 days with mean germination time (MGT) of 8.10 followed by 5.5 days, 11.3 days and MGT of 8.51 at 30°C and 5.8 days and 12.4 days with MGT of 9.35 at 20°C in genotypes WS-134 and WS-20. Maximum mean germination of 83.8% was at 25°C followed by 75.5 at 30°C and minimum at 62.2% at 20°C in genotype WS-134. When individual treatment was considered, seeds treated with gibberellic acid (GA) gave the maximum germination (85-94%) with minimum days for onset of germination and completion of germination with minimum MGT as compared to 40-58% germination in control in WS-134 and 38-51% in WS-20. Genotype WS-134 performed better than WS-20. It could be concluded that under controlled condition seeds treated with GA, would definitely give enhanced germination at a given temperature as compared to a very negligible germination of 40-58%.

Cost of cultivation and economic viability analysis
An example was illustrated by NMPB, Ministry of AYUSH (Kumawat et al. 2020, Medicinal Plants 12(2):161-168) wherein a broad spectrum of cultivation cost of Ashwagandha is given. It clearly shows that farmers incurred on an average, a total cost of ₹112,282/ha. Cost on material inputs was ₹28,637 i.e. 25.5% of the total cost while human labour investment was around 74.5% (₹83,645). The hired labour cost was ₹63,975/ha and ₹19,670/ha in respect of cost of involvement of family members.

Market
Neemuch market in Madhya Pradesh is the biggest ashwagandha market in India. Other markets include Shivpuri in Madhya Pradesh, Amritsar in Punjab, Kolakata and Siliguri in West Bengal, Mumbai in Maharashtra, Dhamtari in Chhattisgarh, Jaipur in Rajasthan and Berhampur in Odisha. The price of root varied from ₹170-350/kg depending upon the quality of the root. The fibrous roots are priced low as compared to the roots with higher starch content. Quality seeds of few recently developed varieties could be made available on indent basis and on priority from ICAR-DMAPR, Anand, Gujarat. Training on ashwagandha cultivation is imparted by the same institute.

The available scientific data support that Ashwagandha is a real potent regenerative tonic (Rasayana of Ayurveda), due to its multiple pharmacological actions like anti-stress, neuroprotective, antitumor, anti-arthritis, analgesic and anti-inflammatory, etc. It is useful for different types of diseases like Parkinson, dementia, memory loss, stress induced diseases, malignoma and others. Ashwagandha is used as a household remedy by Indians, who consider it as the best tonic for old people and children, and as aphrodisiac by young people. It is one of the best nervine tonics of Ayurveda, the most ancient system of Medical Sciences. However, large scale studies are needed to prove its clinical efficacy in stress related disorders, neuronal disorders and cancers. It has been widely accepted due to its medicinal and commercial importance with further acceptability in post Covid-19 situation as it boosts immune system.

For further interaction, please write to:
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Cultivated *Passiflora* sp. in North East region of India

North East region of India is full of wide range of climatic and edaphological condition, and genetic diversity of passion fruits (*Passiflora* spp). The different genotypes are found in Manipur, Mizoram, Meghalaya, Arunachal Pradesh, Sikkim, Nagaland of North East region. Generally it is due to the upland and low land hill conditions, that the yellow, purple and mixed type of passion fruit are found. Purple passion (*Passiflora edulis* Sims) fruit favourably grown at high altitude (>2,000 m), and Yellow or Golden passion fruit (*Passiflora f. flavicarpa* Deg.) at low land, mostly under tropical climate. In some parts of North East, giant granadilla (*Passiflora quadrangularis*) is found which is mostly used for vegetable purpose but more delicious after ripened. Different genotypes under all these species directly help uplift the economy of rural people of these regions.

**Passiflora** comes from Latin word ‘Passio’ meaning ‘suffering’; ‘floris’ meaning ‘flower’, hence the name ‘passion flower’, that was first time discovered by Spanish discoverers in 1529 and was described as a symbol for ‘Passion of Christ’. Passion fruit (*Passiflora* L.), belonging to family Passifloraceae, is a native of Brazil. In family Passifloraceae, >576 species of *Passiflora* L. are present, and *Passiflora quadrangularis* is most important. Passion fruits are herbaceous or woody vines usually climbing with tendrils, but a few are trees or shrubs. Their wide morphological variation seems to be the result of their habitat diversity as well as their co-evolutionary relationships with many organisms, including a wide range of pollinators as small and large insects, birds, and bats. Passion fruits have total cultivated area of about 0.014 million ha with production of 0.082 million tonnes during 2018. The passion fruit is a highly acidic food (pH~3.2) due to the predominance of citric and malic acid. It is also rich in minerals like K, P, Ca, Fe, Na, Mg, S, Cl and protein.

**Uses**

The leaf of passion fruit is used as a vegetable in the hills of North Eastern India. Boiled extract of fresh tender leaves is prescribed as a remedy for diabetes, diarrhoea, gastritis, abdominal flatulence and as a liver tonic. The rinds of passion fruit have very low pectin content (2.4%). In addition, it has potential for extraction of secondary metabolites (as total phenols which have therapeutic effects like immunomodulation, anticarcinogenic, and antioxidant properties. The extract of fresh leaves of *Passiflora edulis* is consumed for the treatment against dysentery and hypertension in Nagaland. The rind residue contains about 5-6% protein and could be used as filler in poultry and stock feed. The seeds yield 23% oil, which is similar to sunflower and soybean oil, and accordingly has edible as well as industrial uses. There is currently a revival of interest in the pharmaceutical industry, especially in Europe, in the use of glycoside, passiflorine, as a sedative or tranquilizer. Italian chemists extracted passiflorine from the air-dried leaves. The fruit provides a good source of nutrients such as vitamin A, B2 and C and non-nutritive phytochemicals, carotenoids and polyphenols. Juice of passion fruit is prescribed as a digestive stimulant and in treatment for gastric cancer.

**Fruit and flower morphology**
Different species in North East regions

Giant granadilla (*Passiflora quadrangularis* L.)

Very large fruit of 20 to 23 cm length, green–yellow skin, oblong shape, is a warm wet tropical lowland environmental adaptation. Giant granadilla is mostly found in Mizoram, Nagaland, Manipur and Arunachal Pradesh. The distribution of HCN (cyanogenic glucosides) in the leaves, stems, tendrils, floral parts, roots are reported up to 138 ppm. The greenish-yellow fruits of *P. quadrangularis* resemble as melons and are the largest in the genus. Fruit flesh is very thick and number of seeds are about 164 per fruits.

Purple passion (*Passiflora edulis* Sims)

Purple passion fruit showed high level of protein, fat and ascorbic acid than the giant granadilla and yellow type. It requires higher elevation (about 2000 m) for proper flowering and fruiting. Temperature below 15°C restrict the vegetative growth and flowering. Fruits are 4-5 cm in diameter, deep purple when ripe each weighing 35-45 g. The juice content varies from 31-35%. The protein and vitamin C content is about 9.4% and 24-30 mg/100 g respectively.

The three main carotenoids in purple passion fruit are carotene, β-carotene and phytofluene. In addition to presence of β-apo-12'-carotenal, β-apo-8' carotenal; cryptoxanthin, auroxanthin and mutatoxanthin are also reported.

Fruit and flower morphology

Yellow or golden passion fruit (*Passiflora f. flavicarpa* Deg)

Yellow type of passion fruit are found at lower elevation and mostly found in foothills of Manipur, Mizoram, Arunachal Pradesh and Nagaland. It is relatively rich in phosphorus, iron, sodium, potassium and vitamin A. Citric acid was the predominant acid in yellow passion fruit (6.6 mg/g). Fruits are larger than purple type.

Local or mix type

Pasighat local red fruit have different morphotype as compared to purple, yellow and giant granadilla. The pulp surface is mix with yellow colour with purple spot on the body.

To increase the shelf-life and market value of the passion fruit, use of shrink wrapping helps, leading directly to upliftment of the economy of rural people of North East Region of India. The post-harvest life of passion fruits can be effectively increased by polyolefin film packaging which helps to maintain the quality of fruits under good condition, reducing the percentage loss of fresh matter content and shrinkage of rind portion. Overwrapping freshly harvested fruits and vegetables by using highly permeable films like HDPE, LDPE, polyvinyl chloride (PVC), etc. helps to maintain the post-harvest quality and extends the shelf-life by minimising transpiration and respiration. The shelf life of purple passion fruit was up to 22 days with attractive colour, appearance and quality when packed in 25 μ thickness of polyolefin film.

Value addition

Squash and nectar

**Beverages:** Passion fruit squash is a delicious drink having excellent nutritive properties. It is a popular after-dinner drink in the warm summer. According to the Indian standards, the minimum sugar concentrations prescribed for cordial, squash, crush and syrup are 30, 40, 55 and 60%, respectively, with a minimum juice content of 25% in each product. They are usually preserved with 220-350 ppm of SO₂ or 600-700 ppm of benzoic acid and are diluted 1:3 to 1:5 with water before consumption.

Wine from passion fruit and Mandarin orange blended juice: Wine from passion fruit and orange juice are recently in demand. Wine is prepared by blending 10%
passion fruit juice in orange juice and inoculated by 5% *Saccharomyces cerevisiae* adjusting TSS 24°Brix with sucrose and acidity 0.7%. The cost of production of 1 litre wine is ₹82. The costs are for laboratory (small) scale preparation of wine. These may still be reduced during mechanization of the process for mass production.

**Conclusion**

This study provides an overview of a variety of genetically different individuals that could be commercialized in Pasighat, Arunachal Pradesh and used in future breeding programs. Cultivation of passion fruit is a technically feasible, financially viable and bankable activity. Population studies of *Passiflora* species are highly relevant to conservation and breeding activities. The therapeutic efficacy of the genus *Passiflora*, extensively used in Indian System of Medicine, has been established through modern testing and evaluation (pre-clinical and clinical trials) in different disease conditions.

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**Book Review**

**Current Horticulture: Improvement, Production, Plant Health Management and Value-Addition**

Singh Balraj, Singh A.K., Tomar B.S. and Dutt Som (Eds).

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In our country, fruit, vegetable, flower medicinal and plantation crops provide food, nutritional, health, economic and environmental security to the people. A number of books and manuals on horticultural crops have been brought by scientists and working groups. The book *Current Horticulture: Improvement, Production, Plant Health Management and Value-Addition*, in two volumes, is a compilation of the latest scientific information to be followed for furtherance of horticultural science and will serve as an encyclopedia for all stakeholders.

Both volumes consisting 38 chapters each, authors have attempted to compile the advances in horticultural science especially on advances in crop improvement, production technology, biotic and abiotic stress and post-harvest management in general and prospects, challenges and future thrust of horticultural crops in particular which have been contributed by experts and eminent horticulturist in the area of specialization.

Major issues and concepts and how to mitigate the changing climatic scenario have been elaborated perfectly and comprehensively in easy-to-understand language. Overall the chapters are nicely written which will be of immense use to the researchers, growers, industrialists, policymakers, students, etc. Thus, the wealth of information documented in these books will serve as a reservoir for exploitation of useful information on various horticultural aspects. Keeping in view the various issues related to horticultural crops, such books are the need of hour to enrich the knowledge of workers in the field of research and development as well as growers and horticultural entrepreneurs of the country.

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Bio-immunization to combat Banana Fusarium wilt tropical race 4

In vitro Bio-immunization technology is a novel tissue culture technology for production of Fusarium wilt disease tolerant plants of banana. The process includes engineering the biomolecule into the banana tissue culture plantlets during in vitro organogenesis phase. Field studies conducted in the hot spot regions of Fusarium wilt at Ayodhya district in Uttar Pradesh and Kattihar district of Bihar revealed that Bio-immunized plantlets were able to sustain the disease incidence to about 98% for a period of 9 months after planting and 85% till harvest.

BANANA is one of the major important and commercial fruit crops of India known for being in cultivation for ages. Maharashtra, Karnataka, Tamil Nadu, Andhra Pradesh, Odisha, Gujarat, and parts of the North East occupy the prime position in banana cultivation. Recently, banana cultivation has been expanding significantly in Uttar Pradesh and Bihar covering about 69,380 ha and 31,070 ha, respectively. In the recent past, the cultivation of commercial cultivar G9 of banana is being threatened by the outbreak of a virulent strain of Fusarium wilt tropical race 4. Fusarium wilt caused by Fusarium oxysporum f. sp. cubense Tropical Race 4 (FOC TR4) is considered to be one of the most devastating complex diseases of banana, limiting its production worldwide. The pathogen is known for its rapid proliferation and devastation of the plantation within a short period causing a huge economic loss to growers. Control of the disease has been a great challenge to researchers across the globe till date.

An outbreak of FOC TR4 has been reported in seven districts of Uttar Pradesh and five districts of Bihar in 2018. The disease nearly affected 8,474 ha in Uttar Pradesh and more than 3,000 ha in Bihar. Farmers effort for mitigating this disease went to vain and around 30% crop was lost resulting in distress. Management of FOC TR4 is a matter of serious concern as the ability of FOC TR4 to survive in the absence of a host has been a significant factor limiting the success of the management practices like crop rotation, use of chemical fungicides. Selection of resistant cultivars seems to be an effective control strategy against the disease, however, considering the rapid spread of the disease and the dependence of the small and marginal farmers on the crop for economic sustenance prompted to exploit the resources for intensively testing the bio-control antagonists. In an attempt towards successful management, ICAR FUSICONT, a bio-fungicide using antagonistic Trichoderma reesei isolate was found effective in managing the disease to about 85%. However, the complex polycyclic nature of the pathogen and its ability to mutate into different Vertical Compatability Groups (VCG’s) warranted the need for supportive technologies to build resistance in the host.

Bio-Immunization

Sustenance of the biological control measures over the long period depends on the supplemental multiple
approaches to induce the tolerance in the host. One such effort resulted in the development of a lipo-polypeptide-based biomolecule “BIO-IMMUNE” and the in vitro Bio-immunization technology, the process of engineering the biomolecule into the banana tissue culture plantlets during in vitro organogenesis. The biomolecule and the process have been patented jointly by ICAR-Central Soil Salinity Research Institute and ICAR-Central Institute for Sub-tropical Horticulture. The current technology is completely different from the bio-priming or bio-hardening process where bacterial and fungal antagonist/ endophytes are being treated to the tissue culture banana plantlets in primary and secondary hardening phases of mass multiplication under polyhouse.

Advantages of the Bio-Immunization

- The lipo-polypeptide-based bio-molecule has been found to possess antifungal properties that induce the tolerance for biotic and abiotic stress in the tissue culture plantlets.
- Significant increase in the shoot and root biomass and reduction in the duration of the shoot and root culture as compared to the normal media used in business as usual was observed.
- The bio-immunized plantlets were found to exhibit more than 90% of field efficacy against the pathogenic strain of Banana Fusarium wilt TR-4 treated plantlets.

Field validation and impact of the Bio-immunized banana plantlets

Field studies conducted in the hot spot regions of Fusarium wilt at Ayodhya district in Uttar Pradesh and Kattihar district of Bihar revealed that Bio-immunized plantlets were able to sustain the disease incidence to about 98% for a period of 9 months after planting and 85% till harvest. Treatments involving two times drenching of 3% ICAR FUSICONT at 5th and 10th month after planting of bio-immunized plantlets showed 92 to 96% disease tolerance against the invasion of FOC TR4 suggesting the synergistic role in the management of the disease.

The technology of bio-immunization was demonstrated in 20 farmer’s fields with the immediate history of the FOC TR4 incidence to 30 to 50%. About 22,500 bio-immunized tissue culture banana plantlets were tested in two hot spot locations (Magalsi village in Ayodhya district and Dighri village in Kattihar district) during 2020-21. Simultaneously, 20 non-adopters were identified whose fields had a similar history of disease incidence ranging from 20-30%. The adopter’s fields were planted with Bio-immunized plantlets while the non-adopters used tissue culture plantlets obtained from private tissue culture firm that was not subjected to in vitro immunization. The adopters were also intervened with 2-time drenching of ICAR FUSICONT at 5th and 10th month after planting while non-adopters followed all standard practices and control measures using Carbendazim 0.5% drenching at 3rd, 6th, 10th month after planting. The disease incidence percentage of the adopters was significantly low (2.77%) compared to the non-adopters (31.58%). The adopters also registered higher average yield per plant and high average net income (₹ 188,997) as compared to the non-adopters whose income was reduced due to the high disease incidence.

Sh. Akilesh Yadav of Kattihar district in Bihar who abandoned the banana cultivation because of continuous loss incurred due to the disease, adopted the technology with complete specification in the ray of hope of bringing his land to disease-free banana cultivation, harvested 2,490 plants successfully among the 2,500 plants planted and earned a net income of ₹ 252,660 due to use of bio-immunized plantlets and two-time application of ICAR FUSICONT. Many banana growers from Kattihar, Purnia of Bihar, and Ayodhya district of Uttar Pradesh have adopted the technology in large numbers during the current season 2021-22. Based on the success of the technology, the state government of Bihar has granted a full subsidy to the farmers of Bihar for the use of Bio-immunized plants. Bio-immunized tissue culture technology is a ray of hope for banana growers. The technology has saved livelihood of scores of farmers of Uttar Pradesh and Bihar.

For further interaction, please write to:
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Role of cooperatives in Indian Horticulture sector

The cooperatives played an important role in horticulture sector by providing marketing and distribution network along with credit and inputs to the farmers, which supplemented the efforts of the state and private sector. The brand image along with community guidelines of these co-operatives helps the farmer in procurement, price/value fixation, limiting the post-harvest losses, mental and social support; as well stability in the market as well as in profession. The National Cooperative Development Corporation (NCDC) is major organization in the country which is meant for promoting, developing and financing post-harvest activities through cooperatives in agriculture and allied sectors. A new ministry with the name of Ministry of Cooperation under the Government of India has recently formed (July 2021) to provide a separate administrative, legal and policy framework for strengthening the cooperative movement in the country. The cooperative scenario is developing in the country with the efforts of growers and the government due to the realization of its enormous potential for socio-economic upliftment of its member and overall community.

Prospects

INDIA is an agrarian economy where more than 55% of the total workforce is engaged in agriculture and its allied sector based enterprises alongside farming. Agriculture is the only sector which has contributed positively to overall Gross Value Added (GVA) in 2nd advance estimate of 2020-21. The share of agriculture in Gross Domestic Product (GDP) is 19.9% in 2020-21, which was 17.8% in 2019-20. This is an encouraging sign after 2003-04, where share of agriculture in GDP reached 20%. This sector has played a vital role in protecting the Indian economy from COVID-19 outbreak in 2020-21 by adding 3.4% incremental share in GDP. On the same line, horticultural crops also gave a boost to the economy by producing 326.58 million tonnes fruits/vegetables in 2020-21, which is an increase of about 5.81 million tonnes (1.81% increment) over 2019-20. This sector contributes 34.04% of the agriculture GDP by producing fruits, vegetables, plantation crops, spices, ornamental plants, and medicinal and aromatic plants.

Growing trends of the horticulture sector promoted agricultural growth in recent past, which played a crucial role in economic and sustainable development by providing employment in primary, secondary and tertiary sector of the economy. It is a matter of great pride that India is the second largest producer of fruits and vegetables after China with first position in the banana, okra, lemon, mango and papaya. The export growth of fresh fruits and vegetables is 14% and of processed fruit and vegetables is 16.27% in term of value. It was realized by the experts that the formation of cooperative societies for the farmers who are engaged in the cultivation of horticultural crops is essential to assure them for better price of their products. Though, the cooperative sector in India is the citadel for the agricultural development.

Cooperatives are socio-economic organizations which are meant to community services and non-profit motive only to support the poor sections of societies. This sector is working on the basic principle of each for all and all for each which is its inherent strength. AMUL is the well-known example of the white revolution’s success through dairy cooperative. MAHAGRAPES (a co-operative partnership firm and well-established brand in international market) is also famous in Maharashtra state for export of grapes with its 16 Grape Grower Cooperative Societies, to fulfill its objective to boost up the export of grapes.

The Indian cooperative movement is the world's largest cooperative system with more than 8 lakh cooperatives with remarkable success and improvement of socio-economic status of resource poor section of the society. At grass-root level, the cooperative sector is bridging the urban-rural divide and creating
opportunities for income and employment generation. The top leadership of the country has also realized that the cooperatives have the potential to revive agriculture and make it sustainable. Keeping in the view of doubling farmers’ income by 2022, cooperatives can play critical role in educating, training the farmer to reduce the cost of cultivation and increased income.

Why cooperatives?
The big institutions like Indian Farmers Fertilizer Cooperative Limited (IFFCO), Krishak Bharati Cooperative Limited (KRIBHCO), Anand Milk Union Limited (AMUL), etc. are the best example of the success stories in cooperative sector. As per the cooperative structure in India, a good amount of cooperatives at the state level, like urban cooperative banks, primary agriculture cooperative societies at the village level, fishery and other forms of cooperatives are making unwavering efforts to improve the status of the people in the rural as well as urban areas. It encourages the women’s participation which will further give a boost to economic activities in rural areas. Therefore, we need to vitalize cooperatives by which it can work for the well-being of the farmers and give them financial support at the time they need it at most on affordable rate of interest/prices. Cooperatives have enormous potential of solving the problem of prevailed unemployment by skillling them in horticulture particularly in the field of post-harvest. Cooperative are not to be aimed to eliminate commission agents but to control the ecosystem activities through laying down community guidelines by its activities and also offering an alternative channel of sale to cultivators. Co-operatives also have a strong element of trust within the organization which is one of the highest social value needed to run an organization successfully as reported widely in the literature. Therefore, it can be stated that co-operative marketing must to be strengthened and encouraged to play a greater role.

A new ministry with the name of Ministry of Co-operation under the Government of India has recently formed (July 2021) to provide a separate administrative, legal and policy framework for strengthening the cooperative movement in the country. The vision statement of this ministry is ‘Sahkar se Samriddhi’ (Prosperity from cooperation). This ministry works in strengthening the co-operatives at the grassroot level working to streamline processes for ease of doing businesses for co-operatives and enabling the development of Multi-State Co-operatives (MSCS).

Cooperatives and Horticulture
With the launch of Golden Revolution in horticultural production, the productivity of horticultural crops has increased significantly. A new programme that is Mission for Integrated Development of Horticulture (MIDH) is a centrally sponsored scheme for robust and sustainable growth and development of horticulture sector in a holistic way. In MIDH, Government of India contributes 60% of the total outlay in all states except North East and Himalayan state (contribute 90%). It includes major five scheme, i.e. National Horticulture Mission (NHM), Horticulture Mission for North East and Himalayan States (HMNEH), National Horticulture Board (NHB), Coconut Development Board (CDB) and Central Institute of Horticulture (CIH). It was anticipated that the cooperative movement would largely be focused in the field of agriculture and playing a significant role across the various operations like production, marketing and distribution.

Farm sector experts notified that cooperatives

The objective of the NCDC Scheme is to provide the benefit of value addition to the cultivators in respect of their horticultural produce through agro-processing in an efficient manner, which in turn may contribute in increment in the income of the farmers. NCDC has released 61.09 crore for 80 fruit and vegetable processing units, as on 31.03.2020 (cumulatively). NCDC has promoted cooperatives involved in processing of Foodgrains, Oilseeds, and Plantation Crops by providing financial support through respective State Governments, as well as directly to the processing societies, to meet the needs of these cooperatives.

NCDC provides financial assistance for setting up of fruit and vegetable processing units to these cooperatives. NCDC is assisting and strengthening the cooperative marketing structure under marketing and input scheme with the objective of ensuring facilitative and remunerative prices to the growers of horticultural commodities and minimizing the price spread between the producer and the consumer. Marketing cooperatives provide very good quality of agriculture inputs at the gate of producers and enable them to have access to agricultural produce and inputs at lowest prices. These cooperatives exert a healthy influence on market prices and thus protect from distress sale.

NCDC has implemented centrally sponsored scheme i.e. Mission for Integrated Development of Horticulture (MIDH) with collaboration of the Department of Agriculture, Co-operation and Farmers’ Welfare (DAC&FW). In this scheme, credit linked back-ended subsidy @ 35% of project cost in general areas and @ 50% of project cost in Hilly, North East and Himalayan Areas, is provided under MIDH/NHB/NHM schemes for establishment of integrated pack house, pre-cooling units, cold room, mobile pre-cooling unit, ripening chambers and refrigerated transport vehicle. However, higher subsidy is available for some small components, like small pack house with size of 9 m*6 m, evaporative/low energy cool chamber (8 MT), preservation unit (low cost), low cost onion storage structure (25 MT) and Pusa Zero energy cool chamber (100 kg) and in their cases 50% of the total cost is provided as subsidy.
have impacted positively to the horticulture through post-harvest processing, storage, transportation, trade, and input procurement for a range of activities in the horticulture sector. A study conducted by National Council of Applied Economic Research (NCAER) with special reference to the role and importance of National Cooperative Development Corporation (NCDC) and found that marginal and small farmers sell their produce to local village trader at substantial lower price due to lack of adequate storage facilities for their produce especially fruits and vegetables (low shelf-life).

Horticulture and plantation crops are both perishable (e.g. fruits, vegetables, ornamentals, mushrooms, tea, etc.) and non-perishable (e.g. spices, cashew nut, etc.) in nature which alone contributes to a heavy loss in the quantity and quality, and making the investments risk oriented. According to the Swaminathan Committee (1985), post-harvest handling accounts for 20 to 40% of the losses at different stages of grading, packing, storage, transport and finally marketing of both fresh and processed products. As per the study conducted by Central Institute of Post-Harvest Engineering and Technology (CIPHET), Ludhiana on harvest and post-harvest losses (including losses during storage for fruits and vegetables) had revealed that the range of these losses is 5% to 16%, where cooperatives can play a major role. The establishment of Cold Chain units is the need of hour; which already gave proven results in dairy sector. Cooperatives also helped in the construction and operation of cold chain which is mostly meant for storage of fruits and vegetables. NCDC provides financial assistance to primary, district and state level cooperatives, either directly or through respective State Governments. Most of the programme of Government of India for development of cold chain projects are credit linked back ended subsidy schemes. The role of NCDC is to provide loan assistance at the reasonable rate of interest for creation of cold chain structure and dovetail the same with the grant-in-aid assistance from the Government of India.

Marketing of horticultural produce is a major constraint in the production and distribution system. A subsistence amount of horticultural product is dealing by cooperative marketing societies.

Various government and non-government organizations are handling with trading and processing of horticulture produce in the country, viz. HOPCOM (Horticultural Producers’ Cooperative Marketing and Processing Society), DHOPGCOMS (The Dakshina Kannada District Horticulture Produce Growers Cooperative Marketing Society Ltd.), FRESH (The Farmers’ Rural Extension Service in Horticulture Marketing Cooperative Limited), Cooperative Fruit (Banana) Sale Societies Jalgaon. HOPCOM, Bengaluru (Karnataka) is a successful cooperative organization for marketing of horticulture produce. The society is operating in the districts of Bengaluru (Urban and Rural), Kolar, Tumkur, Mandya, Shimoga, Dakshina Kannada and Mysore. The main objective of the society is to procure fruits and vegetables from the member growers and supply to consumers through its own retail outlets. There are 405 retail outlets. HOPCOM is handling approximately 44,000 metric tonnes of fruits and vegetables with turnover of ₹400 billion per annum. So, it is thrust area to develop such type of societies to enhance farmer’s income through horticulture.

Government of India under Central Sector Integrated Scheme on Agriculture Cooperation (CSISAC) provides subsidy for development of Cooperatives through NCDC and provide assistance to Cooperatives for Education and Training through National Council for Cooperative Training (NCCT) and National Cooperative Union of India (NCUI). Sahakar Mitra scheme of NCDC for training of youth. NCDC along with others organized the first ever India International Cooperatives Trade fair on 11-13 October, 2019 at Pragati Maidan, New Delhi. The fair provided a platform to Indian Cooperatives to interact with international cooperatives and business houses.

Challenges

Despite of the fact of the motto ‘one for all, all for one’, in many cases, co-operatives did not do wonders in many cases. There were plenty of challenges that have been faced during the replication of the model from one state to another. In case of dairy co-operatives, AMUL model has been tried to be replicated in other states of the country. Uttar Pradesh and Rajasthan are the major milk producers having total milk production more than Gujarat. Still the co-operatives are not as successful in these states as in Gujarat. Many studies have been conducted to indentify the reasons. The researchers majorly found the difference in structure of operation and decision making power. Apart from this, the payment cycles to farmers, veterinary provisions and feed supply to dairy farmers were other big reasons because of which the Amul model did not do well in other states. These challenges could be overcome, if proper attention is paid to the quick decision-making and trust building.

Conclusion

In fact, the all India Rural Credit Survey Committee, way back in 1954 itself, has said ‘the cooperation has failed but cooperation must succeed’. This statement has assumed much more perspective and significance in present context especially with respect to marketing of fruits and vegetables. India’s presence in the world market has been increasing continuously and we have to further strengthen it as the total production of horticulture exceeds the production of food grains in our country. In general, where fruits and vegetable cooperating marketing societies are functioning well, the producers are benefited by marketing (marketing of input and produce both) through these societies. It is evident from various cooperative societies in Gujarat, Karnataka and Maharashtra, could get higher prices selling though cooperative societies compared to other agencies. Horticulture has emerged as an excellent source of income acceleration, employment generation, poverty alleviation and export promotion and ultimately nutritional security too.
Future thrusts

Keeping in view the growth and importance of horticulture sector, there is an immediate need of establishment and strengthen the cooperatives at national level (inclusive) for input, output and post-harvest support with increased quality awareness, adoption of adequate technology with ensured financial and infrastructural support. NCDC is an apex organization in cooperative sector in India, which need to be strengthen according to changing scenario of horticulture sector or increased production and demand of fruits, vegetables, mushrooms. During financial year 2019-20, NCDC has disbursed only 1963.35 crore rupees (7% of total disbursement) for agro processing which includes sugar, textiles, oilseed, food grains, fruits and vegetables. NCDC has been assisting Coir Cooperatives for strengthening of margin money assistance, development of processing facilities, construction of storage structures and showrooms and purchase of transport vehicles by Apex or Regional level coir cooperatives. It facilitates timely agricultural operations thereby enhancing crop productivity. It is suggested that a strong forward and backward linkage must be provided to horticulture growers through cooperatives.

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(To be attached with all articles by authors)

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Article entitled

Author(s)

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Signature and address of the Head of the Organization
Role of non-government organisations in horticultural development in India

Importance of horticulture

Horticulture is an important component of agriculture and a significant constituent of a healthy diet with minerals, vitamins, antioxidants and phytochemicals having medicinal values. It covers high value crops like vegetables, fruits, spices, aromatics, medicinal herbs, flowers and ornamental foliage, with wide opportunities for value addition and employment all-round the year. Horticulture provides raw materials for many industries such as food processing, pharmaceuticals and aromatics, apart from highly potential ornamental plant and seed production opportunities, across the country. Fruits and vegetables are delicious and essential for combating malnutrition, particularly in children.

Horticulture in India started receiving importance in the late 1980s, when the country attained self-sufficiency in food production and the priority was shifted to production of oilseeds, fruits and vegetables. With the economic reforms in the early 1990s and significant rise in the income of the lower, middle and upper-middle income groups, the demand for horticultural produce started increasing progressively and fruit and vegetable cultivation started becoming attractive. In 1980-81, horticultural crops occupied an area of 7.0 million ha, of which 4.9 million ha were under fruits and vegetable crops while 2.1 million ha were under condiments and spices, covering only 4.5% of the total cropping area. After 25 years, in 2005-2006, the total area under horticulture had increased to 12.4 million ha (9.3 million ha under fruits and vegetables and 3.1 million ha under spices), with an average annual growth of 3.12%, representing 6.5% of the total area (Ramesh et al. 2008). The driving force for this shift was the increase in returns which rose from ₹ 70,000 in 1980-81 to ₹ 95,400 per ha in 2005-06 while the net income of cereals increased from ₹ 7,800 to ₹ 13,400 during the same period.

Present scenario

The total horticultural output which was 167 million tonnes in 2004-05, maintained a steady annual growth of 2.7% to reach 329.86 million tonnes (102.76 million tonnes of fruits and 196.27 million tonnes of vegetables) in 2020-21, covering an area of 27.23 million ha. The production of plantation crops was 16.60 million tonnes and that of spices was 10.54 million tonnes during the year. Table 1 presents the area under different fruit crops and the total production in India in 2000-01 and 2020-21. Mango continued to occupy the largest area of 2.315 million ha followed by citrus and banana. It may be observed from the table that the highest increase in production over the last two decades was recorded in papaya (710%), followed by grapes (476%), banana (433%), pomegranate (413% in 10 years) and guava (401%), while many other fruit crops registered a growth of 200-250%. Such high growth rate of production in certain crops can certainly be attributed to factors such as release of promising new varieties, easy access to good quality planting material, improved production technologies, efficient post-harvest management and marketing, apart from the growing demand for these fruits. Farmers growing these crops formed their own associations for aggregation, grading and marketing of the produce. Associations of grapes and pomegranate growers developed their own cultivation practices, in consultation with public research institutions, to meet international quality standards and exported fruits to many countries. The growth rate of some other fruit crops has been slow because of lack of organised effort to promote new technologies and develop the value chain. A glaring example has been the status of the cashew nut industry. India was the world leader in cashew nut export since 1950s, but due to outdated processing infrastructure and lack of technical support to cashew growers, the cashew nut yields remained stagnant at 762 kg/ha. On the contrary, Vietnam, where cashew production was introduced in the late 1980s has captured 65% of the world cashew nut export, while increasing the average raw cashew nut yield to 3,041 kg/ha. There are many fruit crops which are under neglect, due to lack of technology and infrastructure (Hegde 2021).

Table 2 presents the status of vegetable production in the country. Potato, onion and tomato were the major crops occupying about 43.6% of the area under vegetable production, and the other five crops, namely brinjal, peas, okra, cauliflower and cabbage, occupied 25.4% area. The rest of the vegetable crops covered the remaining 31% area. There was 500% increase in the production of onion over 20 years between 2000-01 and 2020-21, partly because of 300% increase in the cultivated area and also because of the introduction of new technologies and varieties. The production of peas and tomato increased by 294% and 270% over the last 20 years, due to increase in the area by 191% and 180% respectively. From this data, it can be observed that there has been no significant breakthrough in giving a boost to vegetable production. The important reasons for slow progress in vegetable production are lack of value chains,
particularly to transfer new production technologies, lack of grading and packaging, transportation support for marketing, and absence of market information services. Unlike fruit growers, vegetable growers are not organised as these are seasonal crops, and are not grown regularly. Being highly perishable, farmers experience heavy losses due to wastage in the absence of proper transportation and marketing facilities. Small farmers engaged in vegetable production are compelled to sell their produce to local traders, who invariably indulge in unfair trade practices.

There has not been any significant development in the production of spices, although India is the top exporter of spices and produces over 75 varieties out of the total 109 products listed in the International Organisation for Standardization (ISO). Indian exports accounted for 20% of the global trade, worth USD 4 billion in 2020-21. The major products exported under this category were chilli, cumin, turmeric, ginger and cardamom. There is good scope to increase the production of spices by establishing a strong backward linkage for mobilizing farmers to adopt advanced technologies. Floriculture also provides an excellent opportunity for small farmers to enhance their income. The area under floriculture has increased from 0.106 million ha in 2001-02, to 0.339 ha in 2018-19, while enhancing the production from 0.535 million tonnes to 1.99 million tonnes during the same period. This sector generated an export revenue of USD 81.94 million in 2018-19, which is fairly encouraging.

Further analysis of the production data reveals that although the horticulture sector has been maintaining a steady annual growth of 3.5%, there is good scope to further improve the yield. It has been reported that small farmers engaged in horticultural production have been facing several challenges in the areas of increasing yields, controlling pests and diseases, timely harvesting, grading, packing, storage and marketing of the produce. Realising these problems, various initiatives were undertaken by the Government and the private sectors with very encouraging results. However, more efforts are needed to organise small farmers and develop strong value chains to enhance the production of most of the horticultural crops in the country.

**Strategy for giving a boost to Indian Horticulture**

Expanding horticultural production is an opportunity to enhance income through cultivation of high value crops, maintaining the land under green cover for longer period, building soil fertility and organic carbon, conserving soil moisture and providing an opportunity to small holders to earn sustainable livelihood. To achieve this goal, the following aspects should be addressed:

**Introduction of new technologies:** Introduction of new varieties, which are attractive to consumers and climate resilient to perform well even under adverse conditions, use of modern tools such as instant soil testing for residue-free nutrition management, automated irrigation devices to irrigate as per the requirements of the crops, monitoring crop health and pest and disease infestation by using GIS and spectrophotometers, biological plant protection and developing kits for testing the quality of the produce with non-destructive sampling, are some the technologies which have not reached most of the farmers in the country. Suitable mechanisms have to be developed to transfer these technologies, particularly to small farmers.

With the advancement in space technology and GIS, the state organisations can now precisely generate information on newly sown area under different crops, incidences of pests, diseases and general health status of the field crops, likely arrivals of produce during the week, weather changes expected, etc. and release such information on daily or weekly basis to farmers, with suitable guidelines. This can be a major breakthrough to suitably plan the farming operations and enhance the production.

**Producers’ organisations and mentoring of small farmers:** Support for backward and forward linkages has been the biggest problem encountered by most of the farmers. Small farmers need good mentoring and support for procuring inputs, adopting modern technologies, using farm machinery, grading and transportation of the produce. Linking with financial institutions, Government agencies, market information and service providers is also essential to take advantage of the available technologies and services.

**Processing of the produce:** Post production handling and processing of fruits, vegetables and spices has excellent scope for wide scale expansion, which will not only add value but also generate assured employment. For fruit and vegetable processing, industries in the private sector can be very efficient. It is also essential to organise the farmers at the village level to tie up with these industries.

**Value chain development:** The success of the agriculture sector depends on the efficiency of the value chain, which can address most of the challenges faced by the farmers as well as the industry. Key players who can contribute to the growth and profitability of the horticultural sector are research institutions who have developed various production and processing technologies, state development departments who provide policy support and financial subsidies, financial institutions who meet the credit needs and industries involved in supply of equipment, biological and chemical inputs and processing of the produce. These agencies should come on a common platform to work with farmers. Non-Government organisations can also play a very important role in providing various services to coordinate and operationalize the value chain. The programme should be technology driven and implemented by the NGOs and industries.

Considering the role of research institutions, it may be ideal if the Government of India can undertake an exercise to prepare an action plan for expanding the production of selected fruit, vegetable, spices and ornamental crops by bringing various stakeholders for each value chain, under the respective National Research Institute involved in the development of those crops. These institutions can also carry out periodic monitoring of the progress of different players in the respective value chain, while the management of the value chains can be handled by other players like business groups involved in processing or farmers’ organisations and NGOs, who are committed to this programme.
Table 1. Area and production of major fruit crops in India in 2000-01 and 2020-21

<table>
<thead>
<tr>
<th>Crop</th>
<th>Area (000 ha)</th>
<th>Production (000 tonnes)</th>
<th>Yield (tonnes/ha)</th>
<th>% Increase in production (2000-01 to 2020-21)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2000-01</td>
<td>2020-21</td>
<td>2000-01</td>
<td>2020-21</td>
</tr>
<tr>
<td>Mango</td>
<td>1077.6</td>
<td>2315</td>
<td>8715.6</td>
<td>20899</td>
</tr>
<tr>
<td>Citrus</td>
<td>295.7</td>
<td>1064</td>
<td>4197.7</td>
<td>14071</td>
</tr>
<tr>
<td>Banana</td>
<td>383.9</td>
<td>916</td>
<td>7790.0</td>
<td>33832</td>
</tr>
<tr>
<td>Apple</td>
<td>194.5</td>
<td>312</td>
<td>1147.7</td>
<td>2057</td>
</tr>
<tr>
<td>Guava</td>
<td>94.0</td>
<td>304</td>
<td>1095.1</td>
<td>4433</td>
</tr>
<tr>
<td>Pomegranate</td>
<td>107.3*</td>
<td>273</td>
<td>743.1</td>
<td>3068</td>
</tr>
<tr>
<td>Jackfruit</td>
<td>166.7*</td>
<td>189</td>
<td>1175.7</td>
<td>1931</td>
</tr>
<tr>
<td>Grape</td>
<td>32.4</td>
<td>152</td>
<td>668.2</td>
<td>3213</td>
</tr>
<tr>
<td>Papaya</td>
<td>45.2</td>
<td>144</td>
<td>805.3</td>
<td>5951</td>
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<tr>
<td>Pineapple</td>
<td>57.1</td>
<td>108</td>
<td>768.5</td>
<td>1777</td>
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<tr>
<td>Walnut</td>
<td>122.7*</td>
<td>108</td>
<td>233.1</td>
<td>284</td>
</tr>
<tr>
<td>Watermelon</td>
<td>-</td>
<td>104</td>
<td>-</td>
<td>2983</td>
</tr>
<tr>
<td>Anola</td>
<td>108.1*</td>
<td>99</td>
<td>1266.5</td>
<td>1216</td>
</tr>
<tr>
<td>Litchi</td>
<td>49.3</td>
<td>98</td>
<td>243.8</td>
<td>728</td>
</tr>
<tr>
<td>Sapota</td>
<td>52.0</td>
<td>77</td>
<td>593.5</td>
<td>816</td>
</tr>
<tr>
<td>Muskemelon</td>
<td>-</td>
<td>60</td>
<td>-</td>
<td>1312</td>
</tr>
<tr>
<td>Ber</td>
<td>40.5*</td>
<td>52</td>
<td>438.0</td>
<td>559</td>
</tr>
<tr>
<td>Custard apple</td>
<td>19.55*</td>
<td>45</td>
<td>135.6</td>
<td>390</td>
</tr>
<tr>
<td>Pear</td>
<td>42.3*</td>
<td>42</td>
<td>295.1</td>
<td>279</td>
</tr>
<tr>
<td>Plum</td>
<td>23.9*</td>
<td>23</td>
<td>74.1</td>
<td>86</td>
</tr>
<tr>
<td>Peach</td>
<td>19.2*</td>
<td>18</td>
<td>97.94</td>
<td>117</td>
</tr>
<tr>
<td>Passion fruit</td>
<td>18.2*</td>
<td>12</td>
<td>100.5</td>
<td>56</td>
</tr>
<tr>
<td>Almond</td>
<td>21.4*</td>
<td>9</td>
<td>10.0</td>
<td>11</td>
</tr>
<tr>
<td>Kiwi</td>
<td>5</td>
<td>14</td>
<td>-</td>
<td>2.8</td>
</tr>
<tr>
<td>Strawberry</td>
<td>3</td>
<td>20</td>
<td>-</td>
<td>6.67</td>
</tr>
<tr>
<td>Others</td>
<td>272</td>
<td>2660</td>
<td>-</td>
<td>0.78</td>
</tr>
<tr>
<td><strong>Total fruits</strong></td>
<td>6806</td>
<td><strong>102764</strong></td>
<td><strong>0.78</strong></td>
<td><strong>14.83</strong></td>
</tr>
</tbody>
</table>

Note: Production in 2020-21 based on 2nd Advance Estimate. * Data is for the year 2011-12.

Role of non-government organisations in horticultural development

It has been observed in the past that in spite of good intentions and well-conceived development projects, farmers have been facing several hurdles because of lack of facilitators and infrastructure. This role has been very efficiently played by several committed Civil Society Organisations or Non-Government Organisations to ensure success. These NGOs, who work closely with small farmers, motivate them to take active role in development, train them to adopt new skills, build their confidence, organise them to form cohesive groups to work together and help them to establish contact with development institutions, banks and markets. If the NGOs are prepared to fill the gaps wherever necessary, even the illiterate farmers will come forward to accept new technologies. Thus, NGOs can be an important player in developing the value chain for different horticultural crops, particularly for active participation of small farmers.

One of the most successful examples in India is the promotion of the Wadi Programme (Tree based farming) for rehabilitation of the Scheduled Tribe families in Gujarat, Maharashtra and many other states by BAIF, a reputed NGO based in Pune. BAIF initiated a programme to develop the denuded lands owned by these families by establishing mango and cashew orchards, while the interspace was used for growing food and vegetable crops. As soon as the project implementation was initiated, the field team faced several hurdles, including reluctance of the alcoholic men to work. So, women were motivated to take part in orchard development activities. However, as the women were often falling sick, activities like healthcare, supply of clean drinking water, family hygiene and sanitation, and awareness about ill-effects of alcohol, etc. were also initiated in this horticultural project. When the orchards
Table 2. Area under major vegetable crops and total production of in India in 2000-01 and 2020-21

<table>
<thead>
<tr>
<th>Crop</th>
<th>Area 000 ha</th>
<th>Production 000 tonnes</th>
<th>Yield tonnes/ha</th>
<th>Increase in production %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2000-01</td>
<td>2020-21</td>
<td>2000-01</td>
<td>2020-21</td>
</tr>
<tr>
<td>Potato</td>
<td>1259.5</td>
<td>2250</td>
<td>24456.1</td>
<td>53687</td>
</tr>
<tr>
<td>Onion</td>
<td>495.8</td>
<td>1654</td>
<td>5252.1</td>
<td>26916</td>
</tr>
<tr>
<td>Tomato</td>
<td>458.1</td>
<td>852</td>
<td>7462.3</td>
<td>21003</td>
</tr>
<tr>
<td>Brinjal</td>
<td>502.4</td>
<td>758</td>
<td>8347.7</td>
<td>13154</td>
</tr>
<tr>
<td>Pea</td>
<td>303.3</td>
<td>573</td>
<td>2038.2</td>
<td>5823</td>
</tr>
<tr>
<td>Okra</td>
<td>347.2</td>
<td>532</td>
<td>3324.7</td>
<td>6513</td>
</tr>
<tr>
<td>Cauliflower</td>
<td>202.8</td>
<td>463</td>
<td>4890.5</td>
<td>9038</td>
</tr>
<tr>
<td>Cabbage</td>
<td>177.3</td>
<td>404</td>
<td>5678.2</td>
<td>9586</td>
</tr>
<tr>
<td>Tapioca</td>
<td>238.9</td>
<td>163</td>
<td>6515.9</td>
<td>5479</td>
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<tr>
<td>Sweet potato</td>
<td>131.9</td>
<td>118</td>
<td>1130.3</td>
<td>1209</td>
</tr>
<tr>
<td>Chillies (Green)</td>
<td>399</td>
<td></td>
<td>4393</td>
<td></td>
</tr>
<tr>
<td>Beans</td>
<td>219</td>
<td></td>
<td>2169</td>
<td></td>
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Note: Production in 2020-21 based on 2nd Advance Estimate. * Data is for the year 2011-12.
Dried rose petals:
From the kitchen to the boudoir

Rose is a universally acknowledged and admired flower. The extortionate price, high perishability, unavailability round the year and ephemeral nature of fresh cut roses eventually abashing passionate rose lovers. So to keep this favourite flower around all year long, drying is the most exercised and exemplary approach. Not only dehydrated rose, anyone can also experience the worthwhile consequences of desiccated rose petals. Dried rose petals in particular can be transformed into many wonderful things. On top of all that, the process of drying them is actually quite simple. They provide an intoxicating fragrance to potpourri and satin sachets, add colour to indoor decorations and create romantic confetti for weddings. Although the spectacular sight and heavenly scent of the flowers do not last long and soon give way to the red coloured rose hips but it is hard not to love a rose. So to preserve its show-stopping aroma and protean utilities, dried rose petals are the pre-eminent recourse.

How to desiccate fresh rose petals?

Literally very fundamental procedures are elected to dry rose petals but prior to subjecting them into drying, harvesting of petals at appropriate stage is mandatory. Gathering of petals should be undertaken from fresh roses when they are at their biggest and brightest as well as also smell their best. Mid morning of a dry day-when the dew has evaporated and there’s been no rain for at least the past two-days is the ideal time to assemble them. Browning petals or hydrated petals should be circumvented to pick, as during drying either they will turn fully brown or begin to rot. Roses ready to release their petals will fall easily into hands by a gentle tugging while the center of the flower will remain intact to produce the rose hip soon after. Petals can also be emancipated from the stems by using scissors to snip around the base of the rose petals. Petals resist to liberate easily and should not be forced since it may result in the pulling off of entire flower. Paper bag or wooden baskets for their aptness are most suitable to store them. There are several modus-operandi of drying of rose petals among which air drying, microwave drying, drying by dehydrator and book drying are few. The best place to keep a drying sheet containing petals in a single layer, is on a flat surface away from direct sunlight and having good air circulation. It should be followed by turning them over at least once a day to ensure air exposure of both sides of each petal. After a couple of days stock of crispy petals can be achieved after removing from drying sheet. In microwave drying method, petals are arranged in a single layer without any overlapping petals on a microwave safe plate lined with a double layer of paper towels followed by drying for approximately 40 sec and storing. Dehydrator is also a good medium to dehydrate rose petals within few hours at the lowest possible setting. Laying of petals inside a book followed by waiting for about a week or two for complete drying is another customary technique. Laying of petals inside a book followed by waiting for about a week or two for complete drying is another customary technique. Merits of successfully dried rose petals can only be experienced by bona fide aftercare, which involves the storing in tightly sealed storage containers to prevent insects from entering and eating the petals.

Multitudinous feasibility of dried rose flowers

Dried flowers of rose are full of subtle colours and myriad textures. It will not be a big surprise to discover dried rose petals as a kitchen ingredient as cooking with rose petals dates back to centuries. All roses are edible, but some taste better than others, and some should be avoided. Roses from the florist shop should not be consumed as insecticides and fungicides are utilized for their growing. Roses that have pleasing fragrance especially pink, yellow and white blooms should be preferred for food purpose. Anyone can savour the amalgamation of various hues of dried petals having different tastes being strewed on toasts. White petals make a nice contrast against the brown of nut butter while dark damask coloured roses lend their perfume to the air before taking a bite. Dried rose petals are more practical in terms of shelf-life and storage, and have long been used to bring floral notes to sugars and spice mixes like ‘rasel hanout’. Another most prevalent sweet preserve of rose petals made in India and in some other Asian countries is ‘Gulkand’ where ‘Gul’ means flower in both Persian and Urdu languages, and ‘qand’ means sweet in Arabic. It is made by using 1 cup
of scented dried petals of *Rosa x damascena* and 3 cups of sugar. Infusion is another common way of cooking with rose petals. This might be a simple rose petal tea, a sugar-water infusion for a flavoured cocktail syrup, or a more complex infusion for custard, gelatine or opaline. Edible dried rose petals are delicious for desserts like almond sponges or semolina puddings collaterally their flavours can be also incorporated in some western dishes like Turkish delight cheesecake for inspiration. Rose petals occasionally appear in Indian dishes too like Hyderabadi Biriyani where dash of rose water is added. They have immense entail for many savoury and meat dishes in Mexican and Mediterranean cooking. They are most usual ingredient in kuli or sweetened rice dishes. In the context of British cooking, clean flavours like cucumber or apple pair well with rose petals. Red, light pink, dark pink, white, yellow, orange, mauve or blue petals also make a stunning contrast against the greens in a salad. Thus, besides their uses for their aromas, floral flavours, symbolism or decorativeness, they are a beautiful addition to the chef’s arsenal.

Multitudinous health benefits can be procured by this flower since fresh as well as dried rose petals contain vitamin C, citric acids, pectin and more than 300 medicinally essential chemical constituents of which only about 100 have been identified. In the 1st century C.E. Pliny first recorded 32 different uses of roses. Distinctively *Rosa gallica* var. *centifolia* or Cabbage rose is quite popular for its various medicinal properties. It is familiar for its astringent and anti-inflammatory properties and also for aphrodisiac, sedative and antidepressant qualities. French rose oil gained reputation as aphrodisiac concocted using cabbage rose petals significantly different by its chemical composition from Bulgarian rose oil. Few natural home remedies formulated from dried rose petals fight against the infection in the digestive tracts and intestines, hasten the elimination of wastes through kidneys and also aid to clean the gall bladder, liver and promote the bile flow. Rose petals are antiviral, antibacterial and antiseptic, so the application of them over a minute wound can act as a protective covering. A decoction prepared by boiling rose petals in water is effective home remedy against sore throat. Rose tea using especially the petals of wild roses (*Rosa acicularis*) also assists to curb diarrhea since roses are astringent. Depending on the source, it has found that per cup of rose tea is able to supply as much as 1,000 mg vitamin C, changes vitamins into pro-oxidant that actually decrease cellular damage caused by unstable free radicals. Similarly, rose oil is quite fruitful for stress related conditions like insomnia, nervous tension and also for skin diseases including rosecea and eczema owing to its emollient, healing and soothing properties. Rose tea makes an excellent emmenagogue to help move blood and quell cramps during menstruation while rose water makes a good eye wash for sore or inflammed eyes. So, wide range of roses namely *R. canina* (Dog rose), *R. arkansana* (Meadow rose), *R. laevigata* (Cherokee rose), *R. damascene* (Damask rose), *R. rugosa* (Rugosa rose) and *R. multiflora* (Japanese rose) can be easily grown to experience their innumerable medicinal benefits.

Roses actually offer multitude beauty-enhancing benefits. Even dried petals of this iconic flower specifically do beauty wonders on the skin. The ancient Greeks and Romans used rose petals in fresh or dried forms to perfume their baths. In distilled forms, they have been included in cosmetics, medicines and therapeutic treatments for centuries. The treatment for a host of ailments including abrasions, burns and skin conditions can be accomplished by antibacterial, antifungal and antiviral property contained rose essential oil. It helps to treat acne and acne-prone skin while due to its cleansing properties, acts as an ideal ingredient in face washes and cleansers. As a natural astringent, rose water formulated using 1 cup of tightly packed fresh or dried rose petals along with boiled 2 cups of spring water followed by straining through a cheese cloth into a glass jar helps to tighten pores, reduces inflammation, fights wrinkles, soothes and rehydrates the skin and also restores suppleness for a glowy complexion. It assists to intercept sunburn by shielding skin cells from damage, since rose holds high amounts of vitamin C, a powerful antioxidant. Not only that but the gentle fragrance acts as antidepressant and has aphrodisiac properties. In fact, dehydrated rose petals are a staple in Ayurvedic medicine to detoxify, calm and sooth the mind. Moreover, rose scented lotion or cream imparts an extra pleasant experience. Many organic
beauty products embrace dried rose petals for its delicate and intense aroma in lieu of artificial fragrances. Natural oils made from dried or fresh petals are predominantly worthwhile for sensitive skin to moisturize and generate a soothing feeling. Besides, the application of a well mixed paste made up of pre-soaked and mashed 8 dried rose petals along with 3 tablespoons of honey followed by a thorough cold water rinse create a calming face mask. So in fine, anyone can discover how these lush dried or fresh blossoms can make ones skin feel as velvety soft as a bed of roses.

In lieu of hurling wilted pretty rose petals of the bouquet in the trash its superior to make an indelible homemade gift i.e sweet rose petal potpourri since dried rose petals have a calming scent, and create a blend that leaves a lovely lingering scent in home easily. Firstly detached petals of 1 dozen roses are desiccated over a newspaper but when they have started to crisp around the edges they’re placed in a sealable glass jar. To arrest the wonderful aroma, fixatives are appended and the mixture of ground cinnamon and ground lavender are sprinkled. Finally, after the inclusion of 4-5 drops of rose essential oil or rosewater, the closed container is left in a warm, dry spot for 24 hours followed by shaking at an interval of couple of days. Conclusively it adds fragrance to unmentionables. Apart from this, they have long been associated with love and help to open the heart chakra, decreases stress, tension, depression, and lighten the mood. Sipping on a cup of rose tea aids to tonify both the male and female reproductive systems by helping in the production of sperms and estrogen in men and women respectively as they are an aphrodisiac and contains flavonoids while phytosterols in roses help both sexes to balance their hormones. Furthermore, package of strewn dried rose petals across the bed and candles can make a candlelit room.

**Economic potential of the dried rose petals**

The easiest and least expensive way to cherish the beauty of flowers are drying. Out of ₹ 570 crore total exports from India during 2018-19 nearly 60% of Indian floriculture exports comprised dry flowers. Even after that the impact of this industry is not so profound due to irregular supply and non-systematic growing of specialized flowers. However, the demand for dried rose petals is increasing at an impressive rate of 8-10% for its significant use as ‘Pot-pourris’ and therefore there is a great scope for the Indian entrepreneurs as our main customer is England. Apart from that, dried rose petals had also been exported from India (Cochin) to United Arab Emirates in 2016 at the quantity of 40 kg of total worth of ₹ 17,823. In view of the lockdown the collection from the natural habitats is hampered. At the same time other key constraints like lack of innovative technologies to meet the western dry flower market, absence of databank or traceability system for wild collection for the local artisans in dry flower industry, non-availability of solar power energy or renewable power sources, etc. has impacted the sector. So, some interventions including setup of research

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<td>Do</td>
<td>Yellow, Peach, Salmon</td>
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<td>Golden Unicorn</td>
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<tr>
<td>Nearly Wild</td>
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<td>Do</td>
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<tr>
<td>Millie Walters</td>
<td>Miniature</td>
<td>Yellow, Peach, Salmon</td>
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<td>Modern Sunrise</td>
<td>Shrub</td>
<td>Do</td>
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<tr>
<td>Sally Holmes</td>
<td>Do</td>
<td>Do</td>
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<tr>
<td>Mountain Music</td>
<td>Do</td>
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<td>Stanwell Perpetual</td>
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<td>Do</td>
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<tr>
<td>Rural Rhythm</td>
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institutions under ICAR exclusively to work for research and development of technologies for dry flowers, NOC from wild life department, documentation and fumigation treatment of dry flower export, development of dry flower infrastructures, etc. are mandatory. Collaterally, participation in specialized international trade fairs i.e. International Floriculture Trade Fair (IFTF) in Holland etc. and organizing market promotion programs in potential importing countries could also dissipate the economic viability of dehydrated rose petals.

**Additional information for young entrepreneur**

Dehydration technology can also be exploited for dehydration of promising colourful dried rose petals in its original colour and shape for long term enjoyment. Dry flower market has grown exponentially as consumers become “eco-conscious” and choose dried flowers as the environmentally friendly and biodegradable alternative to fresh flowers. Training and entrepreneurship promotion for production and export of dried rose petals is paramount, so, tribal women, unemployed youth could be trained under Skilling India and Standup India. Since this industry depends heavily on synthetic dyes for colouring the dry flowers and adding flavors and fragrances, thus, Integrated Flori Malls with essential oil units, pigment and dye extraction units could support the dry flower industry especially the potential of dried pot-pourri to complete the value chain. In nutshell, there is large potential to develop the dried rose petals industry in every country and to provide employment to house wives and rural women.

Now-a-days most of the rose lovers plant roses in their garden specifically for their eat-and use-ability owing to the versatility of dried and fresh rose petals. Roses are heart-stopping beautiful to the eye, and their aroma is equally show-stopping. With such an impressive presence, the rose is bound to stir up attention in human culture, and thus has ancient symbolic meanings throughout human history. They have proved their veritable worth owing to its exhaustive use in health and medicine since their dried petals are affluent by antioxidants and polyphenols furnish innumerable health benefits. Often dried rose petals are preferable when they come to crystallizing and cake decoration while several distinctive rose-flower flavours such as rose water, rose preserves, rose syrups and rose petal infusions can also be prepared from dehydrated ones. Hence, ethereal beauty and soothing fragrance of desiccated rose petals bound rose fans instinctively to entwine them with notions of beauty and love.

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**For further interaction, please write to:**

Dr Moumita Malakar (Assistant Professor), Central University of Tamil Nadu, Tamil Nadu 610 005, India. Corresponding author email: moumitamalakar01@gmail.com

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**Textbook of Field Crops Production – Foodgrain Crops**

The first edition of Textbook of Field Crops Production was published in 2002 and there has been a heavy demand for the book. This book is now being brought out in two volumes. The chapters cover emerging trends in crop production such as System of Rice Intensification (SRI), export quality assurance in the production technology of commodities like Basmati rice, organic farming, resource conservation technologies, herbicide management etc. Good agronomic practices must judiciously inter-mix the applications of soil and plant sciences to produce food, feed, fuel, fibre, and of late nutraceuticals while ensuring sustainability of the system in as much possible environment and eco-friendly manner. The advent of hydroponics, precision farming, bio-sensors, fertigation, landscaping, application of ICT, GPS and GIS tools, micro-irrigation etc. is in the horizon. The textbook covers both the fundamentals of the subject and at the same time inspire and prepare both teachers and students for the emerging frontiers.

**TECHNICAL SPECIFICATIONS**

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Rooftops are underutilized and rarely-considered urban spaces with great potential for terrace gardening. Rapid urbanization, industrialization, land ceiling, construction of buildings, wide roads, offices, markets have resulted in non-availability of land for kitchen gardening activities in big cities and towns. Metropolitan cities have driven out agriculture from their boundaries. Owing to changing climatic conditions, a lot of pesticides and chemicals used in cultivation of fruits and vegetables affect the health of human beings.

SPACE available in the terrace can be effectively utilized for growing fruits, vegetables, spices and herbal plants. It might be roof, porch, terrace or balcony. Instead of garden around the house the plants can be transferred to the existing roof or floor of multi-story apartments, single-storey houses, office premises, storage warehouses. A well-planned terrace garden ensures round the year supply of fruits and vegetables. Involvement in the maintenance of the roof garden will help relieve stress and strains leading to healthy lifestyle. Rooftop gardening can be an attractive and energy-saving alternative as it keeps buildings cooler, saves energy, extends aesthetic value to the useable space on roof.

Points to be considered before planning a rooftop garden

- **Assessment of suitability of rooftop for garden:** Examine the structural integrity of the building and make sure the roof can hold the load. Soil and pots are heavy and will get heavier as the plants grow.
- **Drainage and waterproofing of roof:** Make suitable arrangement for drainage of excess water from irrigation and rainfall. The roof where you are planning to plant your greens should be waterproof, frost-resistant, and durable, especially the areas where you will be planting your greens and placing the pots. Waterproof the rooftop with the use of plastic sheets, polymer coating, etc. The waterproofing membrane to be installed for rooftop should be root and rot-resistant.

- **Sunlight exposure:** When it comes to cultivating any type of plant, sunlight is critical. Make sure you are well-versed with seasonal and daily sun exposure. The site should be open area with plenty of sunlight for 6 to 8 hours at least. The kind of plants, vegetables, flowers, and herbs one can grow on the roof gardens are determined by the amount of sunshine available.
- **Access to the roof:** Access to the roof is an important consideration. Typical access includes stairs and there should be enough space for transporting materials for construction and maintenance.
- **Availability of water for irrigation:** Plants must be watered regularly therefore consider an irrigation system or drip irrigation that will do the job automatically. At least, provision of water tank and tap should be there for watering plants.

**Types of rooftop garden**

**Container gardening:** Container gardening is a less expensive and highly flexible form of gardening that is especially effective for urban settings with little or no changes to the existing roof structure. Container gardening involves placing containers on a rooftop and filling them with soil and plants. It helps to avoid problematic soil by taking soil from area with healthy soil which can be further supplemented with compost produced from the garden’s organic wastes as well as additional organic wastes produced within the building. Containers can be built from a variety of materials ranging from plastic drum, buckets, earthen pots, cement bags, storage container, wooden
boxes that are readily available in household. Container gardening is particularly useful for people who lack the means or the will to make changes to the actual structure of the roof. Containers also have the advantage of providing depth and space for soil and roots, which is difficult to obtain with extensive green roof systems.

**Green roof system:** The second sort of roof garden, in which the rooftop is used as the planting medium, requires more investment but has its own set of benefits, such as better storm-water retention and building insulation. Specially designed layers separate the garden from the hard roof, provide drainage, supply nutrients, and even add contours. This type of rooftop garden is referred as a green roof system. There are two types of green roof systems extensive and intensive. An extensive green roof weighs lesser than an intensive green roof. It generally has shallower growing material and heartier plants that require little maintenance. Intensive green roofs are most like gardens on the ground—with deeper growing material, more intricate plantings, and more maintenance needs such as irrigation and pruning. Green roofs are constructed using a special base layer comprising root and water-proof membrane followed by a root barrier, water retention, drainage layer and lastly soil layer for growing plants. Usually, shallow rooted vegetables are grown in roof gardens and seedlings are removed after maturity periodically for roof garden maintenance.

**Rooftop hydroponics:** In the third rooftop garden possibility, plants are grown on a soilless media. Hydroponics is a means of growing plants with a substrate other than soil which may include peat, sand, rockwool, coconut coir, perlite or vermiculite. A nutrient solution is used to water the plants. Rooftop hydroponics is the lightest of the three choices, and it may allow for faster plant development and higher yield. There are two basic hydroponic systems: a non-recycled nutrient solution, where the nutrient solution is only used once; and a recycled nutrient system. There are also many variations within these two systems and various models and designs are available for use. There are six main types of hydroponic systems to consider for the garden—wick hydroponic system, deep water culture (DWC), nutrient film technique (NFT), ebb and flow, aeroponics, and drip systems.

- **Wick hydroponic system:** It is the simplest type of hydroponic system used to grow plants. It is easy to maintain and does not require aerators, pumps, or electricity. The plants are placed directly within an absorbent substance like perlite or vermiculite covered with nylon wicks into the nutrient solution.
- **Nutrient film technique (NFT):** In this system, the nutrient solution is pumped into channels that hold plants. The channels are slightly sloped, so the nutrient solution flows through the channel, over the plant’s roots and back into the hydroponic reservoir. NFT hydroponic system works best for plants that have a small root system, like leafy vegetables.
- **Deep water culture (DWC) system:** Plants are placed in a net pot and are held by a floating platform above a container of nutrient and water. Plant roots are suspended and stretched into the nutrient-rich oxygenated solution. DWC is comparatively low cost, easy to build and water saving active recovery system. It just requires a net pot, a reservoir/container, a lid, and a pump.
- **Ebb and flow hydroponic systems:** It is also called flood and drain system where plants are placed in large grow beds filled with growing medium. The bed is flooded with nutrient solution until it reaches a certain point. Water pump after running for a predetermined amount of time, shuts off draining the grow bed completely. Nutrient solutions are flooded onto the plant root system and then drain periodically in cyclic manner.
- **Aeroponics:** Plant roots are suspended in the air and are misted with the nutrient solution continuously. The misting interval is fairly short, done by a pump controlled by a timer. Aeroponic system is expensive, and requires regular maintenance as nozzles sparing nutrient mist get choked.
- A drip system is an easy-to-use hydroponic system that can be quickly altered for different types of plants, which makes this a great system for any grower who plans to make regular changes. Drip system pumps the nutrient solution through the tube and drops onto plant roots via a network of drip lines. At the end of each tube is a drip emitter that controls the amount of nutrient solution provided to plants as per the need of individual plant.

**Planning a terrace garden**

**Layout:** The layout of rooftop garden is the first and most important step while setting up a terrace garden. One can either cover the entire surface with soil or use planters to grow plants. Earthen or cement pots or plastic pots can be used to set up a garden. Create an aesthetic
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Intro/Introductory Paragraph: It has gist of the article; Preferably give answers of all 4 Ws and 1 H; Ws stands for: what, where, why and when, H stands for: how; and Intro paragraph should convey the complete message so that reader is satisfied.

Introduction: The very first paragraph of the article is known as Introduction; It is an introduction for the article; It shows the need of writing article. For example, we write an article on a new hybrid. We have to write its importance that it is better in such and such regards, and It should be of one paragraph or two paragraphs, if the subject is broader.

Text of article: Remaining text should be in a descending order of importance; Emphasize on your own findings; Follow proper heading scheme; Use key words in headings; Follow central heading, side heading, subheading, inset heading etc.

General guidelines: Follow guidelines strictly. In popular articles, number of authors should not be more than 3. Stick to number of words required (2,500 words); Do not exceed page limit; Write captions separately; Give 1-2 tables or graphs (avoid repetition); Name(s) of author(s), Complete postal address(es) of affiliations (place where work was conducted). Complete correspondence address including e-mail address of authors should be provided (these are given as footnote on first page).

Units in metric system: Full formats of all abbreviations used in table; source of data should be given in detail. Units of measurement, symbols and standard abbreviations should conform to those recommended by the International Union of Biochemistry (IUB) and the International Union of Pure and Applied Chemistry (IUPAC). Metric measurements are preferred, and dosages should be expressed entirely in metric units (SI units). In exceptional circumstances, others may be used, provided they are consistent.

Figures: Author is required to submit high-resolution (2 MB) images, preferably with the initial submission but no later than revision stage. Electronic (2 MB) images (figures and schemes) must be at a minimum resolution of 600 d.p.i. for line-drawings (black and white) and 300 d.p.i. for colour or gray-scale. Colour figures must be supplied in CMYK not RGB colors. Please ensure that the prepared electronic image files print at a legible size (with lettering of at least 2 mm). A number of file formats are acceptable, including: PowerPoint (.ppt), Tagged Image File Format (.tif), Encapsulated PostScript (.eps), Joint Photographic Experts Group (.jpg), Graphics Interchange Format (.gif), Adobe Illustrator (.ai) (please save your files in Illustrator’s EPS format), Portable Network Graphics (.png), Microsoft Word (.doc), Rich Text Format (.rtf), and Excel (.xls) but not Portable Document Format (PDF). Type in 1.5-spaced everywhere.

Rewrite Your article

Language: Use simple words; Use short sentences in a logical order; Use active voice; Avoid passive voice; Relate all sentences with each other; Maintain coherence; Paragraphs should be short and readable; Short paragraphs give pause to readers; Give human touch to your article to make it interesting, and Give practical information

Writing for success stories: Who has got success in; Introducing new technology/methodology etc.; Diversification of any farming system in a particular area for more return; How he/she is inspiration to other farmer; What is cost:benefit ratio of the farm produce?; What are the prospects of that farm commodity?; Show the difference in adoption of that particular technique, variety, seed, tool etc.

Summary: Summary of article should be provided at the end of article under the heading “Summary”. Papers should be composed in MS Word, and double spaced throughout (including references and tables). Article (including illustrations) should be uploaded on Indian Horticulture site (as given on top), after a careful check up of typographical errors.

Submission preparation checklist
- ✔ As part of the submission process, authors are required to check off their submission’s compliance with all of the following items, and submissions may be returned to authors that do not adhere to these guidelines.
- ✔ The submission has not been previously published, nor is it before another journal for consideration (or an explanation has been provided in Comments to the Editor); and submission file should be in Microsoft Word file format.
- ✔ The text is 1.5-spaced; uses a 12-point font; employs italics, rather than underlining (except with URL addresses); and all illustrations, figures, and tables are placed within the text at the appropriate points, rather than at the end. Data is correct, authentic and updated.
- ✔ If submitting to a peer-reviewed section of the Indian Horticulture, the instructions in Ensuring a Blind Review have been followed.
- ✔ Article is based on recent experiments or practical experience of the author.
- ✔ Article should not be based on compiled matter or on some survey, report or record of extension education.
- ✔ Article should not be of theoretical nature or only of local relevance. Article text gives complete relevant details of practical utility to the farmer in clear and simple English.
Table 1. Season wise vegetables for terrace garden

<table>
<thead>
<tr>
<th>Vegetable name</th>
<th>Growing season - North India</th>
<th>Growing season - South India</th>
<th>Germination temp. (in °C)</th>
<th>Sowing method</th>
<th>Days to maturity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brinjal</td>
<td>Feb-Mar, May-June, Oct</td>
<td>Jan-Feb, Oct</td>
<td>21-27</td>
<td>Nursery of 25-30 days &amp; transplanting of seedling</td>
<td>100-110 days</td>
</tr>
<tr>
<td>Pumpkin</td>
<td>Jan-Mar Sept-Dec May-Jun</td>
<td>Jun-Jul Dec-Jan</td>
<td>20-35</td>
<td>Direct seeded</td>
<td>70-75 days</td>
</tr>
<tr>
<td>Cucumber</td>
<td>Feb-Mar, Jun Jul</td>
<td>Jun-Jul Sept-Oct Dec-Jan</td>
<td>16-32</td>
<td>Direct seeded</td>
<td>50-70 days</td>
</tr>
<tr>
<td>Beans</td>
<td>Feb-Mar Jan-Mar</td>
<td>Jan-Mar</td>
<td>16-30</td>
<td>Direct seeded</td>
<td>45-50 days</td>
</tr>
<tr>
<td>Apple Gourd</td>
<td>Feb-Mar Jun-Jul</td>
<td>Feb-Mar Jun-Jul</td>
<td>20-30</td>
<td>Direct seeded</td>
<td>70-80 days</td>
</tr>
<tr>
<td>Bitter Gourd</td>
<td>Feb-Mar Jun-Jul</td>
<td>Nov-Dec Dec-Jan Jun-Jul</td>
<td>20-30</td>
<td>Direct seeded</td>
<td>55-60 days</td>
</tr>
<tr>
<td>Bottle Gourd</td>
<td>Feb-Mar Jun-Jul</td>
<td>Nov-Dec Dec-Jan Jun-Jul</td>
<td>20-30</td>
<td>Direct seeded</td>
<td>55-60 days</td>
</tr>
<tr>
<td>Broccoli</td>
<td>Aug-Sept</td>
<td>Aug-Sept</td>
<td>21-23</td>
<td>Nursery of 25-30 days &amp; transplanting of seedling</td>
<td>90-100 days</td>
</tr>
<tr>
<td>Cabbage</td>
<td>Sept-Oct</td>
<td>Jun-Jul Oct-Nov</td>
<td>10-20</td>
<td>Nursery of 25-30 days &amp; transplanting of seedling</td>
<td>90-100 days</td>
</tr>
<tr>
<td>Beetroot</td>
<td>Oct-Nov</td>
<td>Aug-Nov</td>
<td>10-30</td>
<td>Direct seeded</td>
<td>80-90 days</td>
</tr>
<tr>
<td>Capsicum</td>
<td>Nov-Jan May-Jun</td>
<td>Jan-Feb May-Jun Oct-Nov</td>
<td>15-25</td>
<td>Nursery of 25-30 days &amp; transplanting of seedling</td>
<td>95-100 days</td>
</tr>
<tr>
<td>Carrot</td>
<td>Aug-Sept-Oct</td>
<td>Aug-Nov</td>
<td>10-30</td>
<td>Direct seeded</td>
<td>75-80 days</td>
</tr>
<tr>
<td>Lettuce</td>
<td>Sept-Oct</td>
<td>Oct-Dec</td>
<td>7-27</td>
<td>Direct/Transplant</td>
<td>45-55 days</td>
</tr>
<tr>
<td>Okra</td>
<td>Feb-Mar Jun-Jul</td>
<td>Jan-Feb May-Jun Oct-Dec</td>
<td>20-32</td>
<td>Direct seeded</td>
<td>50-60 days</td>
</tr>
<tr>
<td>Onion</td>
<td>May-Jun</td>
<td>Mar-Apr May-Jun Sept-Oct</td>
<td>10-32</td>
<td>Transplant</td>
<td>150-160 days</td>
</tr>
<tr>
<td>Radish</td>
<td>Aug-Jan</td>
<td>Sept-Nov</td>
<td>10-30</td>
<td>Direct seeded</td>
<td>40-45 days</td>
</tr>
<tr>
<td>Spinach</td>
<td>Sept-Nov Feb</td>
<td>Sept-Oct-Nov</td>
<td>10-22</td>
<td>Direct seeded</td>
<td>60 days</td>
</tr>
<tr>
<td>Turnip</td>
<td>Oct-Nov</td>
<td>Oct-Nov</td>
<td>15-35</td>
<td>Direct seeded</td>
<td>40-50 days</td>
</tr>
<tr>
<td>Cauliflower (Early)</td>
<td>Mid-June</td>
<td>Jun-Jul Aug-Sept</td>
<td>25-27</td>
<td>Nursery of 25-30 days &amp; transplanting of seedling</td>
<td>120-125 days</td>
</tr>
<tr>
<td>Cauliflower (Late)</td>
<td>Aug-Sept-Oct</td>
<td>Jun-Jul</td>
<td>16-20</td>
<td>Nursery of 25-30 days &amp; transplanting of seedling</td>
<td>120-125 days</td>
</tr>
<tr>
<td>Cauliflower (Mid-season)</td>
<td>Sept-Oct</td>
<td>Jun-Jul Aug-Sept</td>
<td>&lt;16</td>
<td>Nursery of 25-30 days &amp; transplanting of seedling</td>
<td>120-125 days</td>
</tr>
</tbody>
</table>
and functional development plan based on the possibilities and constraints of the site, according to your tastes, your needs, and your budget.

**Selection of plants:** Depending upon the availability of the space, different types of vegetables and fruits can be grown on the terrace garden (Table 1). In addition to fruits and vegetables, think of putting herbal and medicinal plants in your garden. Diversification of plants in the garden is a guarantee for success in a healthy and varied diet. In fact, it will enable you to have access to a higher number of nutritional elements as each food has different characteristics.

**Soil preparation:** In general, the soil used should be fertile, containing the correct levels of moisture and minerals. Fresh soil from any farm with the right amount of organic manure and vermicompost is good for the purpose. Organic manure or aged manures are the best ways to prepare the soil for gardening as they supply almost every nutrient to the plant. For home gardening, soil mixes are available in nurseries. Potting soil is a mixture of peat moss, vermiculite, perlite and compost that is specially formulated to ensure good water retention and good drainage in pots and containers. Coco peat is also a very popular choice for home gardeners as it helps in water retention, aeration for roots and protects the plant from soil fungus. Priority is given to mixtures that are very lightweight and do not contain chemical fertilizers. Homemade compost or vermicompost is the ideal addition since it will allow to complete the food cycle at household.

**Sowing:** The seed of vegetables like lady finger, clusterbean, bitter gourd, bottle gourd and radish are directly sown in the growing medium. The seedling of vegetables like brinjal, tomatoes and chillies, etc. have to be raised in portraits and then transplanted in polybags. These seeds take 25 to 30 days to be eligible for transplantation.

**Management:** The use of organic fertilizers and organic way of pest control can be adopted. To avoid infestation of pests some amount of organic pesticides can be mixed in the soil. The plants can be sprayed with neem oil to control sucking pests which is a major problem in rooftop gardening. The neem oil is mixed in 10 litre of water with addition of 10 g of soap mixture and sprayed over affected vegetable plants. The spray made out of ginger, garlic and chilli paste diluted in water is also very effective in pest control.

**Government initiatives in promoting rooftop gardening**

State governments in some states under the Rashtriya Krishi Vikas scheme and Smart City development is offering 50% subsidy on seeds, fertilizers and farming equipment. House owners with a minimum of 50 to 300 square foot space in their balconies or backyard are eligible for availing 50% subsidy. The gardening and horticultural activities on the rooftops will help in improving the environmental conditions and restoring the climatic imbalance to an extent. Agriculture Skill Council of India (ASCI) conducts training programme on Rooftop Gardener, aims at building the following key competencies amongst the learner:
- Design and execute a rooftop garden as per the instructions received.
- Grow and maintain the condition of plants on a rooftop garden.
- Use and maintain the gardening tools, containers and other equipment.
- Monitor the plants and identify the potential damage due to insect, pests and diseases and learn how to control them.
- Practice health and safety at the work place: Well versed with health and safety measures in terms of personal as well as others safety and introduction to harmful practices of designing and execution.

The type of rooftop garden design depends partly on your interest in gardening and maintenance, and on the environmental benefits you wish to achieve. Rooftop plantings can interact with the heat produced by the building. Vegetation can work to cool buildings by insulating and shading as well as improving urban air quality. Once a rooftop has been developed for gardening, it remains that way, regardless of design, model and size. A rooftop garden is an investment in peace of mind for people living in urban areas, providing hours of relaxation and reward in the form of nutritional supplementation to family.

For further interaction, please write to:
Y P Singh, ATIC, ICAR-IARI, New Delhi 110 012, India.
Corresponding author email: ypicar2016@gmail.com
Areca nut (Areca catechu) is one of the main cash crops of South-East Asian countries mainly in India. It is popularly known as ‘betelnut’ or ‘supari’.

**Botanical name and chromosome number**

*Areca catechu* L., 2n=32

**Family**

Arecaceae

**Origin**

The Malaya Archipelago, the Philippines and other East Indies islands

**Economic part**

Nut (seed endosperm/ dry kernel), leaf sheath

**Uses**

Mastication, medicine and is an essential requisite for several religious and social ceremonies, leaf sheaths are used for making cups, plates, spoons, hats, leaf sheath is also used as alternate fodder for livestock.

**Growth form**

Slender, single-trunked palm

**Leaf**

The leaves are pinnatisect and consist of a sheath, a rachis and leaflets. The leaf sheath completely encircles the stem. The average length of leaf is 1.65 m, which bears about 70 leaflets (varies with the vigour of the palm and fertility of the soil).

**Varieties and Hybrids**

Tall varieties: Sumangala, Sreemangala, Mohitnagar, Swarnamangala, Kahikuchi Tall, Madhuramangala and Nalbari; Semi-Tall varieties: Mangala and Shatamangala; Dwarf hybrids: VTLAH-1, VTLAH-2.

**Inflorescence type**

Spadix

**Pollination**

Highly cross-pollinated

**Pollen agents**

The sweet-scented male flowers are visited by bees and other insects for nectar, but insects have not been observed visiting the female flowers. It is thought that most of the flowers are wind pollinated.

**Anthesis**

Morning hours

**Stigma receptivity**

Up to 6 days

**Climate and Soil**

Altitude: 0-1000 m MSL. Mean annual temperature: 14°C-36°C. Mean annual rainfall: 750-4500 mm. Soil should be deep to ensure a well-developed root system with high organic carbon content and a pH range from acidic to neutral.

**Propagation techniques**

Seeds and tissue culture (Somatic embryogenesis)

**Spacing and planting**

The optimum spacing for planting arecanut is 2.7 m x 2.7 m. Wider spacing of 3.3 m x 3.3 m is advisable for accommodating high value inter/ mixed crops. Crops like cocoa, pepper, banana, acid lime, cardamom, coffee, tea, nutmeg, vegetables, flower crops, medicinal and aromatic plants, etc. can be grown in arecanut gardens.

**Shading**

Arecanut plants are sensitive to sun scorching. Shade plants may be planted along the borders on South-West side. If planting of shade trees is not possible, exposure to sun can be avoided by covering the stem with arecanut or coconut leaves.

**Nutrient management**

Nutrient management strategies need to be planned for arecanut considering the soil fertility status. Application of 100 g N, 40 g P<sub>2</sub>O<sub>5</sub> and 140 g K<sub>2</sub>O is recommended as a general dose of fertilizer every year. P<sub>2</sub>O<sub>5</sub> addition, application of 12 kg each of green leaf and compost per palm is also recommended. The organic manure and 50% of recommended dose of fertilizers i.e. 110 g urea, 100 g rock phosphate and 117 g muriate of potash can be applied during September-October after opening the basin. Same dose of fertilizers can be applied during February-March. Fertilizers should be applied around the palm at a distance of 45-50 cm from the trunk.

**Water management**

Arecanut cannot withstand drought and invariably needs irrigation during rainless period. In drip irrigation, about 16-20 litres of water per day per palm is required based on evaporation rate.

**Drainage**

It is essential to ensure adequate drainage by providing drainage channels in high rainfall areas. Similarly, it is essential to have adequate drainage to prevent water-logging in low-lying areas.

**Yield**

Dry kernel or chali yield varies from 2.54-4.15 kg/palm/year in different genotypes

**Market price**

Market price depends on size and quality of dry kernel (chali). Present market price is ₹440-510 per kg.

**Pests and diseases**

The arecanut plant is prone to the attack of many insect and non-insect pests. Some of the arecanut pests include root grub (Leucophaea spp.), spindle bug (Micraulahoa areca), pentatomid bug (Halyomorpha lineata), leaf mite (Raoiella indica), scale insect (Aonidiella aurantiaca), chalcid (Tithorea sp.), scale insect (Aonidiella aurantiaca), and chalcid (Tithorea sp.). Diseases such as fruit rot, bud rot, crown rot, yellow leaf disease, basal stem rot, inflorescence dieback etc., affects arecanut plant health.

**For further details, please contact or write to:**

N R Nagaraja and V Aparna

ICAR-Central Plantation Crops Research Institute,

Kasaragod 671 124, Kerala, India
The Indian Council of Agricultural Research has brought out the Second enlarged and revised edition of the Handbook of Horticulture. Horticultural crops are gaining more and more importance as they have been instrumental in improving the economic condition of the farmer and contributing significantly to the national GDP. This new revised edition has been divided into 2 volumes – Volume 1 contains General Horticulture and Production Technologies (Fruit, Vegetable and Tuber crops) and Volume 2 has Production Technologies (Flower, Plantation, Spices crops and Medicinal and aromatic plants), Plant Protection and Post-harvest Management. The earlier chapters have been thoroughly revised and new chapters have been added. It is hoped that the readers will find this Second edition more useful and informative.

Technical Specifications

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