ICAR-Central Institute for Subtropical Horticulture was established as the Central Mango Research Station in 1975 and since then has been working on the development of technologies leading to higher yields of quality mangoes and providing solutions to the problems faced by the mango industry. By establishing the world’s largest mango repository, the Institute has made a significant contribution to mango germplasm conservation. The institute released Ambika and Arunika regular bearing red coloured hybrids, suitable for high density orcharding. Thousands of hectares have been rejuvenated using Institute’s technology. A protocol for sea transport of Dashehari mangoes was developed in collaboration with APEDA.

Farmers are following the ICAR-CISH disease and pest management recommendations on more than 32 thousand hectares. More than 1.5 lakh grafts of mango varieties were provided to KVKs, SAUs, the Horticulture Department, and other stakeholders as core planting material for the establishment of mother blocks.

The institute is working to refine existing technology for improving productivity of senile and old orchards, in addition to developing varieties and technology for high-density planting, canopy, water, and nutrient management. Diversification is being attempted to make the mango orchard system more profitable, and disease and pest control approaches with reduced pesticide use are being developed to improve the ecosystem of intensive mango growing orchards.

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July–August 2021
Published bimonthly, Vol. 66, No. 4

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Mango: Storehouse of nutrition

Mango is one of the most popular fruits in the tropics and subtropics of the world. The mango tree is not only revered as a sacred gift from nature, but it is also prized for its immense economic potential. It is primarily used as a source of food, fuel, and fodder in traditional Asian civilizations, and is a source of income for millions of people around the world. It is also a rich source of nutrients and several rare bioactive compound. Mango was previously thought to be primarily an Asian economic crop, but it is now becoming a significant crop in other parts of the world. Mexico is the world’s leading mango exporter, accounting for roughly 17% of the country’s total output. For millions of people living in subtropical, semi-arid, and tropical regions around the world, mango is a source of vitamin A. Mango fruit is high in carbohydrates, minerals, dietary fibre (pectin), vitamin C, and vitamin A. Mangiferin and lupeol, natural bioactive chemicals found in mango, have been shown to have a variety of health-promoting properties, including antitumor activity.

India is renowned around the world for its diverse collection of mango types, each with its own distinct flavour, texture, and aroma. Initially, the US and European markets marketed only red-coloured mango types, but in recent years, yellow-green cultivars have made their way into these markets as well. Majority of the crop is consumed as fresh mangoes, but hundreds of processed goods derived from the fruit are also commercially manufactured and sold. Mango pulp has only a little amount of lipids and can therefore be termed fat-free. A significant concentration of lipids may be found in seeds, and their fatty acid content is comparable to that of cocoa butter. In addition to being a one-of-a-kind crop, mangoes are used for processing at both the raw and mature crop stages, making them a valuable commodity. Early fruit is used to produce chutneys, curries, cool drinks, pickles, and other condiments, as well as pickles and pickle vinegar. Ripe fruits are used to make a variety of products, including puree, squash, nectar, beverages, mango leather, fruit bars, canned and frozen mango slices, and desserts. Mango pulp and pickles are two of India’s most important export products.

The consumption of mangoes, as well as the area under mango production, is steadily expanding since the fruit is recognized as a super fruit. However, the King of Fruits is also confronted with a number of obstacles as a result of the perpetually changing climate and the emergence of biotic pressures in a variety of agro-ecological environments. Mango producing areas in the subtropics are dealing with a variety of issues, including low fruit set caused by temperature fluctuations and a lack of pollination, among others. A number of diseases and pests have emerged as a significant impediment to the production of high-quality mangoes. There is a pressing need to develop technologies that reduce the usage of pesticides while still boosting ecosystem benefits. It is becoming a commodity export crop for a number of countries, resulting in increased competition on the worldwide export market.

The demand for pesticide-free mangoes is increasing, but the amount of pesticides used to manage disease and pests is increasing as well, according to the USDA. For both domestic and foreign markets, high-quality production with a reduced pesticide burden has become a need for success. Therefore, it is necessary to develop methods or produce mangoes that are in line with consumer desires while simultaneously ensuring the long-term viability of the orchard environment.

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Mango – The King of Fruits

Mango, the 'King of Fruits', is an economically significant fruit in different areas of the globe. In addition to its great tropical taste, mangoes encapsulate nutrients and make eating healthy and pleasant sensory experience. Though mango cultivation is recorded from more than 120 nations, simply more than 60% of global mango output comes from India, China, Thailand, Indonesia and Mexico. Major part of produce is eaten as fresh mangoes, however, hundreds of its processed products are also being commercially manufactured. Mangoes are low in sodium but there is sufficient amount of potassium, phosphorus and calcium in the fruit. Apart from nutritional advantages for human health, mangiferin and lupeol, natural bioactive chemicals in mango have shown many health boosting features including antitumor-promoting action.

Prospects

Mango is one of the most significant fruits produced in the tropics and sub-tropics of the globe. The mango tree is not only adored as a sacred item but also is treasured due to its great economic potential since all its components are deemed useful and are utilized for different reasons. It is a source of food, fuel and fodder, mainly in the traditional Asian nations. The mango fruit provides a livelihood for millions of people throughout the world. But the King of Fruits is also experiencing numerous difficulties owing to continuously shifting climate and increasing biotic stressors under diverse agro-ecologies. It is becoming an export crop commodity for many nations leading to worldwide export market rivalry.

Fascinating history of distribution

The mango has a fascinating history of domestication and distribution as the sea transportation was exceedingly important before the early twentieth century. Mangifera indica is thought to have been originated in the Indo-Burma area. The mango has an interesting history of domestication and spread since the sea transportation was extremely significant before the early twentieth century. Traders, explorers and monarchs were captivated by Indian mangoes and their efforts over the past several centuries established mango as a crop in tropics and sub-tropics. Mango was brought to Malay Peninsula by the 'Tamils' and imported from Indo-china Peninsula.

Mango is going to various areas of the globe where it was not produced previously and currently being cultivated in approximately 140 nations. In western hemisphere, in some of the industrialized nations, modern ways of cultivation were adopted for mango cultivation, mostly based on temperate fruit production.

Deeply associated with culture

Prominence of mango in Indian mythology and religious rituals are part of the long history of the nation. Ancient hindus regarded mango highly not only for religious or emotional reasons but also they fully understood its significance in the economic and cultural life of the community. The sanskrit term 'Amra' (mango) indicates that it is the product of multitudes. The hindi term ‘Aam’ denotes the masses or the people. Inflorescence and leaves are utilized by Hindus in different rituals and for the worship of ‘Saraswati’, Goddess of knowledge and arts.

The impact of mango on Indian culture is widely recognized since in ancient India, man and woman connected their names with mango. The woman who gave mango to Lord Buddha was herself called as 'Amradarika'. Name of ragas (scores of music) like Amra-takeswara and Amra-panchma are based on this fruit. In India, mango cultivation is almost as ancient as Indian civilisation. Indian art also acknowledges the ultimate value of mango. 'Barhut Stupa' of 110 BC, 'Ajanta' and 'Ellora', give evidence of its antiquity as being outstanding instances are sculptures of that period.

India is the world leader in the production of mangoes
In Malaysia and Indonesia, the Sanskrit or Tamil name for mango indicates that it was brought from India to Peninsular Malaysia and eastern Asia. Praise of this fruit reached its peak when a Turkman saint and poet, Amir Khusroo praised mango in his poetry. The Ain-i Akbari, an encyclopaedic book of the Moghul emperor Akbar provides a comprehensive description of mango and its variations. Akbar is renowned for plantation of a huge orchard of one lakh mango trees, the ‘Laksh Bhag’ near Darbhanga, of which remnants are still surviving.

**An economically important crop**

Until the middle of the twentieth century, mango was regarded as a significant economic crop in Asian nations only. Later on mango farming spread and now continues to develop in fresh sub-tropical and tropical regions. It has become a significant export commodity in non-traditional mango producing nations where the substantial percentage of their fruit production is exported. Analysis of FAOSTAT, 2014 statistics show that Mexico is the top exporter of mango with approximately 17% of the national output.

The development of Floridian mango cultivars made it adaptable to broad variety of agro-ecologies and responsible for the growth of additional production regions. Indubitably, when it comes to mango production, Asia has a significant share. The top five nations producing mangoes are from Asia. Additionally, Bangladesh and Philippines are on the list of top 10 countries.

**Changing varietal preference in International Markets**

Red-peel cultivars dominate the worldwide mango export market because of their eye-appeal but in Asian nations customers choose the fruits on the basis of total knowledge of the variety. Naturally, this is due to population established preferences for particular local yellow and green colour types. The excellent local cultivars are offered at a premium price but they don’t find place in the international market because of their yellow or yellow green hue even at the ripe stage. Gradually, the situation is changing and yellow skin mangoes are now recognized in the US market because of their quality.

‘Ataulfo’, a yellow coloured variety has garnered increasing attention of customers in the US. At least this variety has played a part in breaking red peel variety preference in the market. This modification may assist in opening way for the outstanding Indian cultivars in the United States, not highly favoured due their yellow or greenish peel. Breeding efforts for creating new mango varieties in India include red peel colour too, as one of the key goals. Thus many of the newly created types are red in colour.

**A nutritionally rich fruit**

Mango fruit is rich in carbohydrates, minerals, dietary fibre (pectin), vitamin C, and vitamin A (β-carotene) and several other phytochemicals of mango help to sustain good health. Mango serves as a source of vitamin A for millions living in the world’s different sub-tropical, semi-arid, and tropical areas, especially in nations where vitamin A deficiency (VAD) is common. In many countries, mango is distributed in plenty in rural regions of industrialized nations.

Mango fruit pulp has very little lipid content and may be regarded as fat free. Seeds are rich in lipids and fatty acids composition is similar with cocoa butter. Mango fat may have an important role in the cosmetics, pharmaceutical and food industries. Mango is a rich source of vital minerals such as calcium, iron, magnesium, phosphorus, potassium, zinc, copper, manganese, and selenium required for human health. The fruits are low in sodium.

**Store house of bioactive compounds**

Mango has been related to numerous pharmacological benefits, including, anti-diabetic, antioxidant, anti-viral and anti-inflammatory properties. Various effects have also been reported, including antibacterial, antifungal, anthelmintic, antiparasitic, anti-HIV, antifungal, antipsasmodic, antipyretic, antidiarrheal, immunomodulation, hypolipidemic, antimicrobial, hepatoprotective and gastroprotective.

The compound, mangiferin, a predominant bioactive ingredient isolated from different parts of mango tree has been extensively studied both in vivo and in vitro for pharmacological effects like antioxidant activity, antidiabetic, antitumor, lipometabolism regulating, cardioprotective, antihyperuricemic, neuroprotective, antioxidant, anti-inflammatory, antipyretic, analgesic, antibacterial, antiviral and immunomodulatory effects. It has been shown that Zynamite®, a mango leaf extract rich in the natural polyphenol and mangiferin, enhances sprint exercise performance when given in combination with luteolin or quercetin. Lupeol, a natural pentacyclic triterpene present in mango fruit has gained attention in recent past which has shown strong anti-inflammatory, anti-arthritic, antimutagenic and antimalarial action. Lupeol has also been shown to have antitumor-promoting effect.

**Numerous usage**

Mango is extensively utilized in culinary, cosmetics and pharmaceutical industry, straight from root to the top of the tree. The fruit is utilized at all phases of development. Premature fruit is used for the production of chutneys, curries, cold drinks, pickles, etc. whereas ripe fruits are used for puree, squash, nectar, beverages, mango leather, fruit bars, canned and frozen mango slices, and sweets. Mango stones are used for growing seedlings, oil, leather, fruit bars, canned and frozen mango slices, and sweets. Mango leaves are used for growing seedlings, oil, fibre and as animal feed. The kernel is a rich source of carbohydrates, calcium and fat and starch which may be generated for industrial uses. Goats and cattle are fond of eating mango leaves while branches and wood are used for fuel, lumber alongside usage of bark for extraction of tannins and gums.

**Invaluable processed products**

Mango is a unique crop, utilized for processing at raw and mature crop stage. The method has been developed for different goods viz. canned and frozen slices, pulp, jelly, squash, tea, nectar and ready-to-serve (RTS) drinks. There are a large number of traditional mango products processed at home or cottage industry level. Mangoes are used for several hundred dishes and
used with pulses, buttermilk, yoghurts, soups, meat, fish curry, spices, etc. Mango pulp and pickles are the most exported commodities from India. Research on innovative processing techniques for retaining nutritional and sensory properties has taken place in the recent years.

Large variation in mango pickles can be attributed to the recipes used in different parts of the world. In India, several varieties, specific to region are known for making specialized pickles. Appimedi pickle famous from western Ghats of Karnataka is made of tender mango mainly grown in forests and also on the riversides. Mango pulp and pickles are the most exported commodities from India.

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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**

- **Size**: Royal Octavo (16 cm x 24 cm)
- **No. of pages**: i-xii + 1618
- **Price**: ₹ 1500
- **Postage**: ₹ 100
- **ISBN No.**: 978-81-7164-096-6

*For obtaining copies:*

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Indian Horticulture

Shailendra Rajan* and Ashish Yadav

Mango hybrids and improved cultivars

The abundance of mango varieties in India is well-known throughout the world. There are thousands of varieties in the country, practically all of which are the product of selections made from the seedling population. A few decades ago, there was a tradition of orchard plantations utilising seedling plants. Almost all varieties have one or more defects, giving rise to mango breeding efforts around the country. Various organisations have developed/identified over 60 hybrids/selections, but only a few of these are being multiplied on a bigger scale and planted by farmers.

EACH mango variety has its own set of advantages and disadvantages. Clonal selection and hybridization have been employed for the development of new mango varieties with desired features. The goal of the initial breeding program was to create a dwarf and regular bearing mango cultivar. However, towards the end of the century, the creation of export-ready colour varieties was also promoted. Breeders strived to develop spongy tissue tolerant cultivars for the commercial production of Alphonso.

**Mango hybrids**

Farmers have embraced only a few hybrids due to distinct climate requirements for quality production and regional consumer preferences. Nonetheless, a few hybrids, such as Amrapali, Mallika, Ambika and Arunika, are being cultivated in various agroecologies around the country. Whereas, excellent hybrids like Ratna are limited to Alphonso growing belt of Maharashtra.

Although the first mango hybrid was released from Bihar Agriculture College Sabour in 1951, large scale multiplication and plantation of hybrids started with Mallika and Amrapali developed at IARI, New Delhi in the seventies of the last century. ICAR-Indian Agricultural Research Institute, New Delhi developed several mango hybrids and improved varieties including Mallika (Neelum × Dashehari), Amrapali (Dashehari × Neelum), Pusa Peetamber (Amrapali × Lal Sundari), Pusa Arunima (Amrapali × Sensation), Pusa Pratibha (Amrapali × Sensation), Pusa Shrestha (Amrapali × Sensation), Pusa Lalima (Dashehari × Sensation) and Pusa Manohari (Amrapali × Lal Sundari).

Amrapali is well known for its regular bearing and excellent performance in areas with good humidity, particularly in coastal parts of West Bengal and Odisha. It has become a popular variety of kitchen gardens and also many high-density plant orchards are coming up in different sub tropics of the country. Amrapali has been used as one of the parents in hybridization programs. Hybrids made out of Amrapali have wider adaptability and regular cropping. The fruits have high carotenoid content. Mallika has been found as a high yielding variety in different parts of the country and has become popular in Karnataka and some southern parts of India.

At ICAR-Indian Institute of Horticultural Research, Bengaluru, hybrids like Arka Anmol (Alphonso × Janardan Pasand) Arka Aruna (Banganapalli × Alphonso), Arka Neelkiran (Alphonso × Neelum) and Arka Puneet (Alphonso × Banganapalli) have been developed. Arka Udaya (Arka Amrapali × Arka Anmol) was released in 2015 with firm pulp and deep yellow, high TSS and...
better quality. Recently Arka Suprabhat (Amrapali × Arka Anmol) was released.

ICAR-Central Institute for Subtropical Horticulture, Lucknow developed and released Ambika (Amrapali × Janardan Pasand) in 2000. It is a regular and late bearing variety. The fruits are bright yellow with a dark red blush, with a dark yellow pulp that is firm and lacking in fibre, weighing 300-350 g. Arunika (Amrapali × Vanraj) released in 2008 has dwarf canopy, regular bearing with red peel. The fruit is smooth, orange yellow with a red blush, medium size, ovate oblique, pulp orange yellow, firm with scanty fibre, pulp about 65%, TSS 24.6 °B. Due to its attractive fruit colour, it has potential for internal and export markets. It has shown wider adaptability and performs well in the subtropics, particularly where the climate is not very dry and irrigation facilities are available. Several other hybrids (H-949, H-1084, H-1739) are in the pre-evaluation stage.

The Regional Fruit Research Station, Vengurla released Ratna (Neelum × Alphonso) in 1981. It is a regular bearing, medium-sized fruits, orange-coloured pulp, free of spongy tissue and fibre. Sindhu (Ratna × Alphonso), Suvarna (Alphonso × Neelum), Konkan Raja (Bangalora × Himayuddin) and Konkan Samrat (Alphonso × Tommy Atkins) are some other hybrids released from Vengurla.

The Agricultural Experiment Station, Navsari, Paria developed and released the hybrids Neeleshan Gujar (Neelum × Baneshan), Neeleshwari (Neelum × Dashehari), Neelphonso (Neelum × Alphonso) and Sonpari (Alphonso × Baneshan).

Bihar Agricultural University, Sabour, Bhagalpur, released Prabhashankar (Bombay × Kalapady) in 1951 as a first mango hybrid. Alfazli (Alphonso × Fazli), and Sundar Langra (Langra × Sunder Pasand) were released in 1980. Sabari (Gulabkhas × Bombay) has a red peel and a reddish yellow pulp. Jawahar (Gulabkhas × Mahmood Bahar) is a mid-season cultivar with greenish-yellow ripening fruits that taste sweet and agreeable.

The Horticultural Research Station, Periyakulam, developed PKM-1 (Chinna Suvarnarekha × Neelum) and PKM-2 (Neelum × Mulgoa), respectively, in 1981 and 1990. Both bear regularly, producing good-quality cluster fruits. Mahatama Phule Krishi Vidyapeeth, Rahuri developed Sai Sugandha (Totapari × Kesar) and released it in 1998.

**Clonal selections**

There has been a lot of variability in the most popular commercial mango types. In addition to hybridization, clonal selection has been employed to identify promising seedlings. The clonal selection or superior seedlings have been identified in different mango growing areas of the country. When compared to the parent type, these clones may produce higher yield, have a better look, or mature earlier. Primarily, fruit yield and quality have been used to identify superior clones.

Cardozo Mankurad is a selection from Mankurad made by the Central Coastal Agricultural Research Institute, Ela, Old Goa. Paiyur-1 is a clonal selection of Neelum mango, released in 1992. It is a regular bearer, with good quality fruits and excellent taste.

Dashehari-35, a clonal selection from Dashehari made by the Central Coastal Agricultural Research Institute, Ela, Old Goa. Paiyur-1 is a clonal selection of Neelum mango, released in 1992. It is a regular bearer, with good quality fruits and excellent taste.

Dashamahar Dashehari clonal selections are, viz. Pant Chandra and Pant Sinduri.

At Sabour, Subhash from Zardalu seedling and Menaka from Gulabkhas seedling were selected. At CHES, Bhubneshwer, Arka Neelachal Kesari, a clonal selection of Gulabkhas was selected. The Fruit Research Station, Sangareddy released Manjeera in 1985.
Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani released Niranjan, as a selection from the Royal. Phule Abhiruchi is a selection of GK-PM-5 in 2014 and is recommended for pickling in Maharashtra. Indira Gandhi Krishi Viswavidyalaya, Chattisgarh released in 2015, Nandiraj is a clonal mango selection from Nayapara, Jagdalpur.

Mango is highly heterozygous, and the majority of important varieties have been identified from seedling orchards. With the prevalent practice of commercial variety graft plantations, the chances for variety development in nature are becoming increasingly slim. As a result, hybridization programmes must be strengthened in order to develop newer hybrids that meet the needs of the domestic and export markets.

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On-farm conservation for traditional mango varieties

Mangoes are plentiful in India, with over a thousand varieties growing in tropical and sub-tropical areas. The majority of these varieties are seedlings that have been passed down from generation to generation as heirloom varieties. Enjoying a specific aroma, taste, maturity time, and use on special occasions are all reasons why farmers grow these varieties. On-farm conservation would not only help farmers conserve their variety, but it would also help them earn profit by registering them as farmer's varieties.

For a variety of reasons, heirloom varieties have been conserved in the orchards. Farmers play an important role in maintenance of non-commercial mango varieties. They experiment with new seedlings and adopt them if they prove to be superior to traditional varieties or landraces. Local mango varieties are advantageous at some places because they yield more, are more resistant to pest infestations, and are more tolerant to abiotic stresses than cultivars. Farmers, on the other hand, have a number of uses for these varieties.

In important mango growing areas of the country, growing multiple varieties in an orchard was an old tradition. These traditional orchards could conserve many rare and important varieties. These multi-varietal orchards helped farmers to increase their income, reduce risks (both the yield and price risks) and secure their livelihoods. Other advantages include extended harvesting season, reduced harvest risks by improving pollination, and reduced crop failure chances of one or two varieties in the orchard.

Need for conservation

About six decades back, in place of grafted plants, people planted new orchards by even using seedling plants but it is a rarity in present days. For few large land owners, space for seedlings was not a constraint and trees were allowed to grow, flower and fruit. Majority of the mango varieties came into world because of this process. New varieties developed as nature’s gift and people were interested in selection and maintaining them. These did not have much commercial value rather owning them due to some unique character was considered as matter of pride.

Although majority of the varieties have disappeared but even then community efforts can conserve the existing ones. Many of the varieties survived in the orchards because of their value for making pickles but gradually they also vanished as their commercial value was not exploited by the owners. Serious threat to the mango varieties warrants efforts for conservation as these are important sources of genes for future breeding programmes.

Rare varieties supporting livelihood

In the wholesale market, traditional varieties are not well respected, and farmers are demoralized as a result of receiving too low price. In some big city colonies, however, these rare varieties are sold at very high price. Mango connoisseurs are willing to pay a premium price for these varieties. Farmers are putting forth extra marketing efforts in order to maximize their profits. Seedlings and local varieties are supporting the livelihood in several tribal areas where commercial varieties are not common. The farmers sell fruits on roadside stalls and products made from these rare varieties. The desire to consume varieties other than commercial ones is gradually growing among city dwellers. Farmers may be able to get a better price if rare mangoes are sold in a more organised manner.

SCMD farmers displaying the mango diversity
Community based efforts for conservation

Collective and community efforts can support the drive to save mango varieties in a big way. ICAR-CISH, with the help of farmers, identified mango varieties in the orchards, and catalogued and popularized them for making them important. Farmers were educated for making less known varieties important and selling even at a better price than Dashehari. Collective marketing of rare varieties by the farmers was demonstrated as a potential tool. Many expert farmers marketed non-commercial mango varieties in posh areas of cities. Their experiences in marketing were demonstrated to other farmers who were normally dumping unique mangoes in wholesale market at very low price.

On-farm conservation of Malihabadi mango varieties was initiated by CISH with the development of a community based organization “Aam Vividhta Sanrakhchan Samiti” (Mango Diversity Conservation Society). Community farmers identified 100 varieties which require on-farm conservation on priority. The Society for Conservation of Mango Diversity (SCMD), empowered the community farmers to appreciate market value and uniqueness of mango diversity as well as on-farm conservation and effective measures for protecting farmers’ variety of the area.

Thousands of grafted plants were made in the community nurseries for planting in the orchards. Many farmers came forward to plant these varieties as they could understand the value of unique varieties. The varieties with potential for pickle making were identified and a community based evaluation was made to make the farmers understand about the selection of pickle varieties.

Important role of custodian farmers

Mango custodian farmers are farmers who maintain, adapt, and promote varieties and related knowledge over time and space in their orchards and are recognized locally for their efforts. Farmers have played a key role in the development of mango varieties and practice on-farm conservation of traditional non-commercial varieties as custodian farmers. In India, local farmers, nurserymen and landlord contributed towards evolving and conserving the varietal diversity. Various motivational factors play role in prompting the custodian farmers for conservation of mango varieties.

Diversity fairs promote conservation

Mango mela, festival or exhibitions are common and provide platform where farmers can showcase their unique varieties and popularize them in different cities of the country. With the help of CBO many good practices to save these varieties were implemented. Mango Festivals are important events in the country and the participants from other states also participate in the event. At many places more than a lakh people may visit to see varieties in this unique event for which not only farmers but all mango lovers wait, for enjoying the event. It is rightly said that it is a festival where not only mango fruits are displayed but several value added products are also sold made from the king of fruits.

Mango diversity shows have their own importance and especially for people who conserve rare mango varieties and wait for this event because they can exhibit the heritage available in their orchards. Many farmers bring their fruits to sell in fair and the urban masses happily purchase these excellent uncommon mangoes at a premium price, many times more than commercial varieties like Dashehari. At this event, mango lovers help each other in exchanging rare mango variety plants. Mango traders also don’t miss this event because they get contract renewed with the progressive farmers who have capacity to produce and supply high quality mangoes for getting premium price in domestic and export markets.

ICAR-CISH organized a number of diversity shows where several hundred mango varieties were displayed. This event is organised to motivate those who are continuously making effort to augment mango varieties in orchards. Institute made efforts to educate people for conserving varieties in their own orchard by following the
principle of "one variety with one farmer" which will make conservation of thousands of mango varieties possible. Collective effort of the community for the conservation of the varieties is the only way how on-farm conservation of rare varieties would be achieved.

**Strategy for conservation**

Malihabad, known for the hundreds of mango varieties is losing varietal wealth developed during 200 years because of urbanization, commercial varieties like Dashehari and declining enthusiasm for rare mangoes. During old days, hundreds of mango varieties were cultivated for passion and mostly the fruits were exchanged with friends or distributed amongst relatives without much commerce. Many a times, mango feasts (dawat) organized by nawabs and big landlords saved a number of varieties in the orchards.

The collective efforts by the communities can help in saving the invaluable mango varieties by taking up a responsibility of planting one variety by one farmer thereby conserving thousands of varieties with limited resources. The conservation drive can also be promoted by consuming rare varieties by the masses and provide market place in the city. It will make the availability easy and provide good returns to farmers.

**Constraints**

Sustainable on-farm conservation is not very easy because of livelihood associated with the farming community. Farmers are interested in planting grafted varieties which have high market value. They want to utilise land not only for mango but for other high return crops. Old orchards have been sold out, thus more than a century old trees have disappeared.

Descendants of big orchards with multiple varieties live in cities and they don’t have much interest in owning varieties. Presently, the scenario has totally changed as mango is being cultivated both by economically rich and resource poor people. For majority, livelihood is mainly supported by the income from the mango orchard. With the increasing cost of land, farmers are interested in selling the cultivated land than growing unique mango varieties.

**SUMMARY**

Mango varieties are abundant in India, as they grow in tropical and sub-tropical climates and come in over a thousand varieties. Traditional mango varieties have a wide range of unique flavours, nutritional and medicinal properties. A large number of old mango varieties are being conserved by custodian farmers. Their efforts will demonstrate on-farm conservation of mango diversity. Non-commercial mango varieties grown by farmers are critical for conservation. Traditional varieties help farmers' livelihoods in areas where commercial varieties are scarce. Mango festivals can play an important role in demonstrating diversity.

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For further interaction, please write to: Shailendra Rajan (Director), ICAR-Central Institute for Subtropical Horticulture, Rehmankhera, Kakori, Lucknow, Uttar Pradesh 226 101. *Corresponding author e-mail: srajanlko@gmail.com*
Mango varieties with G.I. (Geographical Indications) in India

Alphonso, Dusseheri, Kesar, and many other mango varieties are famous around the world for their unique taste, distinct flavour, and aroma, which stems from their unique production location. Some mango varieties have been given G.I. status due to unique characteristics. G.I. is a special tag mainly given to 'agriculture', 'handicraft', 'manufactured' 'food stuff' and 'natural goods'. It is given to products that have a distinct quality and identity as a result of their geographical location. The Geographical Indication, or GI tag, is used to identify products from a specific region. The GI tag serves as proof of a product's quality and unique identity.

Table 1. G.I. Certified mango varieties from different geographical areas of India

<table>
<thead>
<tr>
<th>S.N.</th>
<th>Name of Geographical Indication</th>
<th>Application no.</th>
<th>Specific geographical area</th>
<th>State</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Laxman Bhog</td>
<td>111</td>
<td>Malda</td>
<td>West Bengal</td>
</tr>
<tr>
<td>2</td>
<td>Khirsapati (Himsagar)</td>
<td>112</td>
<td>Malda</td>
<td>West Bengal</td>
</tr>
<tr>
<td>3</td>
<td>Fazli</td>
<td>113</td>
<td>Malda</td>
<td>West Bengal</td>
</tr>
<tr>
<td>4</td>
<td>Malihabadi Dusseheri</td>
<td>125</td>
<td>Lucknow (Malihabad, Mal, Kakori and Bakshi ka Talab along the banks of Gomti river)</td>
<td>Uttar Pradesh</td>
</tr>
<tr>
<td>5</td>
<td>Appimidi</td>
<td>132</td>
<td>Shimoga, Uttara Kannada, Dakshina Kannada, Chikmagalur, Hassan and Udupi regions.</td>
<td>Karnataka</td>
</tr>
<tr>
<td>6</td>
<td>Gir Kesar</td>
<td>185</td>
<td>Junagadh (Around Gir Forest)</td>
<td>Gujarat</td>
</tr>
<tr>
<td>7</td>
<td>Marathwada Kesar</td>
<td>499</td>
<td>Marathwada Division (Aurangabad, Nanded, Parbhani, Latur, Beed, Hingoli, Jalna and Osmanabad)</td>
<td>Maharashtra</td>
</tr>
<tr>
<td>8</td>
<td>Banganapalle</td>
<td>241</td>
<td>Banganapalli (Kurnool)</td>
<td>Andhra Pradesh</td>
</tr>
<tr>
<td>9</td>
<td>Alphonso</td>
<td>139</td>
<td>The Konkan region comprising Palghar, Thane, Raigad, Ratnagiri and Sindhudurg districts</td>
<td>Maharashtra</td>
</tr>
<tr>
<td>10</td>
<td>Zardalu</td>
<td>551</td>
<td>Bhagalpur and surroundings of Banka and Munger district</td>
<td>Bihar district</td>
</tr>
</tbody>
</table>

Mango varieties that have been applied for Geographical Indication

<table>
<thead>
<tr>
<th>S.N.</th>
<th>Name of Mango</th>
<th>Application no.</th>
<th>Specific geographical area</th>
<th>State</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>Rataul</td>
<td>206</td>
<td>Baghpat</td>
<td>Uttar Pradesh</td>
</tr>
<tr>
<td>12</td>
<td>Salem Mango</td>
<td>406</td>
<td>Krishnagiri, Salem, Namakkal, Dharmapuri</td>
<td>Tamil Nadu</td>
</tr>
</tbody>
</table>

GEOGRAPHICAL indications (GI) are becoming increasingly important in the global branding of agricultural products. Farmers can also benefit from GI certification in order to obtain a higher price for their produce. It is especially important for mango because it is grown in tropical and sub-tropical areas of the country. Farmers who produce varieties in a unique area of production will benefit from this certification.

Geographical indications of goods are defined as that aspect of industrial property which refers to the geographical indication referring to a country or to a place situated therein as being the country or place of origin of that product (Intellectual Property India). GI was covered as an element of Intellectual Property Rights (IPRs) under Articles 1 (2) and 10 of the Paris Convention for the Protection of Industrial Property. The World Trade Organization’s (WTO) Convention on Trade Related Aspects of Intellectual Property Rights regulates ICAR-Central Institute for Subtropical Horticulture (CISH) initiated work for registration of Chausa, Langra and Gaurjeet varieties. CISH also helped in getting G.I. for Dashehari and Rataul which has been advertised for getting GI certification.
G.I. certified mango varieties from different regions of India

GI on a global scale. India enacted the Geographical Indications of Goods (Registration and Protection) Act, 1999, as a member of the World Trade Organization (WTO), which took effect on September 15, 2003. GI is a designation given to products that have a specific geographical origin and are distinguished by their unique qualities or reputation as a result of that origin. To function as a GI, a sign must identify the good as coming from a specific location, as well as the product’s qualities, characteristics, or reputation being primarily due to the location of origin. Because the product’s unique characteristics are determined by the geographical location of production, there is a clear link between the product and its place of origin (WIPO). According to Section 2 (f) of the GIG Act 1999, "goods" include agricultural, natural, and manufactured goods, as well as handicraft and industrial goods. In India, a total of 370 goods have been registered for Geographical Indication. G.I. Certified Mangoes is one of the 112 agricultural goods that have been registered.

India is home to many world-famous mango varieties in addition to being the world’s largest producer of mangoes. Mango varieties such as Alphonso, Banganapalli, Chausa, Dussehri, Langra, Himsagar, Vanraj, Sunderja, Mankurad, and Kesar are important varieties grown in various parts of India. Due to their distinct characteristics,
some of the world’s most famous varieties from various Indian regions have been granted Geographical Indication. When grown in specific regions that are distributed throughout India, these varieties are rich in some unique properties. Because of their distinct flavour and aroma, these varieties are extremely popular. The geographical distribution of these varieties, which ranges from Bengal to Gujarat and Uttar Pradesh to Karnataka, demonstrates that they develop unique qualities as a result of their growing environment.

Geographical Indication has been granted to 10 mango varieties so far. Laxman Bhog, Khirsapati (Himsagar), Fazli, Dusseheri, Appimidi, Gir Kesar, Marathwada Kesar, Banganapalli, Alphonso, and Zardalu are some of the varieties available. Apart from these varieties, applications for Geographical Indication have been made for Rataul and Salem mangoes, but these varieties have yet to receive a Geographical Indication certificate.

Benefits of Geographical Indication
1. G.I. provides legal protection to registered mango growers and authorised persons. It prevents the use of G.I. mangoes without permission.
2. G.I. mangoes can easily fetch a premium price, potentially increasing the producers’ profits. It promotes the producers’ overall economic prosperity. It also aids in the expansion of economic activities in a specific geographic region, resulting in economic development.
3. Mango brand building is promoted by G.I.
4. Mango exports are boosted by G.I. certification. It also creates a market with guaranteed security, ensuring that unauthorised individuals or fraudsters are unable to enter.
5. Mango lovers will also benefit from the G.I. certification, which ensures consistency and quality.

For further interaction, please write to:
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Table 2. Some unique characteristics of G.I. certified mango varieties

<table>
<thead>
<tr>
<th>Variety</th>
<th>Uniqueness of variety</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laxman Bhog</td>
<td>• The colour of the fruit skin is appealing.</td>
</tr>
<tr>
<td></td>
<td>• The pulp is firm but melting, and the fibre is almost non-existent.</td>
</tr>
<tr>
<td></td>
<td>• Excellent flavour.</td>
</tr>
<tr>
<td>Khirsapati (Himsagar)</td>
<td>• The colour of the fruit skin is appealing.</td>
</tr>
<tr>
<td></td>
<td>• The flavour is characteristically pleasant, and has a sweet taste.</td>
</tr>
<tr>
<td></td>
<td>• There are fewer fibres.</td>
</tr>
<tr>
<td></td>
<td>• Good keeping quality.</td>
</tr>
<tr>
<td>Fazli</td>
<td>• Sweet and firm flesh but juicy.</td>
</tr>
<tr>
<td></td>
<td>• Fibre is very less.</td>
</tr>
<tr>
<td></td>
<td>• Very pleasant flavour.</td>
</tr>
<tr>
<td>Dusseheri</td>
<td>• Pleasant characteristic flavour and high sweet taste when fully ripened.</td>
</tr>
<tr>
<td></td>
<td>• Fibre less.</td>
</tr>
<tr>
<td></td>
<td>• Good keeping quality.</td>
</tr>
<tr>
<td>Appemidi</td>
<td>• Special variety of pickling mango</td>
</tr>
<tr>
<td></td>
<td>• The fruits are fragile, low in fibre, and have a sour taste.</td>
</tr>
<tr>
<td></td>
<td>• Latex has a very strong aroma.</td>
</tr>
<tr>
<td>Kesar</td>
<td>• The Kesar mango orchards are found in specific areas of the Junagadh region that have ideal climatic conditions and natural soil conditions for cultivation.</td>
</tr>
<tr>
<td></td>
<td>• The variety has the naturally occurring organoleptic characteristics of taste, aroma, pulp colour and mouth feel when combined with improved agro techniques.</td>
</tr>
<tr>
<td>Marathwada Kesar</td>
<td>• Higher amount of TSS (total soluble solids).</td>
</tr>
<tr>
<td></td>
<td>• Colour and taste similar to Saffron due to hot and dry climatic conditions and soil.</td>
</tr>
<tr>
<td></td>
<td>• Yield of Kesar mango is about 3 to 4 times higher than Alphonso mango.</td>
</tr>
<tr>
<td>Banganapalli</td>
<td>• Traditional mango growers in the area claim that the fruits grown in this region differ from those grown in other parts of the state / country in terms of size, shape, colour, taste, and flavour.</td>
</tr>
<tr>
<td></td>
<td>• When the tree is fully ripe, the fruit has a gleaming golden yellow colour with prominent lenticels and no blemishes or marks.</td>
</tr>
<tr>
<td></td>
<td>• Pulp is sweet and firm.</td>
</tr>
<tr>
<td></td>
<td>• It has a pleasant and delightful flavour.</td>
</tr>
<tr>
<td>Alphonso</td>
<td>• Attractive orange yellow colour</td>
</tr>
<tr>
<td></td>
<td>• Pulp is firm but melting.</td>
</tr>
<tr>
<td></td>
<td>• Fibreless, soft texture.</td>
</tr>
<tr>
<td></td>
<td>• Good acid sweet blend and pleasant flavour.</td>
</tr>
<tr>
<td>Zardalu</td>
<td>• Exceptional fruit quality and fairly heavy bearing in nature.</td>
</tr>
<tr>
<td></td>
<td>• Flesh firm, soft, sparingly fibrous.</td>
</tr>
<tr>
<td></td>
<td>• Flavour very pleasant to delightful.</td>
</tr>
<tr>
<td></td>
<td>• Taste sweet and moderately abundant juice and very good fruit quality.</td>
</tr>
</tbody>
</table>

Table 2. Some unique characteristics of G.I. certified mango varieties
The scarcity of high-quality planting material is a major stumbling block to expanding the area covered by elite varieties of mango. Due to climatic conditions, the efficiency of propagation techniques varies from region to region. Mango propagation through seedlings is not recommended due to their long juvenility and heterozygosity. Inarching is still the most widely used traditional propagation method in the country. In previous years, veneer and wedge grafting experiments in Madhya Pradesh, Uttar Pradesh, Andhra Pradesh, and Bihar yielded high success rates. For the Konkan region of Maharashtra and other coastal regions, epicotyl (stone) grafting and soft wood grafting are suitable.

These findings prompted the adoption of newer grafting techniques such as veneer and wedge grafting in north India; soft wood, stone, and wedge grafting in eastern India; and side grafting in western India. Coastal areas with high humidity and moderate temperatures are ideal for stone and epicotyl grafting for mass multiplication. Protected nurseries in poly houses and net houses equipped with sprinklers, foggers, and drips are being used to overcome climatic barriers and increase the humidity level rate for optimal graft success.

Selection of seeds for rootstock growing, superior cultivars (mother-plant) as scion sources; scion preparation, packing, and transport; grafting technique; and maintenance of the grafted plant until planting, are all steps that are required for a successful venture.

Raising of rootstock

In general, standard rootstocks in mango are not used for grafted plant preparation in the country. Salt tolerant rootstock (13-1) has been used in very limited places with problematic soils. Freshly collected stones are sown in raised nursery beds in July and covered with moist leaf mould to raise rootstocks. Within three weeks of sowing, the seeds germinate and about 80% of stones germinate within one month of extraction. To prevent the fungus *Sclerotium* from causing collar rot, the stones should be washed and made pulp-free, treated with fungicide before sowing. When the leaves turn from coppery red to green, the seedlings are moved to permanent nursery beds at 45 cm between rows and 25 cm between seedlings. Directly sowing may be done into porous organic matter and well-drained substrate inside pots or polyethylene bags. Mango seeds should be planted at a depth of 10-15 cm in a seedling bed with a depth of 25 cm of soil substrate. Due to the rapid development of the mango root system, the size and depth of the polyethylene bags are critical. In smaller bags, the roots come into contact with the bag's bottom, resulting in poor root development. Mango grafts can be made using open bottom bags with a type of railing structure that allows for adequate aeration and tap root pruning with a prune scissor, resulting in better secondary and tertiary root growth and more vigorous mango rootstock.

For each cubic metre of substrate for rootstock raising, 3 parts soil, 1 part farmyard manure should be used. The size of the bag is determined by how long grafts will be kept in the nursery before being planted. Bags of common size are 15.0-20.0 cm long, 12.5-15.0 cm wide, and 0.15-0.20 cm thick, containing about 1.8-2.0 kg of mixture for a one-year grafted plant, keeping in mind plant transportation.

Softwood grafting

The softwood grafting is similar to that of cleft or wedge grafting. Grafting is performed on newly emerged flushes. Softwood grafting can be used *in situ* to establish new orchards with pre-existing rootstocks in the field. Softwood grafting on pre-established rootstocks can be useful for establishing orchards in drier areas. The scion wood should be defoliated with the same thickness as the terminal shoot 10 days before grafting. The graft should be firmly secured with a 1.5 cm wide, 200-gauge polyethylene strip. The months of July and August, with high humidity and moderate temperatures, are ideal for softwood grafting success.

In this technique, the graft union is higher above the ground, and rootstock sprouting may interfere with scion
growth if sprouts are not pinched off.

**Veneer grafting**

Veneer grafting has largely replaced inarching in many parts of the country due to its greater efficiency. Several factors, such as the age and thickness of the scion, the time of grafting, and the defoliation period of the scion stick, all play a role in determining grafting success. This method works best with rootstocks that are at least a year old. However, if the stock reaches a suitable thickness (about 1 cm) before a year, it can be used as rootstock. A scion stick that is 4-6 months old has a better chance of success. The scion sticks are pre-defoliated in order to activate the axillary and apical buds. At a height of about 20 cm, a downward and inward 3-4 cm long cut is made in the smooth area of the rootstock. A small shorter cut is made at the base of the cut to intersect the first and remove the piece of wood and bark. To match the stock cuts, the scion stick is given a long slanting cut on one side and a small short cut on the other. The scion is inserted into the stock in such a way that the cambium layers are on the longer side. The graft union is then wrapped in a 1.5 cm wide, 200-gauge polyethylene strip. The rootstock should be clipped in stages after the scion has been green for more than 10 days. Veneer grafting is advantageous because the graft can be prepared from scion sticks found in remote locations.

**Stone (Epicotyl) grafting**

Epicotyl grafting is a fast method of mango propagation that has a success rate of 75-80%. As rootstock, newly sprouted mango stones are used in this technique. The stones are planted on raised beds in June and July. The beds should be prepared by combining soil and FYM in a 2:1 ratio. Seedlings with tender stems and coppery leaves are lifted with stones after germination. After washing the soil, the roots and stones are dipped in a 0.1% Carbendazim solution for 5 min. Seedling stems are headed back, leaving a 6-8 cm long stem. A 4-6 cm longitudinal cut is made through the centre of the stem. On the lower part of the scion stick, a wedge-shaped cut is made starting on both sides. The scion stick should be at least 4-5 months old and 10-15 cm long, with plump terminal buds. The scion stick is then inserted into the seedling cleft and secured with polyethylene strips. After that, the grafts are planted in polyethylene bags containing potting mixture. The bags are kept in the shade to avoid heavy rain. Around 15-20 days after grafting, the scion begins to sprout. During this time, removal of any sprouts on the rootstock below the graft union should be taken care. July is the best month for stone grafting.

The benefits of stone grafting include high success rates in areas with mild climates and high humidity, rootstock that is graftable in a short period of time, and the method being inexpensive and simple. Adverse climatic conditions significantly reduce grafting success rates.

**Wedge grafting**

This technique can be used with rootstock that is larger in diameter than the scion and it can also be used for top working. A healthy and vigorous scion stick is chosen at the age of 3-4 months. The scion (12-15 cm long) should have swollen buds but not sprouted. Grafting can be done on seedlings that are one year old, uniform, and healthy. Rootstocks are defoliated and only 3-4 leaves are left on them. At the bottom of the bud stick, two 3.5 cm long slant cuts are made in a wedge shape. Rootstock should be pushed back 20-30 cm above the ground. A 3-4 cm deep straight cut is made at the top of the rootstock. The scion stick is pushed firmly into the rootstock cut and wrapped with the graft plastic strip tightly. Any buds that sprout beneath the graft union is removed.

Under favourable environmental conditions, the grafting technique has a very high success rate. Pre-defoliated scions outperform freshly defoliated shoots. The grafting operation is carried out during the rainy season. However, the grafting season can be extended if the temperature and humidity in the poly house are made favourable. Before the scion sprouts and grows, the leaves on the rootstock play an important role in grafting.
success. As a result, at least 3-4 leaves are retained on the stalk during grafting. The plastic strip and all shoots that develop below the graft union are removed once a sufficient number of leaves appear on the scion. When the shoots' leaves are mature, the new plant is transplanted.

**Inarching**

Although inarching or approach grafting is a time-consuming and labour-intensive method, it is still the most widely used method for commercial mango propagation in many parts of the country. By approach grafting, the selected shoot (scion) of a desired mother plant is joined to the potted or transplanted seedling (rootstock). Seedlings that are one year old and have reached a height of 30-45 cm and a thickness of 0.75 to 1.5 cm are ideal for this purpose. A thin slice of bark and wood, about 5 cm long, 7.5 mm wide, and 2 mm deep, is removed from the stem of the stock as well as the scion branch with a sharp grafting knife. The resulting cuts should be perfectly flat, clean, boat-shaped, even, and smooth. Both the cut surfaces of the stock and the scion are made to face each other so that there is no hollow space between the two. Polyethylene strips 1.5 cm wide are wrapped around the union. After about a month of operation, the scion below the graft union and the stock above the graft union should be given light “V” shape cuts at weekly intervals until the grafts can finally be detached. Finally, the top of the stock above the graft union should be completely removed.

For further interaction, please write to:

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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.

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Increasing mango productivity through high density planting

Despite being the world leader in mango production, India's productivity is low (9.7 MT/ha) in comparison to Brazil's 12.50 MT/ha. Mango's low output is due to inadequate orchard floor management, sparse planting density, poor canopy control, and lack of training, pruning, nutrient, and water management practices. Furthermore, due to the long gestation period and late orchard income, the present generation is unwilling to adopt mango cultivation. On the other hand, the introduction of dwarf, high and regular yielding cultivars, as well as high density planting strategies, have opened up new commercial options for mango production.

High density planting system

Planting systems with a high density allow for a greater number of plants per unit area. Mango trees are normally planted 10 meters apart, with only 100 plants per hectare. When compared to the HDP system, these plants start late bearing, while per plant yield is high and total yield per unit area is low. In northern India, UHDP is possible with the 'Amrapali' variety at 2.5×2.5 m spacing (1600 plants per hectare), whereas HDP is planted at 5×5 m spacing (400 plants per hectare). HDP orchards require regular pruning and canopy management strategies to keep the canopy under control. Yield and quality degrade as the plant advances in age due to overshadowing, crowding, and a decrease in light penetration inside the canopy.

Suitable varieties for high density planting

Regular bearing varieties are suitable for high-density orcharding of mango; dwarf varieties that are responsive to pruning are usually preferred.

**Amrapali:** A hybrid between ‘Dashehari’ and ‘Neelum’, suitable for high density planting due to dwarfing nature, fruits mature late (Last week of July to mid August), fruit weight 150-350 g, remain green at ripening stage, good taste and flavour.

**Arunika:** It is a cross between ‘Amrapali’ and ‘Vanraj’, dwarf canopy with medium fruit size, fruit weight 150-300 g/fruit, coloured and attractive fruits; mature late, suitable for high density planting.

**Ambika:** It is a cross between ‘Amrapali’ and ‘Janardan Pasand’, fruits oblong to oval in shape, light yellow colour with dark red blush, fruits 250-360 g in weight, TSS 21° Brix, regular bearer and late maturing variety, average yield 80 kg/tree at 10 years of age, suitable for high density planting.
Mallika: A semi-dwarf variety, cross between ‘Dashehari’ and ‘Neelum’, suitable for high density plantation. It is prolific bearer, fibreless, orange in colour, flesh firm suitable for slice making also. Fruit mature late in July to first week of August, 350-480 g fruit weight.

Use of paclobutrazol
Shoots induced due to pruning after the harvest of the fruits may remain unproductive for a year therefore for flower induction paclobutrazol application is practiced. Paclobutrazol reduces annual flushing and shoots linear growth resulting in a smaller canopy. Flowering and fruit production are greatly helped by the application of 4 g of Paclobutrazol per tree (3.2 ml/m canopy diameter) to the soil. Recommended dose of paclobutrazol is dissolved in 15-20 liter water and applied in manuring ring 1.5-2.0 m away from the trunk where the feeding roots are present. It is applied 90-100 days before flowering in the month of September, followed by light irrigation.

Canopy architecture development
During the first 2-3 years of HDP, training is a crucial instrument for developing tree canopy. This is done in order to establish a strong framework for the future, ensuring that the branches are appropriately spaced and capable of carrying the maximum fruit load. For HDP, grafted saplings are taken after planting; 3-4 scaffold branches (as primary branch) at 45-60 cm height from ground level are allowed spirally at 10-15 cm interval. Cut the apical portion of primary scaffolds to allow secondary shoots to grow on it and then tertiary shoots. The upright growing shoots are required to be removed and the scaffolds be allowed to develop at 45-60 degree angle and after attaining the length of 50-60 cm it must be headed back. These operations lead to complete canopy structure with increased number of short shoots. Increased branching results in more fruiting shoots in young trees and encourages precocity which is pre-requisite for high density planting system. Thus, after 2-3 years, the entire canopy develops. The ‘Amrapali’ forming an uneven or irregular canopy where as ‘Ampika’, ‘Arunika’, and ‘Dashehari’ forming a compact, semi-spherical canopy.

Pruning
The tree under high density attains optimum canopy shape and size within 3-4 years and the canopy expansion is slowed down when bearing starts. Pruning strategies for mango is based on requirements of the tree. Annual pruning in mango is done for flowering management,
control tree size; reshaping of the trees to smaller and more manageable size. Pinching and tip pruning force the formation of lateral shoots from dormant lateral stem buds. Through frequent pruning of young trees, tip pruning in mango helps to shorten the juvenility and accelerate branching of lateral branches, resulting in a dense spreading canopy that flower 1-2 years earlier than conventional plantations. Pruning is normally done following the fruit harvest, which takes place in July-August.

**Nutrient and water management**

The success of mango production under high density planting system depends upon proper nutrient and water management. Nutrient applied (three year old plants) at different phenological stages i.e. after harvest (120 g N, 60 g P and 75 g K), pre-flowering (75 g N, 60 g P and 60 g K), flowering to fruit set (60 g N, 30 g P and 75 g K) fruit development (45 g N and 90 g K) in mango. The source of soluble fertilizers such as NPK grade (18:18:18%), Urea and MOP were applied at phenological stages in mango. The nutrient doses as per the stage can be split into six and applied at weekly intervals. The concentrations of the nutrient solution should be >1.5% and injected through ventury. For irrigation, drip irrigation is most effective and efficient technology to supply precise amount of water directly to root zone by saving of water through percolation and seepage losses. The water requirement in mango is determined by using pan evaporation, pan coefficient, crop factor, wetted area, and plant spacing. The water requirement is assessed on daily basis and applied through drip on alternate day. During the rainy season (June to September), rain provides 30-40% of total crop water requirements, whereas from October to May crops require 60-70% irrigation water for better productivity and quality. Drip irrigation is the best method for water management in mango when there is a water shortage.

**Yield**

The mango under high density planting system starts bearing 2nd year onward; however, good fruiting takes place in 3rd year onwards. In Amrapali, 3.5 to 14.0 kg fruits/tree (5.6 to 22.40 t/ha) were harvested after 3 to 5 years. Dashehari bears good fruits at 5×5 m spacing and 6-7 t/ha fruits in 5th year, while in traditional spacing (10×10 m), 2-3 t/ha yield was recorded. Average fruit weight recorded was about 220-260 g in Amrapali and Dashehari.

Mango orcharding under high density planting is more profitable, although it requires more initial investment, which is offset by early production. Since most of the canopy is close to the main trunk hence, more fruit is produced. Because of the controlled canopy growth, HDP is very easy to care for and upkeep. After 4-6 years, HDP yields are 10-12 times higher than standard spacing.

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Paclobutrazol – A mileage for mango production

Paclobutrazol is considered as one of the most potential plant growth retardant which restricts vegetative growth, inhibits gibberellin biosynthesis, induce flowering and control biennial bearing in mango. It has been characterized as an environmentally stable compound in soil with half-life of more than one year under different conditions. However, when it is applied at an optimized rate, the residual level detected will not be above the quantifiable level in soil and fruits. The main objective of the article is to provide contemporary information about paclobutrazol in mango production and its risk assessment.

Biennial bearing is one of the most serious issues with mango and one of the most significant barriers to increasing production. In the biennial years, the yield varies greatly, with the year of optimum or heavy fruiting (on year) being followed by a year of little or no fruiting (off year). There are numerous mango varieties, but only a few are commercially important. Since a specific variety of mango is not expected to perform equally well under different sets of climatic factors, each region of the country has its own commercial varieties. The majority of commercial varieties in the country, such as Alphonso, Dashehari, Langra, Chausa, Bombay green, and Lucknow Safeda, are biennial bearers; however, their cultivation is critical to the economies of the respective regions.

Some of the causes of biennial bearing in mango are excessive vegetative growth, high gibberellin synthesis, an imbalance of C/N ratio at the time of flower bud genesis, and heavy fruiting in one year causing nutritional deficiency in the following fruiting year. Slowing vegetative growth, reducing gibberellin biosynthesis, providing adequate nutrition, and bringing the C/N ratio to the level at which flower bud differentiates are all necessary steps in increasing the tree’s reproductive performance. The majority of these properties are shared by paclobutrazol, a growth retardant and this issue has been addressed through soil application of this chemical.

Paclobutrazol is effective not only for flower induction but also for early and off-season flower induction in mango, as well as for canopy volume reduction. Paclobutrazol’s action is heavily influenced by the rate of administration as well as the surrounding environment. However, the slow mobility and hazardous nature of the vehicle raise legitimate concerns about its long-term use.
Mode of application
When applied to the soil at a rate of 4g a.i. per tree, this chemical is effective in controlling biennial bearing. The dose is calculated based on the tree canopy, and soil drenching at 3.2 ml per metre canopy diameter is very effective in controlling biennial bearing and increasing yield. Apply paclobutrazol to the tree basin soil during the last week of September to the first week of October by digging a 15 cm deep and 30 cm wide furrow at a radial diameter of 1.0-1.5 m from the tree trunk. The required dose of paclobutrazol is mixed with 10 liters of water and applied in furrow by line pouring method to maintain uniformity during application. For two rings around the trunk at the same distance in radial diameter and with the same concentration when the tree is old and has a large canopy area. Although foliar application is possible, soil application is more effective. Where mango performance is heavily influenced by climatic fluctuations such as frequent and untimely rain, staggered flowering and fruiting, especially in the Konkan region, foliar application is generally effective.

Vegetative and reproductive growth
Vegetative growth in mango is through cyclic flushing. The flushing is more frequent as temperature increases. Episodic or recurrent flushing is common in subtropical and tropical regions. The timing of flush development is important for successful flowering and fruiting because bud release, for vegetative or reproductive growth, can only occur from mature flush. However, the paclobutrazol treatments which reduce vegetative vigour manipulate the timing of flush development may help in bud release around the time of inductive temperatures. The production of vegetative shoots in place of reproductive shoots is due to the elevated level of gibberellin which is considered as a vegetative promoter. Paclobutrazol, a gibberellin inhibitor, reduces level of vegetative promoter and stimulates flowering in inductive shoots. Moreover, fruit load may nullify the inductive effects of paclobutrazol.

There are different fruit load value in different cultivars, above which paclobutrazol is ineffective.

Hormonal relationship of paclobutrazol associated with floral induction
There are some evidences that the indigenous hormonal level, GA in particular, regulates floral initiation in mango. The concentration of GA in terminal bud decreased prior to panicle emergence in trees that flowered and increased during the same period in trees that remained vegetative. This suggests that GA plays a direct inhibitory role in mango floral initiation. Our recent study clearly demonstrated that paclobutrazol treatment reduces the concentration of various forms of GA (GA4, GA3, GA7, and GA1) content in both leaves and buds, with buds being more sensitive to paclobutrazol treatment. Paclobutrazol, in addition to affecting gibberellins, increases ABA and cytokinin contents in mango buds, as well as the C: N ratio and leaf water potential, in order to elicit flowering responses.

Root activity and nutrient dynamics
In paclobutrazol-treated mango, there is a significant increase in root activity towards the trunk and close to the soil surface, but less root activity in the subsoil zone. Paclobutrazol has an inhibitory effect on soil nutrient status and microbial population at higher concentrations. The effect of paclobutrazol on leaf nutrient content is inconsistent, as it varies with crop geometry and soil conditions.

Off-season flowering and fruiting
Paclobutrazol is the most widely used chemical for commercial off-season flower induction and fruit production in many mango growing areas, whereas early flower induction in the subtropics is possible but has no commercial value due to flower initiation when temperature regimes are not suitable for fruit development. Where paclobutrazol can successfully induce early crop, precise cultural operations are required to support advanced fruit harvesting and warrant induction of vegetative shoots for their sustainable conversion to flowering shoots to bear regularly.
Residual effect and risk assessment of paclobutrazol

Long term effect on plant growth

Paclobutrazol is a persistent plant growth regulator with a long history of prolonged persistence in soil and primarily translocated in the xylem through the stems and accumulated in the leaves. However, no basipetal movement is reported. PBZ exhibits differential genotypic effect in mango as residue persist in soil of Dashehari orchard could regulates the fruiting with its half dose in the second year. Increasing dose of PBZ application in mango caused reduction in length of new shoots produced. Reduction of root hydraulic conductivity, alteration in nutrient uptake and morphological alteration in young roots and shoots are observed after PBZ treatment.

Residual effect on fruits

Higher persistence in soil does not match with its residue level in mango fruits which might be due to the biodegradation of PBZ or decreased hydraulic conductivity of leaves and thereby reducing its translocation to fruits. Its residue was detected in unripe mango fruits (cv. Dashehari) below its MRL value of 0.5 mg/kg, the same was not found in fully mature fruit and its pulp. Use of paclobutrazol in mango continuously at recommended doses may not result in its residues in mango fruits at harvest levels which may pose any risk to human health. However, in areas where paclobutrazol is applied regularly, there may be risk of environmental contamination due to its residues persisting in soil for a very long time.

Degradation and persistence in orchard soil

In India, PBZ has been reported persistent from 210 to 300 days in mango orchard soil of different locations. In Southern India, PBZ has been found persistent up to 210 days in 0-15 cm soil layer after its application at 5 and 10g a.i./tree. Prolonged persistence of PBZ in mango orchard soil up to 3 years was also observed from the highest dose (1.0 mg/kg at 8 g a.i./tree), which was found sufficient for inducing flowering in Dashehari and discontinuation of its application or lowering the dose in subsequent year was suggested. Paclobutrazol has a history of prolonged persistence in soil which makes it susceptible for microbial degradation. A microbial consortium having *Pseudomonas* sp. was found effective in degrading PBZ.

Precautions

1. Wear gloves and a mask over your mouth when using paclobutrazol. Smoking and eating should be avoided while using paclobutrazol.
2. Paclobutrazol has the potential to cause minor skin and eye irritation. After use, thoroughly rinse the skin and eyes with water.
3. Because treated soil is likely to be washed away by rainfall or irrigation runoff, extreme caution should be exercised when applying soil, particularly in orchards located in sloppy areas. Extreme caution should be exercised in such areas to prevent contaminated soil from eroding into bodies of water. Furthermore, in such cases, terracing and bunds may be an effective approach.
4. Do not pollute water sources with empty cans of paclobutrazol that have been left out after use.
5. Excessive paclobutrazol use can harm mango orchard soil health, particularly the fauna and flora found in this ecosystem, resulting in low quality fruit production.
6. Paclobutrazol has a remote chance of contaminating the environment due to its low mobility and high persistence, but the risk cannot be completely eliminated. To significantly reduce residue threats, it is recommended that the optimal dose be used at the appropriate time, and that the amount of paclobutrazol applied the following year be based on the residue available in orchard soil.
7. Increased paclobutrazol concentrations cause panicle compaction, which creates ideal conditions for disease and pests while also complicating phytosanitary control.

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Diversifying mango orchards with compatible understorey crops for enhanced profitability

Mango orchards occupy 6.5 million ha area in our country. Monoculture of agricultural crops poses several problems pertaining to productivity and profitability. Mango orchards offer unique scope for integration of compatible intercrops for enhancing orchard productivity and farmers’ income. Diversifying agriculture and horticulture is the only alternative left for enhanced productivity and profitability under the burgeoning population pressure as there is little scope for expanding area due to declining man to land ratio.

Mango is an evergreen tree which bears on mature shoots. In northern India, commercial cultivars like Dashehari, Langra and Chausa have excessive vegetative growth, often with a tendency to bear heavily in alternate years. Research work done during the last few decades has proved that mango trees, if pruned and managed properly, ensure higher productivity and fruit quality in addition to ensuring light for growing under-storey crops. For this purpose, old and unproductive orchards of 40 years and above need rejuvenation, while mid-age orchards with an age ranging from 15 to 35 years are managed through centre openings. As mango growing belts offer unique scope for integration of various shade tolerant tuber crops like turmeric and elephant foot yam, growing these crops in mango orchards is a source of additional income if managed properly.

Centre opening

The term ‘centre opening’ refers to thinning out or removal of a centrally located, top most, upright growing branch or portion of branches in the center of the tree to facilitate light penetration inside the canopy. This is recommended for mid-aged orchards, i.e. in the age group of 20-35 years. The best time for the operation is between December and January. It not only facilitates light penetration into the tree canopy, but also reduces tree height, improves fruit size, the quality of fruits and facilitates the growing of intercrops successfully. In the initial years of orchard establishment, it is easy to grow crops in the interspaces as there is no competition for light, but in later stages, tree canopies are managed with a centre opening in such a way that it facilitates the growth of intercrops.

Orchard preparation for inter-cropping

If we wish to grow intercrops in a mango orchard, first of all, efforts are made to level the orchard area by ploughing and levelling the field. Provision of drainage by making drainage lines is a must for the success of intercrops as water stagnation and high humidity lead to the incidence of various diseases, resulting in a huge loss to the farmers. Well rotten farm yard manure @ 25 to 30 MT/hectare should be applied invariably before sowing of any tuber crops like turmeric, elephant foot yam during summer. FYM is also applied to standing crops before weeding and earthing them during the rainy season. As stated earlier, mid-aged trees are pruned in such a way that they are centrally opened to facilitate sufficient solar radiation for the success of both the main crop as well as the intercrop. While sowing or planting, care is taken to avoid any sowing or planting in the tree basin area up to 2-2.5 m away from and around the tree trunk. A basin is prepared around the tree trunk for irrigation and other purposes. Thus, approximately 70-80% area of the orchard is available for intercropping depending upon the age of orchard. The cultivation practices for these crops are given below.
Growing turmeric (*Curcuma longa* L.) in a mango orchard

Turmeric has immense potential for growing as an intercrop in mango orchards as it tolerates shade to a great extent. Sandy loam soil is considered the best as it facilitates the growth of the rhizomes.

Turmeric varieties, viz. Rajendra Sonia, Narendra Turmeric-1, Narendra Turmeric-2, Narendra Turmeric-3, are popular in Uttar Pradesh. Other varieties, like Suvarna, Suguna, Sudarsana, IISR Prabha, IISR Prathibha, IISR Alleppey Supreme and IISR Kedaram from ICAR-IISR, Kozhikode, Kerala; Co-1, BSR-1, BSR-2 from TNAU, Coimbatore; Roma, Suroma, Ranga, Rasmi and Surangi from OUAT, Odisha; Mega Turmeric-1 from ICAR Complex, NEH region Meghalaya; Kanti, Sohba, Sona and Varna from KAU, Thrissur and Sugandham from Sardarmkrushinagar Dantiwada Agriculture University, Jagudan have also been recommended for cultivation in different parts of the country. Varieties recommended for the region should only be selected for intercropping.

The soil is brought to a fine tilth by ploughing and planking. Fertilizers should be applied based on soil test. In general, a dose of 100-120 kg nitrogen, 60 kg phosphorus and 60 kg potash is sufficient for one hectare of orchard area. Full dose of phosphorus, potash and half dose of nitrogen is given as basal dose at the time of sowing while rest nitrogen is applied as top dressing in two split doses, first at 35-40 days and second 75-90 days after sowing.

Planting should be done in orchard by making furrows and ridges. Well developed, healthy, disease free, split mother or finger rhizomes are used for planting. A seed rhizome of around 20-30 g weight and with at least 3 nodes is ideal for sowing. These rhizomes should be treated with mancozeb 0.3% (3 g/liter of water) for 30 minutes, shade dried for 3-4 hrs and planted. A seed rate of 1500 kg/ha is sufficient for intercropping in an orchard. Ideal time of sowing in the orchard is April-June. Seed rhizomes are placed 5 cm deep in the soil and covered. Crop should be mulched immediately after planting with leaves.

Weeds should be removed by regular weeding as and when they appear. Three to four weedings are sufficient. Regular irrigations are given at 10-20 days interval depending upon soil moisture content and weather conditions. Turmeric is ready for harvest in 6-9 months depending upon variety and time of sowing. On maturity, the leaves turn yellowish to light brown in colour and dry. Harvesting is often done manually using pick axe. For manual harvesting, land can also be ploughed, the clumps carefully lifted with spade and rhizomes are gathered by hand picking. Rhizomes are collected removing all the extraneous material adhering to it. Turmeric when grown in a mango orchard if managed properly give an average yield of 10 to 15 tonnes/ha.

Farmers in the demonstrations conducted at their field in Malihabad mango belt obtained an average yield of 12-15 tonnes with Narendra Turmeric-2 while the yield was
higher and up to 20-30 tonnes/ha with Sudarsan variety of turmeric. Economic analysis of mango+turmeric farmers gave a B:C ratio of 3.96.

**Elephant foot yam (Amorphophallus paoniifolius)**

Elephant foot yam is also known as suran, zimikand or ole in different parts of country. It gives high productivity and is a very remunerative intercrop as it tolerates shade very well. It has lot of medicinal uses though corms are mainly used for vegetable purpose or for pickle making. It has great demand in markets especially in Bihar, West Bengal and north eastern states besides northern India. It grows very well in tropical and sub-tropical regions. Well drained sandy loam soils are preferred for it.

‘Sree Padma’ from CTCRI and ‘Gajendra’ from ANGRAU are most commonly grown varieties in different parts of country. After preparing the land to a fine soil tilth, vertically cut corm pieces, each with a portion of apical bud are planted during February–March or April–May. Before planting, corms are field dried for 40-45 days. Whole corm size of 500 to 750 gram is generally recommended for use as seed for commercial cultivation but in case of non-availability, bigger size corms of 2-3 kg are cut vertically into 4-6 pieces, retaining a portion of central apical bud for sowing.

Generally, a seed rate of 2500 to 4000 kg/ha is sufficient for a mango orchard. Mini-sett transplanting planting using vertically cut pieces of 100 g has also been standardized which cuts down the requirement of seed corms drastically, reducing the cost of cultivation. One corm of around 1.5 kg can be cut vertically into as many as 15 vertical pieces-mini/sets of 100 g retaining a portion of apical bud. Sets after treating with fungicide or trichoderma enriched cow dung slurry are kept for drying for 24 hours before planting. The treatment helps in protecting the crop from collar rot. Ideal spacing for planting in a mango orchard is 60 cm (row-to-row) × 45 cm (plant-to-plant).

Sowing can be done either in pits or on ridges and furrows. Cut pieces of planting material are buried vertically in prepared pits or furrows, compacted and covered with soil and organic mulch. Earthing up is done after emergence of new shoots. As regards to nutrient management, a dose of 40 kg, 60 kg and 50 kg of NPK is applied 45 days after planting, while another dose of 40 kg N and 50 kg K is top dressed after one month of the first dose. Fertilizer application is followed by shallow inter-cultural operations like weeding, light digging and earthing up.

Crop is ready for harvest in 7-9 months after planting, however crop can be harvested after 6 months, looking to the better market price. There is great demand of elephant foot yam during Diwali festival season. Underground corms are harvested with pick-axe or by digging when the top leaves are completely withered and fallen. An average yield of 20 to 30 tonnes/ha can easily be obtained by intercropping it in a mango orchard depending upon the age of orchard and management.

Elephant foot yam was found more remunerative than turmeric in the demonstrations conducted at farmers’ field in Malihabad mango belt. Farmers obtained a corm yield of 20-25 tonnes/ha. Farmers were able to sell their produce in the local market at a price of ₹ 25-30/kg.

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Flowers always make people better, happier, and more helpful; they are sunshine, food and medicine for the soul.

– Luther Burbank
Why mango orchard based poultry farming?
Majority of mango orchards are raised as mono crop. The livelihood of mango growers depends solely on sale of mango fruits. Increasing production cost due to indiscriminate use of pesticide has led to distress particularly for small and marginal farmers. Failure of mango crop severely affects the livelihood options for farmers. There is need for diversification in mango orchards. Mango orchard ecosystem suits for rearing of poultry birds. Not only this gives farmers much needed income throughout year but it also reduces the pest load and reduces the need for pesticide which eventually reduces the cost of production.

How to start mango based poultry farming?
**Housing in mango orchards:** Housing is important for the birds as it protects them from extremities of temperature, rain, wind and predators. Shelters should be constructed in mango orchards in the dimensions of 4×3.5×8 or 12 ft (H×W×L) and can be extended as per the need using mud for wall, polythene sheet for roof and a small door made of wire mesh and waste materials.

**Suitable poultry strains for mango ecosystem:** Four poultry strains viz. CARI-Devendra, Nibheek, Shyama and Kadaknath, used in mango orchards, CARI-Nibheek and CARI-Shyama gave maximum eggs (175-185) and egg laying starts from 5th month onwards. CARI Devendra attains body weight of 1.5 kg in 4 months times. CARI Devendra and Shyama strains gain body weight faster and fetches ₹300-400 per bird. Kadaknath attains 1.5 kg in 7-8 months but fetches ₹800-1000 per bird in the market. Kadaknath was found to be very agile and controls mango pests from upper canopy.

**Feed for mango orchard based poultry:** Strains identified for mango-based poultry farming can scavenge/graze well for its feed in the mango orchard. During the process of grazing in the mango orchard these birds will feed on insects, green weeds, grass seed, etc. Feed supplementation in the form of scratches usually given in morning/evening. *Azolla* is also provided to birds as supplemented feed because it contains nearly 24% crude protein (with digestibility around 50%), besides being rich in minerals and vitamins. Depending on the availability of orchard area the requirement of supplemented feed varies 30-45 gm/bird/day.

**Age of orchard**
In young plantations, the sunlight availability is more. This makes ideal situation for *azolla* cultivation but comparatively poor situation for insect population. Use of dung and manure will invite more insects which may be a source for poultry. Therefore, space requirement will vary among new and old plantations. Generally 5-10 m²/bird space is sufficient if supplementary feeding is not done but if *azolla* is supplemented the space requirement will be drastically reduced. Furthermore, the agro-climate will also influence

**Night shelter for poultry**
the space requirement. In young plantations, if manuring and Azolla is practiced, the space requirement will be much lower and about 2-3 m²/bird space (grown) is sufficient.

**Improvement in orchard ecosystem**

The birds derived their food from the pupa, larvae, maggot and borers underneath the mango canopy, as a result the technology reduced the mango pest population and requirement for pesticide sprays. Certain bird strains such as Kadaknath exhibited high flight and fed on mango hoppers and leaf webber insect situated on upper canopy. Reduced weed population in mango orchards was observed owing to integration or rural poultry. Each bird in a mango orchard supplemented 45 kg manure in the form of droppings in its entire life cycle. Orchard having flock size of 500 birds gets around 225 quintal of poultry manure. Birds while scavenging, pulverized the soil and ensured better aeration. The mango orchards which integrated rural poultry were found to have improved orchard ecosystem requiring lesser pesticide which results in reduced cost of production.

**Sustainability of the system**

Many profitable models developed by researchers disappeared once the interventions dependent on outside input or lack of expertise stopped. Keeping in view the facts, this model was developed to have simplicity, easy adaptability and cost effectiveness. The shelters are sustainable for 3-5 years except replacing the polysheets, bamboo structures, etc. The capital investment is around ₹5,000-10,000 and thus can be easily adapted by resource poor farmers. Marketability is also not a problem as raw chicken or its products or produce have wide market acceptance everywhere. The only remaining input are chicks and Azolla. Azolla in north Indian climate can propagate itself in 2 seasons extending upto 8-9 months. Therefore, saving seed in extreme cold and hot situations, supportive techniques/ measures developed need incorporation in the system. It is discussed under feeding practices.

The main input is continuous chick supply in the system and it is still a major challenge. The lower egg production by parental stock and thus lesser chicks per hen limits the profitability of the commercial ventures. This is reason why private hatcheries are not producing the chicks needed for such system. Another factor is demand of chicks which can create interest of private entrepreneurs. The hatcheries in Government sector neither have the capacity nor the will to do so. As the demand will increase the local youth will come forward for entrepreneurship. Private hatcheries with established infrastructures and operational facilities will be compelling to participate and share the market demand as soon as the model adoptability will increase. In such scenario, following interventions are being recommended/ adopted locally wherever, the models are being practiced by farmers.

**Constraints in integrating rural poultry with mango orchards**

1. Low productivity
2. High mortality rates in tropical conditions
3. Presence of common predators such as dogs, cats, snakes, eagles, hawks and thieves
4. Lack of veterinary healthcare and extension services
5. Unavailability of small hatchery units to cater the need of chicks.

**Augmenting income through mango based poultry farming**

Farmers realized the net returns of ₹ 1,71,828 per acre by integrating rural poultry in mango orchard which was higher in comparison to non integrated orchards (₹12,223 per acre). The returns per rupee of expenditure of mango orchard-based poultry farming was significantly higher (1.96) as compared to mono-crop of mango production which registered lower returns per rupee of expenditure (1.21).

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Strategies for organic production of mango

Indiscriminate use of agro-chemicals in mango production has resulted in various environmental and health hazards along with socio-economic problems. The degenerative effects of agro-chemicals based farming practices have forced for alternative system of farming. However, high cost of chemical fertilizers, their toxic effect on fruit quality and health of soil has prompted to find out alternative source(s) of nutrients. In general, 4-6 sprays of pesticides are being done in mango production. Presence of residual toxicity of agro-chemicals is one of the major bottlenecks in capturing international markets. In mango crops, there is ample scope of organic farming and produce so obtained, is of superior quality and safe for health. Sometimes quality of externally sourced organic inputs is doubtful and they are also not cost effective. Therefore, emphasis for on-farm production of organic inputs is to be given to maintain the quality as well as cost effectiveness.

Nutrient management

In newly planted mango plants (1-5 years), 10-20 kg of well decomposed compost is applied 0.3 meter away from the trunk in trench during the month of September-October. About 3-4 inch thick mulching with orchard’s organic wastes is done in basin. In 10 or more than 10 years old tree 30-40 kg vermi/biodynamic compost is applied one meter away from the trunk in trench and trench should be covered with soil during the months from July-September. Basin should be mulched with on-farm available organic wastes and drenched with 20% jeevaamrita twice in the year i.e. before rainy and after season. Tree trunk should be pasted up to the height of 1.5 meter from ground level with biodynamic tree paste twice in a year for the management of gummosis and stem borer. Foliar spraying of vermiwash (50%) is also helpful for better growth, flowering and fruiting.

Insect pest management

Mango hopper

Incidence of mango hopper occur during flowering and fruiting. Severe incidence causes fruit drop and heavy loss to the growers. Adult insects secrete honey dew on the leaves which causes incidence of black shooty mould. Infected leaves become black and photosynthesis is affected due to black layer of mould developed on upper surface of leaves. For the management of mango hopper, spraying of bio-pesticides should be done at the time of panicle emergence. First spray should be done with biodynamic liquid pesticide. Afterwards neem seed extract (4-5%) should be done. 4-5 sprays of neem based bio-pesticide have been found effective for the management of mango hopper.
Mealy bug

Nymph of this insect crawl on the tree during the month of December-January and suck the sap from small fruits, new leaves and causes fruit drop. For effective management of this insect 20-30 cm wide polythene is wrapped on the trunk one feet above the ground. Both the upper and lower ends of polythene are pasted with grease which protect the nymphs from climbing on the tree. Hoeing of mango basin during September-October also kills the eggs of the insect. Application of 250 g of Beauveria bassiana in the basin of tree during December-January has also been found beneficial in management of mealy bug.

Fruit fly

Fruit fly incidence is common in late maturing mango varieties. Female fly lays egg in the fruit and after hatching of egg, larva start eating fruit flesh which leads to rotting of fruits. For the management of fruit fly, all the infected fruits are to be collected and buried in soil. Hanging of 4-5 pheromone traps per acre also helps in management of fruit fly incidence.

Stem borer

Maximum incidence of stem borer occurs during rainy season. Incidence of stem borer is very common in old and senile mango orchards. Insect makes hole in the trunk and eat the xylem part vigorously, which causes slow dying of the tree. For the management of stem borer, hole should be cleared with thick iron wire or spike of the bicycle and plucked after insertion of cotton soaked with neem oil or petrol.

Tent caterpillar

Caterpillar makes bunch of leaves of new shoots during rainy season and eats new leaves. In severe incidence, tree shows burning appearance, which affect flowering, and fruiting in coming season. For the management of tent caterpillar, removal of tent with tool is necessary and removed bunches of leaves should be destroyed. After removal of leaf bunch 2-3 spraying of biodynamic liquid pesticide/neem seed extract have been found effective in management of tent caterpillar.

Powdery mildew

Symptoms of powdery mildew can be seen on leaves, panicles and fruit with appearance of white powder. Affected panicles and fruits dry up and fall on the ground. Foliar sprays of bioynamic preparation-501 (13g/100 liter of water)/lime sulphur (2%) have been found for the management of powdery mildew.

Anthracnose

Black spots are developed on the fruits and leaves after incidence of anthracnose. The size of these spots increases with time. After harvesting of fruits, black spots develop in storage and cause severe loss due to rotting of fruits. Hot water treatment (52°C) for 10 minutes helps in management of disease. Pre-harvest foliar spraying of copper oxychloride/bordeux mixture (2%) at the interval of 15 days is also helpful in management of anthracnose.

Gummosis

Oozing of gum from the trunk and branches causes drying of the tree. In severe case trees start dying back and ultimately dies after few months. For the management of this disease, pasting of affected part with biodynamic tree paste has been found helpful. After cleaning of gum, pasting of affected part with bordeaux mixture/copper oxychloride has also been found helpful. Pasting of tree trunk of healthy trees with biodynamic tree paste twice in a year is also effective in management of gummosis.

Panicle midge

Midge incidence commonly occurs on panicle and new leaves. Adult makes hole in the panicle for egg laying. After hatching of eggs, larva comes out and eats the tissues of the panicle. In severe incidence panicle dries up. Foliar application of 20% biodynamic liquid pesticide/neem oil (3%) at the interval of 7 days has been found effective in management of midge.

Thrips

Thrips incidence occur at the time of flowering and fruit setting during April and May. In severe cases brown spots develop and size of spots increase with time, growth and development of fruits significantly affected and fruits become unmarketable. For effective management of this insect, 2-3 foliar sprays of biodynamic liquid pesticide/3% neem oil at the interval of 7 days is recommended.
Mango malformation

Mango malformation is an important problem of mango in north Indian conditions. It causes maximum economic loss to Mango growers. In nursery, it affects the growth of grafted and seedling plants. Floral malformation affects the growth of panicles in bearing trees. Vegetative and floral malformation both affect the growth, development, and yield of plant. In seedling plants, leaves are converted into the bunch and affect the growth and development. In floral malformation, panicle becomes malformed and persist for longer time on the plants. Affected panicles bear no fruit. Pruning and burning of malformed panicles every year, reduces the occurrence in coming year. Pruning and burning of vegetative malformation is also recommended for minimizing the incidence. Plant propagation from affected mother plants should be avoided to reduce this disease.

Brief accounts of organic production of mango and possibilities of their integration to develop organic farming package of practices are enumerated below.

Salient features of organic production

- Proper habitat development around orchards by encouraging wide range of plantation i.e. trees, shrubs, water bodies, for providing congenial atmosphere, proper ecosystem creation and biomass production.
- Establishment of young orchard and its management with organic inputs.
- Encouraging mixed farming by inclusion of annual crops and short duration fruits such as papaya, guava, drumsticks, etc. as per soil, climate, family and market demand.
- Nutrient management through organic means, i.e. use of composts, leaf mould, bio-enhancers, mulching and need base foliar sprays of bio-pesticides.
- Pests and disease management with organic techniques.
- Rejuvenation of old orchard and organic management.
- Promotion of export quality varieties and organic production to capture export market.
- Integration of post-harvest handling and processing with organic techniques.

Nutrient management

- Growing of legumes for green manuring or as inter/cover crops as per requirement in young orchards.
- Application of organic manures (30-40 kg/tree) through NADEP, vermi/biodynamic after fruit harvest in trench 1.5 meter away from the trunk in 10 or more than 10 years old trees.
- Mulching after application of 100 g CPP, spraying of cow horn manure (BD-500)/3% of Panchagavya/20% Jeevamrita/Amritpani.
- Two foliar spraying of biodynamic liquid manures/vermi-wash at the interval of 15 days after fruit harvest for proper growth and development.

Insect pest management

- Spraying of biodynamic liquid pesticides as per requirement and experience.
- Nettle leaves extract sprays to manage hard pests like mango hopper, mites, etc.
- Use of NSKE for the management of mango hopper.
- Application of tree paste for repelling stem borer twice in a year i.e. before and after rainy season.
- Manual killing of stem borers, injecting neem oil and plugging bores with clay soil during September -October.
- Use of pheromone traps for the management of fruit fly in late maturing cultivars.
- Biodynamic tree paste/cow dung paste for the management of gummosis and dieback.
- Two sprays of cow horn silica (BD-501)/2% wettable sulphur/lime for the management of powdery mildew.
- Spraying of horsetail (Equisetum arvensis)/casuarina leaves extract for the management of other fungal diseases.
- Spraying of 2% bordeaux mixture for anthracnose and 2% lime sulphur for powdery mildew management.

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Rejuvenating old and unproductive mango orchards for enhanced farmers’ income

India is a leading mango producer, producing 21.80 million MT from 2.25 million ha, accounting for 45% of total fruit production in India. Though India is a major mango producer, exports are extremely limited due to quality factors. The main concern about mango export is poor quality standards, which limit India’s share of the international market. Old and unproductive orchards with huge tree size and without proper canopy management is the major reason responsible for poor mango productivity and quality, especially the fruit size. Such orchards account for 35-40% of total area in mango growing belts.

FRUIT trees, invariably, after a certain period of successful production, have a tendency to lose their productivity and quality, making the orchards unproductive and non-remunerative. Replacing the old and senile orchards through replanting is a long term strategy which requires many years to reach the desired level of productivity. Rejuvenation technology for such unproductive trees offers many benefits, such as early and quality production from such trees through better light penetration and efficient utilization of available space and inputs. Keeping this in view, a technology for rejuvenating old and unproductive mango orchards has been developed at ICAR-CISH, Lucknow, refining the old rejuvenation technology, developed around 20 years back.

Identification of unproductive mango orchards for rejuvenation

If yield records show that trees have consistently performed poorly over the last five years. Besides this, trees which have grown over-size, become dense with branches crossing each other, allowing little sunlight to penetrate inside the canopy and fruiting limited only to the outer periphery. Such orchards, at around 45 to 60 years of age, are ideal for rejuvenation. Very old trees with low vigour, or with hollow stem, heavily infested with pests and diseases or poorly performing trees due to poor soil and climatic conditions may not be suitable for rejuvenation.

Constraints faced in old mango rejuvenation technology

The technology developed by ICAR-CISH, Lucknow was disseminated widely in various mango growing belts of the country through State Horticulture Departments, besides the National Horticulture Board and the National and State Horticulture Missions. Mango tree mortality rates of up to 40-50% have been reported in many areas due to a heavy infestation of stem borers. The study of such cases revealed a lack of proper after-care of orchards, especially after the cutting of primary branches for the induction of new shoots. The farmers with relatively small land holdings who could manage the infestation of stem...
borer with the recommended measures were successful, while, the farmers, who neglected the orchards after hard pruning suffered. Many times, it is not possible to manage the stem borer infestation on a large scale in big orchards. Besides, when we go for such rejuvenation, farmers lose the crop in the initial 2-3 years due to shoot growth and canopy development. Keeping this in view, efforts were made to further refine the technology for enhanced success and profitability.

**Refined mango rejuvenation technology**

Work done at ICAR-CISH, Lucknow during recent years has helped in understanding the problem and further refining the technology without any mortality of plants due to stem borer infestation. Besides that, technology has also ensured continuous income from the orchard without losing the crop completely. The following are the technological steps:

1. The orchards are identified on the basis of their consistent performance and growth of the canopy, as stated earlier.
2. First of all, the centrally located upright growing branch of the tree, if present, is thinned out completely. This branch will be removed from the point of its origin without leaving any portion of it. Thus, efforts are made to have a canopy open in the centre, which facilitates light penetration inside the canopy. In north India, the best time to prune mango trees is between December and mid-January.
3. Three to five wide-angle primary branches well distributed on all sides are selected for the development of the canopy in the years to come. All other branches growing very low in height and interfering with the cultural operations or intermingling with the selected branches will also be removed from the point of their origin.
4. After thinning out the central leader in the first year of operation, two primary branches opposite to each other and located on the top are headed back, leaving a stump of 1-1.5 m for secondary branch regeneration. All of the remaining selected branches will be kept for fruiting. The cut portions will be smeared with a fungicidal paste/Bordeaux paste which facilitates the healing of cut portions without any further infection.
5. In the second year, the next two branches are headed back in a similar fashion, leaving the stump behind them. Only healthy shoots growing in the proper direction are allowed for canopy development, while others are thinned out. The remaining branches are headed back in the third year, and the plant is ready for fruiting in the third year. In the first year, fruit yield of 100 to 150 kg while in second year 20-50 kg/tree was obtained. In the third year, a fruit yield of 20-30 kg was obtained from the newly developed canopy after the removal of all the old primary branches. The fruit yield increases thereafter with an increase in the canopy size.
6. Fertilizer application, viz. 2.5 kg urea, 3.0 kg single super phosphate and 1.5 kg muriate of potash along with 50-100 kg of well rotten farm yard manure (FYM) should, as recommended for mango orchards, be applied. A full dose of FYM is applied just after harvesting during the rainy season. Half dose of nitrogen, full dose of phosphorus and half dose of potash is applied in September while remaining
Orchard before rejuvenation

Revised rejuvenation technique demonstrated at Sitapur

dose of nitrogen and potash is recommended for application just after fruit setting.

7. Thinning of excessive shoots arising from cut stumps is done during April and June to allow only 5-8 healthy shoots per branch for ideal canopy development. Monitoring and management of stem borer, leaf eating insect pests or fungal diseases is a must for success. During the summer, irrigation is applied at 15-day intervals from fruit setting to fruit maturity.

8. No mortality of trees/primary branches was observed due to stem borer infestation in case of this rejuvenation technology. Farmers' fields have been used to test the technology.

Demonstration of technology-An experience

This new refined mango rejuvenation technology was also demonstrated in a farmer’s field in Udhwapur village, Sitapur district, Uttar Pradesh. The farmer had more than 60 years old 85 mango trees of cultivar Dashehari, which had a huge canopy with poor productivity. After obtaining permission from the state department, the rejuvenation work started in December 2018 with the heading back of selected two branches and the removal of the top upright growing branch. A total of 85 trees were subject to the rejuvenation. After cutting the branch, anti-fungal paste was smeared as recommended. Stem borer infestation was easily managed with cleaning of holes and localized application of dichlorvos/kerosene/petrol soaked cotton in the holes wherever observed. There was no tree/primary branch mortality, so the success rate was 100%.

The fruit yield recorded in the first year (2019) was in the range of 118-160 kg/tree, while it was between 80-142 kg/tree in the second year (2020). The third and final cutting of remaining primary branches was done in December 2020 and a fruit yield of 18-26 kg/tree was observed in 2021 from ten trees out of 85 trees as all the old primary branches were removed for shoot development. For nutrient management, a fertilizer dose of 1 kg urea, 4 kg SSP and 1.0 kg MOP is applied every year by the farmer in the month of September and 1 kg each of urea and MOP is also applied in March–April just after fruit setting. Farmers also use organic liquid manure and bioagents such as *Beauveria bassiana* and *Trichoderma* on a regular basis.

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Small tractor mounted hydraulic platform

The development of suitable matching equipment for small tractor is of prime importance due to small fragmented land holdings, hill agriculture, shifting cultivation and lack of mechanization for leading horticultural sector. The operating height of the machine is 3 m (10 feet approx.). Overall dimension of the system is 3,000 × 1,500 × 1,450 mm, it weighs 700 kg and its load carrying capacity is 150 kg. Spraying system (500 l tank capacity) is attached with platform for application of fungicides/pesticides from top of the plant aiming at uniform distribution over the canopy. The field capacity and field efficiency of the machine is 0.3 ha/h and 85%, respectively for orchards having 6 × 6 m plant geometry. Cost of the equipment is ₹ 400,000. Operating cost of the equipment is ₹ 6,520/ha. The developed system can also be used for other operations in orchard crops like pruning, spraying and fruits plucking.

Source: ICAR Annual Report 2020
Conservation of mango insect pollinators

Mango is the country’s most important commercially grown fruit crop. Millions of farmers rely on this important fruit crop for their livelihood. Because of pollination, farmers in several important mango-growing areas in India are unable to harvest their crops even after abundant flowering. Mango productivity is highly dependent on pollination in some areas. Mango orchard pollination has become a challenge as a result of excessive pesticide use and ecosystem destruction. Pollinator deficit is one of the many factors that contributes to mango’s low productivity.

Mangoes produce male and hermaphrodite flowers. The tiny red-yellowish flowers with five sepals and three to nine (usually five) petals. Petals are small and are not much attractive to insects. The flowers are arranged on the branched and clustered panicles that range in length from 10 to 45 cm. A single tree can have between 200 and 3,000 panicles, each with 500 to 10,000 flowers. A significant proportion (30–80%) of flowers are imperfect or staminate (i.e. lacking a style and therefore incapable of being fertilized). Flowers in their ideal state have a globular ovary and lateral style, as well as one to three functional stamens. As compared to staminate flowers, white flowers are too less in number. Only a small percentage of perfect flowers bear fruit (zero to three per panicle).

The fragrant flowers open early in the morning, immediately produce nectar and are pollination-receptive. Pollen shedding occurs slightly later, peaking between 8 AM and noon. Numerous pollinators visit the flowers, including flies, wasps, wild and domesticated bees, butterflies, moths, beetles, ants, and other bugs. Despite this prominent visitation, early reports indicated that mangoes were pollinated by wind. While some of the disagreements centre on cultivar differences, the several evidence indicate that insect pollinators, in particular, play a critical role.

Insect mediated pollination in mango

The mango’s ability to attract insects by producing nectar also indicates that it is entomophilous. Mango flowers are unspecialized, allowing most insects to pollinate them. These pollinators are necessary for the fruit set to be successful. Flies, wasps, bees, butterflies, moths, beetles, ants, and other bugs visit mango flowers to drink the nectar, and some of them transfer pollen, but there is some self-pollination as well. According to observations, the most important floral visitors are Diptera (Syrphid flies and house flies), Hymenoptera (Honeybees, stingless bees, bumblebees, solitary bees, and other non-apis bees), Lepidoptera (Moths and Butterflies), and Coleoptera (Beetles).

In India, researchers looked into the types and biology of mango pollinators and discovered that Diptera and Hymenoptera insects play a significant role in mango pollination. A few examples of insects that visit mango flowers are listed in Table 1. The table shows the common and scientific names of the insects, the order and family to which they belong, and the floral visitors that are important for mango fruit set.

### Table 1. Diversity of the insect visitors/pollinators on mango flowers at Lucknow

<table>
<thead>
<tr>
<th>Common name</th>
<th>Scientific Name</th>
<th>Order: Family</th>
</tr>
</thead>
<tbody>
<tr>
<td>Little honey bee</td>
<td><em>Apis florea</em> Fab.</td>
<td>Hymenoptera: Apidae</td>
</tr>
<tr>
<td>Stingless bee</td>
<td><em>Tetragonula iridipennis</em> Smith</td>
<td>Hymenoptera: Apidae</td>
</tr>
<tr>
<td>Giant honey bee</td>
<td><em>Apis dorsata</em> Fab.</td>
<td>Hymenoptera: Apidae</td>
</tr>
<tr>
<td>Indian honey bee</td>
<td><em>Apis cerana indica</em> Fab.</td>
<td>Hymenoptera: Apidae</td>
</tr>
<tr>
<td>European honey bee</td>
<td><em>Apis mellifera</em> L.</td>
<td>Hymenoptera: Apidae</td>
</tr>
<tr>
<td>Blowflies</td>
<td><em>Chrysomya</em> sp.</td>
<td>Diptera: Calliphoridae</td>
</tr>
<tr>
<td>Syrphid fly</td>
<td><em>Syrphus corollae</em> Fab.</td>
<td>Diptera: Syrphidae</td>
</tr>
<tr>
<td>Syrphid fly</td>
<td><em>Eristalinus</em> sp.</td>
<td>Diptera: Syrphidae</td>
</tr>
<tr>
<td>Housefly</td>
<td><em>Musca domestica</em> L.</td>
<td>Diptera: Muscidae</td>
</tr>
<tr>
<td>Wasp</td>
<td><em>Vespula orientalis</em> L.</td>
<td>Hymenoptera: Vespidae</td>
</tr>
</tbody>
</table>
pollination. Insects are thought to play a 53% role in mango fruit sets. The removal of flying and crawling flower visitors from mango panicles reduced fruit set by 79%.

Pollinator population declines, both in natural and agro-ecosystems, have recently become a matter of concern. Large-scale insecticide use, clean cultivation, large tracts of monocropping, lack of off-season flora, and climate change are all contributing to pollinator decline.

The pollinator density in commercial orchards is significantly lower than in undisturbed orchards, according to surveys conducted by ICAR-CISH under the NICRA (National Initiative on Climate Resilient Agriculture) project in major mango-growing areas of the country.

**Insect pollinator conservation is critical in the mango ecosystem**

Though the practice of introducing honey bee colonies to achieve pollination is popular, it has limited application in mango because of the efficiency of hive bees, such as *Apis cerana* and *A. mellifera*, in mango pollination, is often questioned due to the small amount of pollen produced by mango. Scheduled insecticide sprayings to control leafhoppers and inflorescence caterpillars during the blossom period make introduced honey bees vulnerable, resulting in colony desertion and thus limiting their economic viability. Aside from the cost, another important limitation for the large-scale use of bee colonies in mango orchards is the availability of an adequate number of colonies within a reasonable distance.

**Pollinator conservation strategies in mango orchards**

- Protection and encouragement of alternative nectar sources for pollinators. Nature is full of pollinators; however, the concern is how to attract them to the orchard. There are two suggested ways, first, make some artificial attractant bait stations in the orchard so that surroundings pollinators are attracted. The second is to bio-intensify the orchard with pollen and nectar-producing flora like lucerne, *Cassia occidentalis*, *Cassia tora*, Indian Senna, Cotton, *Vicia angustifolia*, cowpea, maize or lantana, etc.
- Provision of protection and encouragement of pollinators by developing entomophagy parks in orchards where round the year pollen and nectar are available for pollinators.
- The modern generation insecticides like neonicotinoids are reported to cause great damage to pollinators in mango. These chemicals are widely used to protect the mango crop from hoppers at the flowering stage which is the crucial pollination stage. There is an array of other chemicals which are relatively less harmful to pollinators. These chemicals may be assessed for their efficacy to the hopper and their safety to pollinators. The schedule of the spray on the mango for the management of major pests may be modified in line with the pollinator’s safety.
- Restricted weeding and weeding operations within orchards may lead to the growth and maintenance of various kinds of weed flora. Being small heightened these weeds have no competition with mango rather enrich underground soil with various kinds of root exudates and multiplication of underground flora and fauna. On the other hand, these weeds give pollen and nectar to harmless insect conservation. These insects help in pollination in the main season.
- As such, there is a need to re-define the mango production system in light of improving the insect-mediated pollination in the mango ecosystem.

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Severe disease challenges faced in mango production

Mango is plagued by a number of diseases, only a few of which are serious enough to cause crop loss or even tree death due to infection. Mango is home to hundreds of pathogens, some of which are worldwide, some are localized, and others are only present on rare occasions. Some pathogens are seasonal, while others are active year-round, depending on the susceptible phenological stages and weather conditions. Climate change has accelerated the spread of new diseases while also reducing the severity of existing ones. The major disease challenges in mango production are described for the benefit of growers in the current mango production scenario.

DISEASES are one of the major challenges behind the low productivity of mango. Among a large number of diseases, wilt, decline, twig drying, dieback, blossom blight, powdery mildew, anthracnose and shoulder browning are of economic importance and are responsible for severe losses. In order to avoid significant economic losses, integrated disease management practices have been developed, refined and practiced. Recent trends in disease management have been based on awareness of toxic residues, export prospects and sustainability. The success of management strategy depends upon the knowledge of the causal agent, correct diagnosis and understanding of disease epidemiology, disease cycle and the critical level of infection for management actions. Major diseases of mango are described with necessary details.

Wilt and decline

The mango wilt and decline diseases are caused by the fungi, *Ceratocystis fimbriata* and *Berkeleyomyces basicola*, which are basically soil borne pathogens, but may be transmitted by planting material, wind, water, soil, human and beetles. The pathogens enter the host mostly through injured portions. Scolytid/ambrosia beetles (*Hypocryphalus mangifera* and *Xyleborus* spp.) are basically found in dead wood on mango trees and are attracted to *Ceratocystis* infected trees due to fruity odour of the fungus. They

Symptoms of wilt and decline (Fig. 1a. beetle infestation, b. wilt, c. decline, d. wood staining, e. gum oozing)
produce large amounts of fine wood shavings when creating breeding galleries in the trunk and branches, which contain spores and fragments of mycelium. Uncontrolled irrigation, intercropping, tree wounding, and improper fertilizer application all contribute to mango tree wilt. The infection of *C. fimbriata* in the main trunk of trees causes sudden wilt symptoms but infection of either of the pathogens in the roots causes a decline. The internal symptoms develop as dark staining of infected wood followed by exudation of gum from the trunk and branches (Fig. 1a-e).

**Management**
- Avoid damage to the roots, minimum tillage should be adopted and deep ploughing should completely be avoided in mango orchards. Intercrops should always be grown beyond the canopy area, especially if they are grown in young orchards.
- Wilt affected and nearby trees should be treated with thiophanate methyl 70WP @ 50-150 g or hexaconazole 5 SC @ 50-150 ml per tree according to the age of the trees as a soil drench.
- Infected or wilted branches should be cut and cut ends should be pasted with Bordo Paste (1:1:10) or 5.0% solution of copper oxychloride.
- The aerial portion of trees should be sprayed with tetraconazole 3.8 EW propiconazole 25EC @ 0.1% at the appearance of the first symptom.
- If an infestation of Scolytid beetles is observed in an orchard, it should be managed by spray of Malathion 50 EC @ 0.2 to 0.3% on the trunk at a 15 day interval.
- Irrigation must be done by a drip system or by using channels to avoid disease dispersal through water from infected trees to healthy trees.

**Dieback and twig drying**
Dieback or drying of the plant from the top downwards or random drying of twigs is caused by a wound parasite, *Lasiodiplodia theobromae*. High summer temperatures predispose the trees to infection during the rainy season and symptoms appear after the rainy season. Relative humidity of more than 80%, temperatures ranging from 26 to 32°C, and rain all contribute to disease development. The disease is characterized by dying back of twigs from top downwards, followed by complete defoliation (Fig. 2a). External evidence of a disease is discoloration or darkening of the bark on young green twigs. The leaves lose their healthy green colour and gradually turn brown. Cracks may appear on branches, which exude gum before they die. Twig drying takes place randomly on a part or on the whole tree (Fig. 2b).

**Management**
- Pruning of the diseased twigs 5-10 cm below the infection site followed by a spray of Bordeaux mixture (5:5:50) or copper oxychloride (0.3%) has been effective in managing the disease. However, extra care of trees for water and nutrition is necessary for better recovery.

**Blossom blight**
Blossom blight is a disease that affects plants all over the world and is caused by the fungi *Alternaria alternata* and *Colletotriculum gloeosporioides*. Blighted panicles may not bear fruit and, thus, the disease is of great economic significance. The symptoms appear during panicle development and flowering. The earliest recognizable symptoms of the disease are the production of blackish brown specks or spots on the peduncle and flowers (Fig. 3).
Small black spots appear in the open flower panicle, which gradually enlarge and often coalesce to cause the death of flowers, either directly or indirectly by the drying up of the flower stalks. The infected flowers fall off, leaving the more persistent spikes on the peduncles. The severity of the disease may vary depending on the prevailing weather conditions. A positive correlation between the severity of the blossom blight and rainfall, rainy days and the vapour pressure deficit has been observed. In dry weather, disease do not cause significant losses.

**Management**

Management efforts should be based on weather prediction and the possibility of economic damage. Disease can be managed by a spray of carbendazim (12%) + mancozeb (63%) formulation @ 0.2%, azoxystrobin 23SC @ 0.1% or propineb 70WP @ 0.2%.

**Powdery mildew**

Powdery mildew, caused by the fungus, *Oidium mangiferae* is a widespread, devastating disease. Its severity mainly depends on weather conditions and susceptible crop stage and available inoculum load. The infection is caused by wind-borne conidia, and the life cycle is completed in 5-9 days. Spore release was positively correlated with temperature and negatively correlated with humidity, vapour pressure deficit and leaf wetness. Minimum temperatures of 10-13°C and maximum temperatures of 27-31°C, combined with high humidity, were found to be the most conducive to disease development. Whereas, temperatures below 27°C and above 35°C do not cause economically significant losses.

The characteristic symptom is the white superficial, powdery appearance of fungal growth on inflorescences, stalks of the inflorescences (Fig. 4a), leaves (Fig. 4b), and young fruits. The mildew attack on mango flowers results in the dropping of the infected flowers. Infected young fruits either drop or if they grow, their epidermis in the infected area cracks and a corky tissue is formed.

**Management**

Since, the incidence of disease is weather dependent, spraying should be done only after the assessment of the possibility of economically significant damage. Sulphur 80WDG 0.2% or hexaconazole 5SC @ 0.1% can be used to treat it.

**Anthracnose**

Anthracnose disease, caused by the fungus, *Colletotrichum gloeosporioides* is a destructive and widespread disease. The fungus infects the entire mango tree, causing symptoms such as leaf spots, twig blight, wither tip, blossom blight, and fruit rot. Anthracnose losses have been estimated to be between 2 and 39%. Numerous oval or irregular brown or deep brownish spots of variable size, round or angular in shape, scattered over the leaf surface, are the characteristic symptoms (Fig. 5a). The spot may begin randomly on any part or on the whole leaf. Under damp conditions, the spots grow rapidly, forming elongated brown necrotic areas, which later rupture and give the older leaves a shot hole appearance (Fig. 5b). Young leaves are more prone to attacks than old ones. White tip symptoms are caused by infection at the tip of very young branches. Small fruits are also affected under favourable weather conditions (Fig. 5c). The infection is favoured by high humidity at moderate temperatures.
Conidia were observed to germinate and form appressoria between 95 and 100% relative humidity.

**Management**

In order to avoid fresh infection, the sources of infection should be eliminated. Diseased twigs, leaves, and fruits that fall to the ground in the orchard should be collected, and severely infected twigs from the tree should be pruned and burnt, as the fungus has a long saprophytic survival ability on dead twigs. Plants may be sprayed with suitable fungicides like copper oxychloride 50WP @ 0.3%, propineb 70WP @ 0.2%, carbendazim (12%) + mancozeb (63%) @ 0.2% or azoxystrobin 23SC @ 0.1% in places where the disease exists.

**Shoulder browning**

Shoulder browning disease is caused by the complex of *Colletotrichum gloeosporioides*, *Alternaria alternata* and *Capnodium mangiferae* during the monsoon months. The incidence of the disease has been recorded at up to 100% with a severity of up to 71%. Rainfall plays a key role in the development of the disease. Apart from rainfall, temperature, relative humidity and wind speed were found to be responsible for disease dynamism. The symptoms appear as depositions on the fruit’s shoulders (Fig. 6a). The deposit contains stains and spores of fungi existing on tree. The number and amount of rain gradually increases the deposition of spores and staining of the epicarp (Fig. 6b).

**Management**

Management of this disease is of great significance for the market value of fruits as well as for reducing the postharvest rotting of fruits. It can be controlled by bagging fruits, spraying with difenoconazole at a concentration of 0.05%, propineb 70WP at a concentration of 0.2%, or spraying oil at a concentration of 1.0%.

For further interaction, please write to:
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Mango insect pests and their integrated management strategies

Plant protection research is focused on integrating new tools and technologies into IPM in horticulture. The fruit sector in India recorded a growth of around 16% last year, compared to 12% for vegetables and 10.8% for food grains. When used in conjunction with other pest control measures, plant protection research in horticulture has produced many technologies, some of which have been standardized for commercial application and are claimed to provide better pest control and crop economics than conventional chemical control. Nonetheless, due to a variety of technological, socio-economic, institutional, and policy factors, the development and adoption of many of these technologies have been slow. Owing to the complexity of biotic stress in horticulture under changing climatic scenarios, technology generation, and other factors, testing and adoption remain a significant challenge, particularly given the constraints and limited ability of smallholding farmers. There have been overlapping IPM approaches in India, such as the traditional, exploitive/maximization phase, optimization phase, sustainable phase, and organic methods.

Farmers in the green revolution era are frequently overly ambitious in their efforts to achieve rapid plant protection results on their farms, resulting in the overuse and misuse of pesticides, which poses significant risks because they are carried out with only an immediate profit or production motive. Many concerns have emerged as a consequence of this, including excessive and untimely use of natural resources, insecticide resistance, pest resurgence, pest control failures, environmental and ecological imbalances, reduced biodiversity, and inappropriate input use. This article provides a brief overview of mango pests.

Almost a dozen insect pests have been noticed damaging the crop to a significant extent, causing severe losses, and may thus be classified as major pests of mango. The hopper, mealybug, inflorescence midge, fruit fly, scale insect, shoot borer, leaf Webber, and stone weevil are among them. Insects that infest the crop during the flowering and fruiting periods cause the most severe damage.

Hopper (Idioscopus clypealis, I. nitidulus and Amritodus atkinsoni)

The hoppers are the most damaging and prevalent of all mango pests. The tender plant parts are punctured and sucked into the sap by a large number of nymphs and adult hoppers. This affects the vigour of the plants. Hoppers also secrete a sticky, sweet substance that promotes the growth of sooty mold. Throughout the year, there is a low population of hoppers, but it spikes in February-April and June-August. Their multiplication is aided by the presence of shade and high humidity. Such conditions are common in orchards that are old, neglected, and densely planted.

IPM strategy
- Prune, avoid high-density planting, and regulate flushes by reducing input.
- Verticillium lecanii, Beauveria bassiana, Coccinellid beetles, spiders, reduviid keep the hopper population in check.
Spraying of Lambda cyhalothrin 0.0025% in mango orchards during the off-season (November), especially on the trunks.

Integrating chemical insecticides with neem products depending on hopper density. The first spray should be given at early panicle emergence with the following.

(i) At high hopper density (>4 hoppers/panicle), spray Imidachloprid 0.005% or Lambda cyhalothrin 0.0025%

Mealy bug (*Drosicha mangiferae*)

It is a serious pest that plays havoc on mango trees. The sap is sucked by nymphs and adults, lowering the plant's vitality. Honeydew is produced by them, which promotes the growth of sooty mold. After copulation, the female crawls down the tree in April-May to deposit eggs in great numbers covered with white egg sacs in the crevices in the soil. Until November or December, the eggs are in the diapause stage in the soil. The tiny newly hatched nymphs climb up the tree shortly after hatching. They begin sucking the sap of delicate plant parts after crawling up the tree.

**IPM strategy**

- Polythene (400 gauge) bands of 25 cm width around the tree trunk in November and December have been found to be an effective barrier to stop the ascent of nymphs to the trees.
- The entomogenous fungus *Beauveria bassiana* has been found to be an effective bio-agent in controlling the nymphs of the mealybug.
- The flooding of orchards with water in October kills the eggs and ploughing the orchards in November exposes the eggs to the sun's heat.
- If nymphs ascend on the tree, spray malathion 50 EC (0.075 %).

Inflorescence midge (Procontarinia mangiferae and Erosomyia indica Grover)

The midge damages crops in three stages. The first attack occurs when the floral buds burst, followed by fruit set and tender new leaves. The most destructive attack is the first, which destroys the entire inflorescence before flowering and fruiting. The flies deposit their eggs on the inflorescence. The minute maggots penetrate the tender parts and feed on them after hatching. The floral parts eventually dry and fall off. Pupation occurs when the mature larvae drop down into the soil. Between January and March, there are three to four overlapping generations of the pest. When the weather becomes unfavourable, the mature larvae go into diapause in the soil rather than pupating. They end their diapause in January of the following year.

**IPM strategy**

- Because the larvae pupate in the soil, ploughing the orchards exposes both pupating and diapausing larvae to the sun's heat, killing them.
- Spraying of 0.045% Dimethoate at the bud burst stage of the inflorescence has been found effective in controlling the pest population.

Fruit flies (*Bactrocera dorsalis* Hendel and *B. zonata*).

The oriental fruit fly is one of the most serious pests of mango in the country, causing problems with fresh fruit exports. The most common fruit flies are *Bactrocera dorsalis* and *B. zonata*. The female uses its pointed ovipositor to puncture the outer wall of mature fruits and insert eggs in small clusters inside the mesocarp of maturing fruits. After hatching, the larva feeds on the pulp of the fruit, which appears normal from the outside but eventually drops down. The mature maggots drop into the soil to pupate. The emergence of fruit flies begins in April, with the highest population recorded between May and July, which coincides with fruit maturity.
**IPM strategy**

- The soil is raked around and below the trees to a depth of 6 cm twice – Two weeks after the fruit reaches maturity and three weeks later.
- Ploughing may be done in the winter.
- Collection and destruction of fallen fruits weekly starting from the initiation of fruit maturity.
- Male Annihilation Technique (MAT) @ 10 blocks/ha starting from 45 days before fruit maturity. Replace the blocks after 30 days or even early.
- Bait Annihilation Technique (BAT) [0.1% insecticide, 10% jaggery or banana in water] starting 45 days before fruit maturity. Spray in spots of 40 ml at a rate of 200 spots (approximately 8 l/ha). Apply bait spray in spots to surroundings hedges also.
- One spray of Deltamehtrin 0.0014% + Azadirachtin (3000 ppm) @ 2ml/l three weeks before harvest.
- Avoid delays in harvesting and, if needed, give post-harvest hot water treatment within 24 hours after harvest.

**CISH OMAT fruit fly trap:** The technology is meant for fruit fly trapping. About 4.5×4.5×1.2 cm wood killing block impregnated with methyl eugenol and killing mixture, fitted in water/rainproof trap container of 1,100 ml capacity. It remains effective for 60-90 days depending on season.

**Hot water treatment or salt water treatment (VHT):** This procedure for fruits before storage and ripening to kill the larvae. After proper harvesting, select uniform-sized, undamaged fruits. Dip them in a 5% solution of sodium chloride in cold water for one hour. This will kill 95% of the eggs in the fruit epicarp and also remove the externally present pesticide residues. Post-harvest immersion of mango fruits in hot water at 48 ± 1°C for 45-60 minutes gives 100% mortality of fruit fly eggs in the epicarp without affecting the fruit quality.

**Scale insects**

Scale insects have assumed the status of a serious pest in certain parts of the country. Pulcinaria polygonata, Aspidiatus destructor, Ceroplastis sp. and Rastococcus sp. are some of the most common scale insects infesting the mango crop. The nymphs and adult scales suck the sap of the leaves and other tender parts and reduce the vigour of the plants. They also secrete honeydew, which promotes the growth of sooty mold.

**IPM strategy**

- Pruning of infested branches and burning.
- Around 40 species of predators and parasites have been reported to attack the scale.
- Chemicals used on scales that are usually used include dimethoate (0.05%) and malathion (0.075%).
- Sprays are only effective on the crawler stage of the scales.
Control is difficult in other life stages.
Adults are firmly attached to the plant and remain so after their death. That may give a false impression of the pest’s status. The application of pesticides may kill natural enemies of the scale and result in a resurgence of the pest.

**Bark-eating caterpillar**
This pest is more likely to attack old, shady, and neglected orchards. Larvae of this moth feed on the bark. The caterpillar spins a brown silken web on the tree which consists of its excreta and wood particles. Larvae also make shelter tunnels inside the stem in which they rest. Larvae feed from April to December. There is only one generation in a year.

**IPM strategy**
- The caterpillars can be killed by inserting an iron spike into the tunnels.
- Remove the webs from tree trunks and put an emulsion of malathion 50 EC (0.05%) in each hole and plug them with mud.
- Mix malathion 50 EC (0.05%) per liter of water and apply it to the bark-eating caterpillar-infested area with a brush at 15 days intervals.
- As a preventive measure, spraying of the attacked trunk and branches with 0.05% chlorpyrifos may be done.

**Stem borer (Batocera rufomaculata)**
This beetle’s grub feeds inside the stems, boring upward, causing the branches to dry out. Eggs are laid either in the slits of the tree trunk or in the cavities in the main branches and stems, covered with a viscous fluid. Pupation takes place within the stem. In July and August, the beetles emerge. There is only one generation of the pest in a year.

**IPM strategy**
- Exclude alternative host trees from mango orchards and remove the dead trees and infested branches from the garden to prevent the spread of the pest.
- Keep the orchards clean and follow recommended agro-techniques.
- Mechanically, remove the grubs from the infected trunk holes by using an iron wire/hook.
- Clean the holes and insert a cotton wick soaked in a solution of malathion 50 EC (5 ml/litre) and close the holes with mud plaster.
- If the infestation is severe, then apply the copper oxychloride paste on the trunk of the tree to prevent disease incidence.

**Shoot gall psylla (Apsylla cistellata)**
It is a major pest of mangoes in many parts of India, particularly the Terai region of Uttar Pradesh, north Bihar, and West Bengal. This pest creates green conical galls in the leaf axis. The activity of the pest starts in August. The galls dry out after the emergence of psyllid adults in March. The females lay eggs in the midribs as well as in the lateral axis of the new leaves. Nymphs emerge from eggs during August-September and crawl to the adjacent buds to suck cell sap. As a result of feeding, the buds develop into hard conical green galls. The galls are usually seen in September-October. Consequently, there is no fruit set. There is only one generation of the pest in a year.

**IPM strategy**
- The galls with nymphs inside should be collected and destroyed to prevent the carryover of the pest.
- Spray with Thiomethoxam @0.5 g/litre or Dimethoate @ 1.5 ml/litre during the middle of August (Nymphal emergence time) to reduce the infestation.

**Stone weevil**
A female lays eggs on the epicarp of partially developed fruits or under the rind of ripening fruits. Newly emerged grubs bore through the pulp, feed on the seed...
Thrips damage on mango

Stone weevil damage on mango fruits

coat, and later cause damage to the cotyledons. Pupation takes place inside the seed. Discolouration of the pulp adjacent to the affected portion has been observed. This is a major pest that affects the export and processing industry. There is only one generation in a year.

**IPM strategy**
- Sticky bands should be applied at the upper end of the tree trunk to prevent the migration of weevils to branches for egg laying on fruits during February.
- Collection of all the fallen-infested fruits and their destruction.
- Keep the tree basins clean to prevent the hiding of adult weevils.
- Spray deltamethrin (0.0025%) six weeks after the fruit set.

Thrips (*Scirtothrips dorsalis*)
Thrips have created havoc in most of the mango-growing areas of the country. Thrips caused approximately half of the fruit damage recorded in severely affected orchards. Infestation starts with the new flushes and panicle emergence during the 13th to 22nd standard meteorological weeks (Second week of March to the last week of May) in the northern plains. The larval and adult stages are the damaging stages. The damage to the mango young leaves, growing buds, inflorescence, flowers, immature and developing fruits is by lacerating and sucking the sap from the tissues. This causes silvery or brown patches on the affected parts where the plant cells have been destroyed. As a result of the damage, curling up of the leaves and wilting of the inflorescences were also recorded. In severe cases, affected fruits become rusty in appearance. This pest can damage the entire new growth, if not treated properly.

**IPM strategy**
- Monitor for thrips infestation by placing blue or yellow sticky traps at regular intervals.
- Neem-based pesticides control young nymphs effectively, inhibit the growth of older nymphs and reduce the egg-laying ability of adults. Spaying of neem seed kernel extract (5%) or neem oil (2%) reduces the initial stages of the thrips effectively.
- If the infestation is severe, spray with insecticides like thiamethoxam 25% WG (0.3 g/litre) or Imidacloprid 17.8% SL (0.3 ml/litre).

Fruit borer
The fruit borer affects both mesocarp as well as seeds. The young larvae scrap the epidermal tissue and the mature ones bore into the fruit and feed on the pulp. The affected fruits exude resin and black or brown rough sticky patches can be seen in the infected areas.

**Management**
- The spray of Lambda-Cyhalothrin 5 EC (1 ml per litre of water) at the marble stage of fruit and, if needed, repeat the spray after 15 days.

Leaf webber (*Orthaga euadrusalis* Walker)
This pest has become a serious and emerging problem as one of the most obnoxious pests in the northern states. Old orchards with less space between the tree canopies harbour more insects than open orchards. Its infestation begins in April and lasts until December. Initially, caterpillars feed on the leaf surface by scrapping. Later they make a web of tender shoots and leaves together and feed within them. The infestation is severe in shady conditions.

**IPM strategy**
- Mechanical removal of leaf webs infested by leaf Webber by leaf web removing device and burning them.
- Spraying with lambda-cyhalothrin @ 1ml/litre at 15 days interval
Fruit borer attack on mango

Leaf webber damage on mango

Shoot borer (*Chlumetia transversa* Walker)
Larvae enter the mid rib of leaves and then enter into the young shoots through the growing points by tunneling downwards. They excrete their excreta through the entrance hole and the shoot becomes hollow. Larvae bore into the young shoots, resulting in the drooping of the leaves and the wilting of the shoots. Larvae also bore into the inflorescence stalk.

Management
Need based spray of lambda cyhalothrin @1 ml/litre at fortnightly intervals during the emergence of new flush.

CRISPR/Cas9 mediated genome editing of mango fruit fly, *Bactrocera dorsalis*

Utility of genome editing of mango fruit fly, *Bactrocera dorsalis* mediated by CRISPR/Cas9 was demonstrated by disrupting the white gene, spermatogenesis pathway genes such as topi, per. Editing was achieved by delivering single guide RNAs (sgRNAs) along with Cas9 protein through embryonic microinjection and by electroporation. Disruption of white gene produced greenish metallic eye color and variation in pigmentation in cephalothoracic region. This successful lead could be useful for developing male only strains by disrupting oogenesis and speramatozoa production pathway genes. This will enable future environmental release of sterile males for area wide pest management of *B. dorsalis*.
Physiological disorders in mango and their management

A number of eco-physiological disorders in the mango crop limit fruit production and quality. Black tip, soft nose, clustering (Jhumka), fruit drop, internal necrosis, fruit cracking, softening of fruits (jelly seed), and spongy tissue are the most serious issues that must be addressed. The main goal of this chapter is to explain the causes of these disorders and how to manage them.

Black tip
Black tip is a serious type of physiological disorder that causes significant economic loss to orchardists. Dashehari has the highest risk of the disorder, while Lucknow Safeda has the lowest. Fruits are affected at the marble stage, resulting in a distinctive yellowing of tissues at the distal end. The colour intensities gradually fade into brown and, finally, black. The development of the fruits is slowed at this age, and the black spot at the tip gradually extends towards the upper part of the fruits. Such fruits ripen prematurely and yield very low returns. The black tip has a greater impact on orchards located near brick kilns. The fumes from the brick kilns are the culprits. It was discovered that there was an inverse relationship between the incidence and the distance of the orchard from the brick kiln. Spraying borax or washing soda on the marble stage of fruits was found to be effective in controlling the disease. Because borax undergoes alkaline hydrolysis in water, it could act as a buffering agent against the acidic constituents of brick kiln fumes. Other alkaline compounds, such as caustic soda and washing soda, have also been found to be beneficial.

Internal necrosis
Internal necrosis is also a serious problem of mango fruits. During the initial stages of internal necrosis, water soaked brownish areas on the fruits are developed which gradually coalesce to form dark brown patches on the internal surface. The lower part of the affected fruits turns brown, sometimes black with corky and leathery skin. These fruits are normally not retained for a longer period and drop off before attaining the physiological maturity. The disorder can be corrected by soil or foliar application of boron. For soil application, boron @ 250 g per tree should be incorporated at the time of October fertilization. Foliar spray of 1% borax is recommended to be given when fruit attain pea size followed by two more sprays at 10-15 days intervals which could minimise the disorder.

Fruit cracking
Mango fruit cracking is causing significant loss. Cracked fruits deteriorate quickly and frequently suffer secondary infestation by disease and pest, and the fruits eventually become unmarketable, causing significant financial loss to the grower. Pre-harvest sprays of NAA, potassium and boron and maintaining adequate soil moisture during the dry period were found to be beneficial in reducing cracking in fruit crops.

Fruit drop
In mango, in spite of profuse fruit set, the ultimate retention and harvestable produce is phenomenally very
low primarily due to heavy fruit drop. The fruit drop is very high at the early stages of development but continues at a low rate till the fruits attain more than half size. The initial set varied from 23.5 fruits per panicle to 74.5 fruits, however, despite heavy initial number, fruit retention at harvest varied between 0.4 and 0.8 fruits per panicle. Besides many factors, the main factor for early drop is the low level of auxins and gibberellins and high level of ABA and ethylene. The extent of fruit drop can be reduced significantly by mulching and irrigation during fruit development, use of plant growth regulators NAA (20 ppm) timely and effective control measures against major pests and disease with proper nutrition.

Clustering or ‘Jhumka’

The disorder is characterized by the formation of a bunch of fruitlets of the size of marble at the tip of the panicle. The fruitlets are dark green in colour and their shape is much more curved than the normal shape of a developing fruit. This shape resembles that of unfertilized fruits which drop out very quickly after turning yellow. The dark green colour after attaining the size of marble, further growth ceases and thus remains in the panicle for a considerable period. The retention of these fruitlets for a longer period gives a general impression that there will be good set. However, these fruitlets do not grow further. Lack of pollination and fertilization owing to aberrant weather conditions, heavy spray of pesticides, which kills the pollinators resulted failure of pollination and fertilization of the fruit, which have been ascribed as the reasons for the occurrence of clustering.

Application of NAA (300 ppm) in the month of November on Dashehari reduced the clustered panicles. Lower concentrations of NAA (100-200 ppm) also reduced the clustered panicles.

Soft nose

A breakdown of the flesh on the ventral side and towards the apex in mango fruits, even when on the tree prior to harvest, has been termed ‘Soft Nose’. In Malaysia, the condition known as ‘Yeasty fruit rot’ or ‘Insidious fruit rot’ is probably identical with soft nose. Similar disorder was also noticed in Dashehari. Such physiological breakdown in Kent and Haden mangoes described as soft
nose, has been engaging the attention of commerce and research workers. Investigation revealed that the disorder is of physiological nature but cure is not known.

**Jelly seed**

Jelly seed is characterised by loosening of pulp tissues and jelly formation around the stone during the advance stage of maturity of the fruit. This malady renders the fruit unfit for consumption, reducing nutritional level and consumer acceptance which has become a bottleneck in export and expansion of mango industry. Small fruit and fruit harvested when ripe, as opposed to unripe but mature, appear more prone to breakdown. Nutrient imbalance, particularly the deficiency of calcium may be an important factor but evidence is lacking to enable any firm conclusion. In India it is restricted to cultivar Dashehari, however, cvs. Chausa and Amrapali were also observed to develop jelly seed when they were harvested in late season. Sometimes fibrous type of mango like polyembryonic cultivar Turpentine has never exhibited such symptoms. As a method of control, preharvest spray of dihydrated calcium was found effective to reduce the occurrence of jelly seed formation.

**Spongy tissue**

Spongy tissue in mango fruits
(a) Alphanso, (b) cv. Mallika

Alphonso mango, which is the main export cultivar of India, suffers from a serious malady known as spongy tissue. In this disorder the external symptoms are not visible at harvesting, but when cut in half, the flesh is pale yellow in colour, soft or spongy with or without air cavity and has an off flavour. This disorder renders the fruit unfit for consumption and export to some extent. Earlier, this disorder was confined only in the cultivars grown at coastal region but recently the cultivar Mallika grown on dry track of subtropical region was also found affected with this disorder. Similar disorder was also noticed in Dashehari from Lucknow. In this cultivar the disorder invariably starts from the surface of the stone and maximum damage was noticed in the lower part as compared to middle and upper part. Convicting heat arising from soil and intense solar radiation are reported to be the main cause for this disorder. Different types of mulching were found effective for the control.

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Mango fruit diseases management to reduce postharvest rotting

Out of the total harvest, almost 15-20% of the fruits spoil. Fungi are the most common cause of mango fruit decay after harvest. It can be decreased by employing effective pre- and post-harvest practices in the production, harvesting, and post-harvest handling processes. The purpose of this article is to make end users aware of their obligations to reduce losses and the implications of such losses.

Mangoes are grown in a variety of climate across India. The quality of produce is determined by climatic and weather conditions. Mango varieties are grown in various climate zones and have varying shelf lives. The sensitivity of mango cultivars’ fruits to different pathogenic fungus varies as well. During the early stages of growth, mango fruits are relatively resistant to infection; but, as the fruits mature, their vulnerability to infection rises, and they become very sensitive during the period between harvest and consumption due to biochemical changes. Fruit rotting is caused by both saprophytic and pathogenic fungi. Depending on the factors affecting and practices followed, postharvest losses might range from 0 to 80%.

The well-known major diseases are presented in order to provide a better understanding of how to protect mango fruits from losses.

**Anthracnose**

It is the most serious postharvest disease in the world, especially in areas where there are frequent rains during the development and maturity of the fruit. Anthracnose is caused by the fungus *Colletotrichum gloeosporioides*, which infects every tender part of the mango tree, including developing and mature fruits. Because the fungus is active all year in orchards, fruits on trees can be infected at any time if the weather conditions are favourable, such as optimum temperature (20-30°C), high relative humidity, prolonged rainfall, or heavy dew. The number and amount of rains are directly proportional to disease incidence and severity. Conidial germination, which is the primary and secondary inoculum source of infection, requires free water on the fruit surface as well as high humidity for more than 10 hours. However, if the storage temperature rises to 40°C during ripening, severe rotting is more likely. Initially, the infection is contained in the epicarp, but it spreads to the pulp in a short period of time. During the ripening of fruits, the disease appears as dark lesions on the harvested fruits. In severe cases, the disease progresses quickly and the entire fruit rots within a few days. The greatest cause of concern is rotting of mature fruits during postharvest handling, ripening, and transportation, which reduces the number of consumable fruits and results in significant losses. The pre-harvest care is directly linked to post-harvest rot when fruits are symptomless and a quiescent infection occurs during fruit development, but decay and rotting occurs after harvest during ripening.

**Stem-end rot**

The next most economically important postharvest disease of mango fruits is stem-end rot. Several fungi have been found to cause stem-end rot in mango fruits, including *Lasiodiplodia theobromae*, *Aspergillus niger*, *Phomopsis mangiferae* or *Dithiorella dominicana*, and *Colletotrichum gloeosporioides*. *L. theobromae* has been...
identified as the most important secondary pathogen among these. The fungi that cause stem-end rot can also be found in soil and fallen leaves, from which the fruit can become infected after harvest. The pathogen is thought to enter mango trees through natural openings or wounds, then cause latent infection in the fruit by entering through the stem ends. Under high humidity, the conidia dispersed and released with free water. The pathogen can survive the winter on a tree or in the soil.

The disease is more common in orchards with older trees, in areas with a lot of rain, and when fruits are stored for a long time. The fungi remain latently infected within the branches and twigs. The endophytic hyphae colonizes the inflorescence and extends to the stem end several weeks after flowering, but not into the fruit until harvest. In unripe fruit, the pathogen remains dormant. As the ripening process progresses, the fruit begins to rot near the stem end, turning brown-grey, soft, and rotting the entire fruit surface. When healthy fruits come into physical contact with decaying fruits, they become infected as well. Depending on the cause, the symptoms may differ. *P. mangiferae* causes firmer, more defined lesions that spread more slowly than those caused by other stem-end rot fungi.

**Bacterial black spot (canker)**

The black spots are caused due to bacterial infection that causes cankers on fruits. In general, *Xanthomonas campestris* pv. *mangiferae indicae* infection is not considered a significant postharvest disease of mango fruits; however, when exposed to high humidity during storage, severely infected fruits may rot. The disease starts out as light-coloured water-soaked spots that progress to dark star-shaped cankers. Oozing of gummy substance from cracks caused by infection confirms bacterial infection. Other saprophytic fungi can grow in the tissue that has been damaged by bacterial infection.

**Rot (Black)**

Several species of the fungus *Aspergillus* cause black rot (*A. niger, A. variecolor, A. nidulans, A. fumigatus, A. flavus, A. chevalieri*). Fungus enters the fruits through wounds or cut ends after harvest, and infection begins as pale brown soft sunken spots that later coalesce into dark brown to black lesions that spread quickly. Later on, these lesions develop a lot of fungal growth. At 30-36°C, the disease progresses more quickly.

**Other types of fruit rot**

Mango fruit rotting is common after harvest due to the fungi mentioned above, but rotting can also be caused by infection or infestation by a variety of other fungi (*Botryosphaeria ribis, Ceratocystis paradoxa, Pestalotiopsis versicolor, Macrophomina phaseolina, M. mangiferae, Alternaria tenuissima, Phoma mangiferae, Rhizopus arrhizus, Cladosporium herbarum, Cladosporium cladosporioides, Fusarium oxysporum and Rhizoctonia solani*).

**Factors influencing the onset of postharvest disease**

Fruit yield and quality are influenced by a variety of factors, but good horticultural practices and timely application can help greatly.

*Elements of the weather*

Inoculum buildup, disease development, and ultimately, the extent of losses are all influenced by the weather and environment within the canopy. Canopy that allows free flow of air and light penetration creates a microclimate that is resistant to the majority of diseases. In orchards, rain facilitates pathogen invasion and the development of inoculums. During the monsoon season, the temperature drops to the ideal level for fungi to infect mature fruits. It remains dormant until the ripening process begins, at which point it causes severe rotting.

*Cultural practices*

Each and every activity which contributes towards minimizing incidence of diseases and promoting plant growth is important. Ploughing, weed management, pruning of infected twigs, and removal of fallen leaves, twigs, and fruits can all help to reduce pathogen inoculum build-up.
Pest management

In orchards where integrated pest management practices are used throughout the year, harvested fruits are safe. Sooty moulds are less likely to develop when sucking pests are controlled, resulting in reduced incidence of shoulder browning and sooty blotch.

Harvesting method, stage and postharvest handling

Fruits should be harvested when they are fully mature and without injury; otherwise, infection/infestation and rotting are more likely. Picking fruits with a 2 cm stalk portion by hand with secateurs, keeping them gently in plastic crates, de-sapping, hot water treatment, cooling, drying, and packing into CF Boxes may be the best option.

Postharvest disease management

Postharvest management includes the treatment of fruits after they have been harvested in order to extend their disease-free shelf life and maintain their appearance. Harvesting, de-sapping, grading, packaging, storage, and transportation, etc. all require caution. Huge losses are caused by the majority of mango growers’ lack of seriousness. Farmers must recognize the importance of postharvest handling and understand that their responsibility does not end till the fruit reaches the consumer. The following measures can be used to manage a variety of postharvest diseases.
1. New orchards should not be planted in areas that receive a lot of rain during the fruiting season.
2. Taking care of each new flush and orchard sanitation can help reduce anthracnose fungus inoculum build-up within the canopy.
3. Pruning and orchard sanitation can reduce latent infection of the stem end rot pathogen in branches and twigs.
4. It has been discovered that covering fruits with paper bags is effective.
5. Fungicide pre-harvest sprays (difenconazole 25EC @ 0.05%, propineb 70WP @ 0.2%, thiophanate methyl 70WP @ 0.1%, azoxystrobin 23SC @ 0.1%) performed 21-30 days before harvest resulted in excellent disease control.
6. Bacillus licheniformis, Bacillus pumilus, and Bacillus subtilis have been found to be effective against anthracnose when applied to fruits after harvest.
7. Hot water treatment of fruits has proven to be a safe method of controlling all pathogens that cause postharvest rots. The recommended temperature of water and time for dipping fruits has varied, but treatment at 52±1°C for 10 minutes has been found to be the most convenient and effective.
8. Castor oil, eucalyptus oil, lemongrass oil, and garlic bulb, Azadirachta indica, Zingiber officinale, Lantana, and Curcuma longa extracts have all been found to be effective against anthracnose.

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New mango harvester for reducing drudgery and harvesting losses

Mango is generally harvested by shaking and beating of branches which causes cracking and bruising of fruits, which results in about 8-10% losses at farm level. ICAR-CISH, Lucknow has developed a light-weight, user friendly mango harvester for reducing drudgery and harvesting losses. Fruit loss was observed to be 40% less with new harvester as compared with the old metallic harvester.

Due to shaking, some fruits get latent injuries during harvesting that result in rotting of fruits later during transport and marketing chain. As observed, the situation in irrigated fields was slightly better than unirrigated fields as cracking was apparently less i.e. 6.35-6.5% of the harvested fruits. However, only 1.4 to 1.6% of the fruits got cracked during harvesting with metallic pole harvester with a fruit collecting net designed and developed by ICAR-CISH, Lucknow earlier. Under Farmer FIRST Project (ICAR), several focused group discussions and farmer-scientist meetings were conducted for implementation of good agricultural practices (GAP) in mango orchards. The following reasons were attributed by mango farmers for less adoption (only 6% orchardists) of the metallic mango harvester:

- Heavy weight of harvester involves more drudgery in the harvesting operation.
- Blades mounted on the harvester for cutting of fruit pedicels are prone to rusting and frequently become blunt.
- It requires more time and labour for harvesting of fruits.

Keeping the above facts and limitations in consideration, a new light weight mango harvester was designed and developed by ICAR-CISH, Lucknow under Farmer FIRST project and validated at farmers’ field. This tool is made from high density polyethylene fibre and therefore weighs 43.4% less than the metallic pole harvester. It is fitted with a removable high carbon steel (surgical grade) blade instead of mild steel as in old harvester. This tool is capable of cutting the pedicle up to 10 mm length, which is recommended by CODEX and facilitates harvesting up to 5 to 6 m height from the ground. The difference between the old and new harvesters is presented in Table 1.

Construction details
The main components of the harvester are cutting blades, frame, fruit collection net and aluminum pipe. The leaf shaped frame made from high density polyethylene (HDPE) is 390 mm long, 12 mm thick...
and 210 mm wide at the center. Two sharp cutting blades (surgical grade) are mounted in the shape of inverted ‘V’ with screws on the external edge of the frame. In the main frame, a provision was made to attach an aluminum pole of 25 mm diameter. Fruit collection net made of nylon is tied on the periphery of the main frame.

**Operating procedure**

The operator has to hold the harvester with both hands and carry it near the target fruits. The operator has to ensure that fruits with pedicle lie inside the periphery of the tool and then pull it to cut the pedicle through shearing action and cut fruits are collected in the fruit collection net. The collection net can be emptied out by bringing it to the ground and flipping the tool upside down when it becomes heavy or after harvesting of sufficient fruits. About 650-900 fruits can be harvested with this tool per hour as per the distribution of the fruits in the tree canopy. The blades used in this tool are sharper and heavy duty and can be replaced when they wear out.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Old CISH mango harvester</th>
<th>New CISH mango harvester</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight</td>
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<tr>
<td>Material of construction</td>
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<td>650-900 fruits/hr</td>
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<tr>
<td>Cost per unit, (₹)</td>
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</table>

**Reduction in harvesting losses**

The newly developed harvester was distributed among farmers for field evaluation. There was very less (0.9%) fruit loss observed with new harvester developed by the institute as compared to old CISH harvester as well as other harvesting methods.
Sometimes small sized fruits get damaged due to bruising though blades while pulling the harvester, however this can be avoided with proper attention. Drudgery in harvesting was considerably reduced with new harvester due to less fatigue associated with light weight of the tool.

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HANDBOOK OF AGRICULTURAL ENGINEERING

Agricultural Engineering interventions have led to significant improvement in agricultural productivity by timeliness of operations, reduction in drudgery, prevention of post-harvest losses and achieving higher cultivation intensity. Timely farm operations with efficient use of inputs, post-harvest processing and value addition to agricultural produce and conservation and sustainable use of natural resources are essential for ensuring higher returns to the cultivators. This is the maiden attempt of the Indian Council of Agricultural Research to publish the Handbook of Agricultural Engineering. The handbook comprises 50 chapters under four sections, namely Farm Machinery and Power, Soil and Water Engineering, Energy in Agriculture and Agro-Process Engineering. This publication would be useful to farmers, students, researchers, extension workers, policy makers, entrepreneurs and other stakeholders.

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TECHNICAL SPECIFICATIONS

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Eating mangoes: A natural way to heal

There is an overwhelming evidence that the presence of health promoting phytochemicals makes fruits and vegetables an ideal food for lowering the risk of chronic diseases like cancer, cardiovascular problems, diabetes and obesity, and for improving the immune function. The interest in fruits and vegetables as excellent natural source of immunity-boosting bioactive compounds has steadily grown; and the ongoing Covid-19 pandemic has particularly stimulated huge interest in phytochemical rich natural foods. Identification and development of phytochemical-rich mango cultivars and hybrids has received a lot of research and policy attention in India, in line with current global trends. ICAR-Central Institute of Subtropical Horticulture, Lucknow is working in this direction with the overall goal of increasing the supply of bioactive compound rich mango fruits to the emerging health-conscious mango consumers, while also enabling mango growers to reap rich dividends by selling phytochemical-dense mangoes on the market.

Mango fruit is increasingly being recognized as a cheap, nutrient-dense food with immense health boosting benefits. Mango fruit pulp contains a variety of nutrient and non-nutrient bioactive compounds that have anti-carcinogenic, anti-hyperglycemic, anti-inflammatory, and antioxidant properties. Furthermore, the newly discovered health benefits of mango consumption (anti-wrinkle, anti-allergic, hypcholesterolemic, and immunomodulatory) are piquing interest in mango as a super fruit for improving human health and wellbeing.

Nutraceutical compounds in mango
Mango fruit is a rich source of health protecting vitamins (A and C), minerals (potassium, phosphorus and calcium) and sugars (glucose, fructose and sucrose). Ripe fruits are particularly rich in vitamin A, and mango consumption can greatly supplement the retinol equivalent requirements in humans. Mango fruit also has a moderate energy value, and can thus supplement the daily energy needs to a considerable extent. Though rich in sugars, mango consumption in moderate amounts seems to be safe even for diabetics. The polyphenols (e.g. mangiferin and lupeol) present in mango pulp show excellent anti-glycemic properties. Some clinical studies have also shown a lower glycomic index of mango: moderate amounts of mango consumption do not cause a post-meal increase in blood sugar (hyperglycemia) in both normal and diabetic individuals. The growing interest in mango as a functional food is mainly attributed to the presence of a wide range of carotenoids, flavonoids and polyphenols.

Carotenoids
Carotenoids, the pigments that impart a bright yellow color to mango pulp, exhibit strong free radical scavenging (antioxidant) effects, and are thus linked to reduced risk of chronic health problems like cancer, diabetes and heart diseases. β-carotene (pro-vitamin A) is the most abundant carotenoid in mango pulp; other lesser-known carotenoids include neo-b-carotene, auroxanthin, luteoxanthin, violaxanthin and zeaxanthin. A medium-sized ripe mango can enrich the diet with pro-vitamin A. In many countries, where dietary vitamin A needs are often met by artificial substitutes harmful to health; regular mango consumption can greatly meet daily vitamin A needs and eating the fruit regularly maintains eye health. Unlike other fruits like grapes in which carotenoid content drops after veraison, ripe mangoes continue to maintain carotenoid levels, making them an excellent material for developing β-carotene fortified products like wine.

Ascorbic acid
Ascorbic acid (vitamin C) acts as a strong antioxidant, offering protection against oxidative stress-induced health ailments. Further, it helps prevent scurvy, boosts the immune system and aids in healing. Mango fruits are an excellent source of ascorbic acid, and their vitamin C is comparable with citrus fruits and melons. Indian mango cultivars ‘Langra’ and ‘Mallika’ are quite rich in vitamin C (~50 mg/100 g of pulp).

Mangiferin
Mango is amongst a few plants that are abundant in mangiferin, a xanthone with remarkable health boosting properties. Mangiferin displays strong antioxidant, anti-glycemic, anti-cancer, anti-microbial and anti-inflammatory effects, to name a few. Being a xanthone, the antioxidant capacity of mangiferin may even be greater than super oxidants (vitamin C and vitamin E). It controls
the blood glucose level by inhibiting glucose absorption from the intestine: defying the popular belief that mango consumption is not good for diabetic patients. Thanks to its antioxidant, anti-inflammatory and gene modulatory properties, mangiferin has gained wide attention as a potential therapeutic for cancer treatment. Recently, mangiferin was found to inhibit the growth of Covid-19 virus (SARS-CoV-2) in molecular docking studies and thus could be a safe therapeutic alternative to chemical inhibitors.

Lupeol
Chemically a triterpene, lupeol is found in high amounts in mango pulp. It shows a range of pharmacological properties against acute or chronic health problems like arthritis, cancer, cardiovascular ailments, diabetes and microbial infections, and is known to accelerate wound healing. Lupeol efficiently alleviates arthritis-related symptoms like inflammation, swelling and pain. Thanks to their strong anti-mutagenic effects, lupeol and its derivatives are considered as excellent starting materials for developing anti-cancerous drugs. Noticeably, while killing cancerous cells, lupeol does not have any harmful effects on normal human cells. Like mangiferin, lupeol also suppresses carbohydrate absorption in the intestine and inhibits the activity of the enzyme α-amylase, thereby lowering the risk of diabetes.

Flavonoids
Flavonoids, the most abundant polyphenols in human diet, are grouped into several classes, like flavones, flavonols and anthocyanins. Besides free radical scavenging properties, flavonoids also exhibit anti-microbial, anti-inflammatory and anti-allergic effects. Catechin, epicatechin, myricetin, kaempferol, rutin and quercetin are the major flavonoids found in mango pulp. Catechin has strong antioxidant, anti-carcinogenic and anti-ageing properties. Myricetin is known for its iron-chelating, antioxidant and anti-inflammatory properties, and is increasingly being seen as a novel therapeutic agent for alleviating iron deficiency-related health problems like anemia. It is worth mentioning that several mango cultivars contain 3-4 times more myricetin than quercetin, another flavonoid valued for its highly beneficial effects in osteoporosis, lung cancer and cardiovascular problems. Hesperidin, a rare flavonone found in some mango cultivars (e.g. Alphonso), shows anti-carcinogenic properties.

Phenolic acids
Mango fruit pulp contains a range of phenolic acids, valued for their functional and nutraceutical properties. Ellagic acid, one of the main phenolic acids found in mango, is quite effective in overcoming obesity and obesity-related health problems like atherosclerosis, type-2 diabetes and non-alcoholic fatty liver disease. It also shows strong antioxidant, anti-carcinogenic, anti-mutagenic and anti-viral effects. The waste generated during mango pulp processing offers a novel source for extracting ellagic acid. Ferulic acid, another prominent phenolic acid in mango pulp, is known for its strong anti-ageing and skin rejuvenation effects. Salicylic acid, known for its skin-caring and anti-acne effects and linked to the reduced risk of colon cancer, was recently identified in the pulp and peel of some mango cultivars. p-Coumaric acid and syringic acid are other lesser-known phenolic acids found in mango pulp. It is believed that yet-to-be-discovered phenolic acids might account for a range of medicinal benefits associated with mango consumption. Further, it is worth mentioning that the aforementioned phenolic acids are often present only in a selected number of mango cultivars; implying the need for tapping the huge genetic wealth of mangoes for identifying these and potentially novel phenolic acids for commercial applications.

Harnessing Indian mangoes for nutraceuticals
In India, bioactive compound profiling in mango fruit pulp and other economically significant parts is a relatively new field of study. ICAR-CISH, Lucknow, has recently begun studies to understand the diversity of bioactive compounds in mango pulp of commercial Indian cultivars and newly developed mango hybrids, given the importance of mango in India’s horticulture and health sectors. The overall goal of this research is to promote Indian mango cultivars as affordable nutraceutical-rich fruits in export markets while also ensuring better profit margins to the mango growers. Mangiferin and lupeol, two major bioactive compounds of interest in mango pulp, have been found to be particularly abundant in Indian mangoes, according to recent research. Fruit pulp of ‘Dashehari’ mango is exceptionally rich in lupeol. Mangiferin and lupeol are abundant in the fruit pulp of the newly developed mango hybrids ‘Ambika’ and ‘Arunka,’ respectively. Micronutrients are abundant in the fruit pulp of North Indian mango cultivars ‘Bombay Green’ and ‘Dashehari,’ as well as other popular cultivars such as ‘Langra’ and ‘Chausa’.

SUMMARY
The bioactive compound profile of fresh fruits, including mango, is influenced by a number of factors, including genotype (cultivar), crop management practices, maturity stage, transport and storage conditions, pre-harvest sprays, and so on. Although it may not be possible to screen all genotypes/accessions, the bioactive compound profiles of as many commercially grown, lesser known but potential farmers’ varieties, exotic accessions, and promising hybrids as possible must be evaluated so that those with exceptionally high levels of polyphenols, flavonoids, and phenolic acids can be vigorously promoted for export, and are further used in genetic improvement programs. Furthermore, growers must pay close attention to the best crop management, harvesting, and storage practices developed for mango in order to ensure phytochemical-dense and high-quality fruits.

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July–August 2021

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Mango product diversification and waste utilization

The global processed mango products market size in 2019 was estimated to be USD 17.4 billion and projected to register a CAGR of 6.4% during the next year. India, though, leader in mango production, is far behind in global trade of the fruit. Mexico is the leading supplier of mango and its products globally with a share of 16%, while India’s share is only 9%. In India, Chittoor and Krishnagiri are the main processing hubs of mango. In Chittoor, there are about 67 registered units in the mango pulp industry, of which 55 were operational in 2018. Most mangoes produced in Chittoor are processed into pulp, which accounts for about 70% of the region’s total pulp production. The main varieties Totapuri and Alphonso are processed into aseptic mango pulp or pulp concentrate. The total number of mango pulp/puree industries in India are about 100 in which about 4% industries are large scale, 20% medium and 76% small scale running in India. India produces about 0.5 million tonne of mango pulp and exports about 10.1% of it.

Mangoes are processed into many products at two stages of maturity i.e. green fruit and ripe mangoes. Pulp, the primary processed product of mango, is used mainly for manufacturing mango beverages and concentrates. However, recently use of pulp has increased in puddings, fruit meals for children, bakery fillings, and ice-cream mixes, etc. Recently IQF mangoes have shown substantial use in manufacturing confectionary products, frozen salads, and smoothie mixtures. These fruits have a longer shelf life due to instant quick freezing of the fruits. Dried or dehydrated mango is another product having numerous applications in skin care products used for soothing inflammations and minimizing appearance of spots, blemishes, and wrinkles.

Secondary processed mango products include juices, squashes, powder mixes to be used with milk or water for preparing refreshment drinks, canned and frozen slices, fruit bars and candies, jellies, jams, pickles, and fruit-based cosmetics containing fruit extracts, etc. Raw mangoes are also used to produce condiments like chutneys and pickles, curries and dehydrated products. These products are increasingly becoming popular owing to their taste and long shelf-life, contributing to the segment growth. ICAR-CISH has developed fermented mango products including cider, wine, vinegar, ketchup, yoghurt, probiotic mango pulp and RTS drink.

Mango processing waste

One major factor leading to less profitability of mango processing industry is non-utilization of mango processing waste. During processing of mango for pulp, huge quantities of solid and liquid wastes are generated. Solid waste is comprised of mango peel, stones, and stalk, trimmings and fibrous materials obtained during preparation of raw material. This constitutes about 40-50% of total fruits waste, of which 12-15% is peel, 5-10% is pulper waste and 15-20% is kernel. This waste could be used in two ways. Firstly, it is used either as such or after drying for animal feed; secondly it is converted into a higher valued product either by chemical treatment or by fermentation.

Mango peel

Mango peel is generally termed as total waste. If a factory is processing 5 tonnes of Totapuri mangoes per hour, say working for 8 hours a day, about 6 tonnes of peel would be available as waste. This waste is either used as cattle feed or is dumped in open areas where it adds to environmental pollution. Since 2-5% of total produce is processed, bulk of waste comes from table consumption of mango fruits which is difficult to collect as most of it is thrown in the garbage.

Mango peel is a rich source of pectin and fibre. Pectin is an extremely versatile ingredient that is used to improve the quality of many food and pharmaceutical products. Pectin obtained from peel of mango cultivars cv. Chausa and Saheb Pasand has good jelly grade and the yield is also high, hence can be commercially exploited to extract pectin. Among the varieties used for fibre extraction, Chausa peel contained maximum fibre (5.4%) while it ranged between 3.0 to 3.6% in peel of other varieties. Mango peel is difficult to decompose because of its complex ligno-cellulosic composition. However, good quality compost could be prepared in...
40 days by co-composting it with cow dung in 3:1 ratio. Mango peel can also be used for biogas production after adding urea in 20-30:1. The biogas yields obtained using mango waste as one of the substrate, was 0.6 m³/kg volatile solids added with methane generation of 52%. Mango peel could be used as a substrate for mushroom cultivation after supplementing it with rice straw. Mango peel as animal feed has poor nutritive value because of its low protein content. However, its protein value could be enhanced five folds by solid-state fermentation using *Aspergillus niger*. Citric acid and lactic acid are used widely in processing and pharmaceutical industries, and could be produced from mango peel using *A. niger* and *Rhizopus oryzae*. The peel could also be utilized for wine and vinegar production after partial precipitation of tannins to reduce the astringency. At ICaR-CISH, vinegar was produced from mango peel using immobilized cells of *Acetobacter aceti*. In fruit processing industries various enzymes such as cellulases, pectinases and amylases are invariably used for pulp liquefaction, juice clarification, etc. There is now increased interest in enzyme production from food processing wastes. At ICAR-CISH, Lucknow, cellulases and pectinases could be produced from mango peel using *A. niger*. At ICAR-CISH, Lucknow good quality herbal tea infusion, and antioxidant enriched capsules were prepared from mango peel.

**Kernel**

Kernel is obtained by breaking the hard seed coat of mango stone. It is rich in fat, starch, protein, tannins, vitamins, fibres, sterols and triterpene alcohol. It has been found that stearic and oleic acid constitute about 85% of total fatty acid while palmitic, linoleic and arachidic acids are present in minor quantities. ICAR-CISH has developed good quality face and body scrub using mango peel and kernel. The fat extracted from kernel are used mainly for manufacturing soap while small quantities are used during preparation of other cosmetic products. The quality of lipid extracted from mango kernel has been found comparable to those of other edible oils like sunflower, sesame and groundnut, and has been found to be suitable for human consumption. It has also been found as suitable substitute to coca butter in the preparation of confectionary products. The kernel is a rich source of protein that varies from 5.6 to 9.0% but its nature and properties are less defined. The total amino acid content in proteins have been found to be 88-97% of which 31-35% are glutamic acid, aspartic acid and leucine, while sulphur containing amino acid acids are present in small amounts. The essential amino acid content except that of methionine and isoleucine of mango kernel have been found to be higher than in reference proteins identified by FAO. The kernel proteins could be used to produce food mixtures of high nutritive value due to higher content of essential amino acids. The tannin content in kernel varies from 10.6 to 18%. ICAR-CISH has developed coffee powder from mango kernel. In some parts of the country kernel is eaten after boiling and baking. The flour made from tannin removed or defatted kernel could be utilized for making chapattis etc. by replacing the wheat flour to the extent of 40%. The cake made from mango kernel could be used as alternative to wheat and maize flour. However, if the mango kernel has to be used for human consumption these have to be hygienically processed and stabilized. Mango kernel is a rich source of starch (approximately 60% on dry weight basis) which could be utilized for industrial purpose. At ICAR-CISH, mango kernel was used for ethanol production by co-culture fermentation using *A. niger* (amylolytic fungus) along with *Saccharomyces cerevisiae*. About 10% alcohol could be obtained by this method. Mango kernel can also be used for amylase production using amylolytic microorganisms. Pre-treatments like steeping or defatting of mango kernel result in increased amylase production. *Aspergillus oryzae* and *Syncephalastrum racemosum* have been found to be efficient amylase producer using mango kernel as substrate. Mango kernel can also be used for citric acid production using *A. niger*.

**Pulper waste**

The peel and fibrous material of the pulp after juice extraction from whole fruit is termed as pulper waste. This material could be utilized to manufacture juice, nectar, etc. by treating it with pectic enzymes for better liquefaction. The recovery of the juice was found to be 75-80% from the waste pulp and 51% from peel. The quality of the nectar prepared from the pulp supplemented with juice, recovered from mango waste, was found acceptable. ICAR-CISH has developed fibre enriched biscuits from this waste after some pre-treatments.

Utilization of waste is both a necessity and challenge. This will not only economize the cost of finished product, increase profitability and reduce the pollution level, but also lead to more complete utilisation of the raw material.

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*Corresponding author e-mail: neelimagargg@gmail.com*
Status and prospects of Indian mango export industry

**Mango (Mangifera indica)** is Asia’s most popular fruit, and it has gained popularity around the world. It has long been a component of culture and religion as a useful and tasty fruit. In addition to taste, it has many good qualities, thus making it to be called as ‘King of Fruits’. Mango is grown in an area of 5.58 million hectares of area in the world. India is the largest producer of mangoes with 46.02% and 45.88% of the total world area and production, respectively. Thus, India has immense potential to assert a strong presence in the global mango market, which is still under-developed.

**Prospects**

In India, mango is grown in an area of 2.26 million ha with a production of 21.82 million tonnes and productivity of 9.66 tonnes per ha during 2017-18. India is blessed with different agro-climatic conditions and is a home for more than 1000 different cultivars of mango. Inspite of this, only few varieties are being exported. Alphonso, Totapuri, Kesar, Dashehari, Rajapuri, Banganapalli are leading export varieties of mango from India. Though India is the largest producer of mango in the world, its share in global export of mangoes is not utilized fully.

**Important market for Indian mangoes**

The export value of fresh mangoes has increased from 200.53 crore rupees in 2009-10 to 400.21 crore rupees in 2019-20. The major destinations of cumulative export quantity of mangoes from India during 2000 to 2010 were Bangladesh (47.67%), United Arab Emirates (31.33%), Nepal (5.95%), Saudi Arabia (3.86%), United Kingdom (2.87%) and Bahrain (1.24%) whereas export to other countries was less than one percent of the total exports. Major junk of the Indian mangoes was exported only to the nearest countries like Bangladesh, UAE and Nepal (84.95% of total exports). Indian mangoes were not able to reach other overseas markets during the period 2000-2010. The possible reasons were that, mango being very perishable crop, higher freight charges, long distance and stringent sanitary and phyto-sanitary restrictions by the importing countries.

During the period 2010-2020, the major destinations of cumulative export quantity of mangoes from India were United Arab Emirates (48.75%), Bangladesh (14.06%), Nepal (11.63 %), United Kingdom (5.81%), Saudi Arabia (3.85%), Qatar (3.16%), Kuwait (2.60%), Oman (2.50%), Bahrain (1.61%) and Singapore (1.38%) whereas export to other countries was less than one percent of the total exports. During this period, destination of Indian mangoes was diversified which resulted in higher export earnings. During 2019-20, India exported 49,659 tonnes of mangoes to the global market (Table 1).

India besides exporting fresh mangoes also exports mango pulp. India has exported 85,725.55 MT of mango pulp to the world at a worth of 584.32 crore rupees during the year 2019-20. Major destinations of mango pulp export are Saudi Arab, Yemen Republic, Netherland, Kuwait and United States of America. Alphonso, Totapuri and Kesar are the major processing varieties cultivated in India. Chittoor in Andhra Pradesh and Krishnagiri in Tamil Nadu are the two clusters where mango pulp is processed and exported to other countries. Apart from this, few of the processing plants are located in Maharashtra and Gujarat.

**Table 1. Trends in export of Indian mangoes (Quantity) during 2010-11 to 2019-20**

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Changing scenario of export

Trend analysis indicated that, export of Indian mangoes is decreasing at the rate of 2.24% annually during 2010-11 to 2019-20. Exports to United Arab Emirates and Bangladesh are decreasing at the rate of 5 and 28% annually. Exports to Oman, Nepal and Qatar are increasing at the rate of 47, 23 and 21% annually (Table 1). Though UAE, Bangladesh are the major export destinations in the current period but it is evident from the CAGR that the directions of trade may change. Oman, Nepal, Qatar and Singapore can be the major destinations in the near future period. Indian mangoes are still struggling to find its market in USA, Australia and many other distant countries.

Suggestions for promotion of mango export

There are over 1000 mango cultivars in India, but only a few have export potential. Importers’ lack of knowledge or widespread publicity about the nutritional value, taste, and aroma of many locally cultivated mangoes is also a barrier to the export of such cultivars, and the variety that has an international market is limited to a few places in India. Trade fairs dedicated to organising Indian mango globalisation each year and inviting other countries to participate in them are therefore required.

Due to the strong competition from other countries, especially Pakistan, Brazil, South America, and South Africa, there is a strong fight for distant US and UK mango markets. Compared to other exporting countries India has disadvantage of high transportation charges. Transportation charges for mangoes to distant markets reduce the profit in export. Therefore, sea transport protocols can significantly reduce the expenditure on transportation. Their is need for refinement of sea transportation protocol for mango.

Pesticides used for managing pests and diseases may increase pesticide residue and, as a result, the shipment may be rejected or not accepted by countries that import mangoes. Use of recommended pesticides at the correct times and quantities may reduce pesticide residue. Farmers should employ pesticide load reducing technology (integrated pest management, washing with 2% salt water, hot water dip, bubble wash).

Organically or pesticide residue free mango culture should be encouraged. The general support in this regard should be given to the adoption of “GAP”. Thereby new markets can be opened for Indian mangoes.

Concerted efforts are required for documentation and registration of farmers. Products shall be obtained from registered farmers to establish traceability in order to comply with importing nation standards.

The lack of adequate implementation of farm-level post-harvest practises affects the shelf-life and quality of the product. For this purpose, farmers must undertake measures such as harvesting with mango harvesters at the right time and proper post-harvest management. Training and skill development in this area will improve post-harvest life of mango fruits.

By 2021, the total number of mango packaging houses recognised by APEDA was just 48, which, compared with total mango area/production, was very low. As a result, in all mango growing regions, capacity and the number of modern packaging houses have to be increased.

Mango is highly perishable and must be exported through airways, which raises the price on the international market of Indian mangoes and makes them costly or inexpensive for many countries. This should prioritise long sea shipping and extend the shelf-life of mango to at least 30 days. If the protocol for maritime transport is perfected, India can compete in the export of mango in addition to other countries.

India also has the potential for mango pulp exports, as well as exporting fresh fruits. In order to build on the untapped potential, efforts must be standardised to develop treatment facilities for local varieties.

For further interaction, please write to:
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Bottle gourd at a glance

Indigenous to tropical Africa. India is secondary centre of origin. Belongs to Cucurbitaceae family and widely cultivated in tropics and subtropics. Grown in both rainy and summer seasons.

**Botanical name and chromosome number**

*L. siceraria* (Mol.) Standl. 2n = 2x = 22

**Species**

*L. siceraria* is the only cultivated monoecious species while five others viz. *L. breviflora* (Benth.) Roberty, *L. abyssinica* (Hook F.) Jeffrey, *L. rufa* (Gilg.) Jeffrey, *L. sphaerica* (Son-der) Naudin and *L. guineensis* (G. Don) Jeffrey are wild perennial, dioecious forms from Africa and Madagascar.

**Status in India**

In India, it occupies 157 thousand hectares of land with yearly production of 2.68 million MT (NHb, 2018-19).

**Commercial varieties**

Pusa Naveen, Pusa Santushti, Pusa Samridhi, Pusa Sandesh, Pusa Hybrid-3, Kashi Kriti, Kashi Kundal, Kashi Kiran, Arka Bahar, Kashi Bahar, Pant Luaki Sankar-1, Narendra Rashmi, Narendra Dharidar, Punjab Komal.

**Uses**

Its fruit is used as cooked vegetable and available in the market throughout the year. The fruit is used for variety of purposes, tender fruits used as vegetable and for preparing sweet dishes, raita and pickles. Pulp of bottle gourd is used for overcoming constipation, cough, night blindness and as an antidote against certain poisons. In West Bengal and some north eastern states, its leaf and tender branch are also used as vegetable.

**Propagation techniques**

Through seed; Either directly sown in the field or transplanting of seedling. Seedlings are raised in plug tray during winter (Dec-Jan) under polyhouse and transplanted in February to get early crop during summer.

**Crop geometry**

Rainy season: 3.5m × 0.6m; Summer season: 3.0m × 0.5m

**Climate**

Require hot and humid climate. The optimum growth, good fruit set and their development required the range of night and day temperature of 18-22°C and 30-35°C, respectively

**Pollination**

Cross pollinated through insect (honeybees, bumble bees and many other insects) due to monoecious sex form where male and female flowers are solitary and appear on different leaf axils.

**Economic yield**

Variety: 250-450q/ha; hybrid up to 550 q/ha

**Pests**

Red pumpkin beetles (*Aulacophora foveicollis*), Bottle gourd plume moth (*Sphenarches caffer*), Leaf miner (*Liniomyza trifoli*).

**Diseases**

Anthracnose (*Colletotrichum orbiculare*), Downy mildew (*Pseudoperonospora cubensis*), Powdery mildew (*Spaerothea fuligena*), Gummy stem blight (*Didymella bryoniae*).

**Nutritional value**

The nutrient content per 100 g edible portions of fruit are: moisture (96.10%), protein (0.20%), fat (0.10%), fibre (0.60%), carbohydrate (2.50 mg), energy (12 kcal), Ca (20 mg), phosphorous (10 mg), Fe (0.70 mg), niacin (0.20 mg) and vitamin C (0.30%).
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.

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Printed by Indian Council of Agricultural Research, New Delhi, and published by Dr S K Singh, Project Director (DKMA), on behalf of Indian Council of Agricultural Research, New Delhi, and printed at M/s Royal Offset Printers, A-89/1, Naraina Industrial Area, Phase-I, New Delhi 110028, and published at ICAR, Krishi Anusandhan Bhavan I, Pusa, New Delhi 110012. Editing: Ravindra Verma