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Mango

The common mango (*Mangifera indica*) is acclaimed as the King of Fruits in Indian continent owing to its exquisite taste, flavour, attractive colour, nutritional value and diverse end uses. The mango is native to South and Southeast Asia, from where it has been distributed worldwide to become one of the most cultivated and the choicest fruit in the tropical and sub-tropical world. The centre of diversity for the *Mangifera* is tropical and sub-tropical Asia, ranging from equator to 27° latitude and as far-east as the Caroline Islands. Wild mangoes occur naturally in India, Sri Lanka, Bangladesh, Myanmar, Sikkim, Thailand, Kampuchea, Vietnam, Laos, southern China, Malaysia, Singapore, Indonesia, Brunei, the Philippines, Papua New Guinea, and the Solomon and Caroline Islands. Maximum species diversity occurs in western Malesia and about 28 species are found in this region. The highest concentration of *Mangifera* species is reported to be in the Malay Peninsula, Indonesian archipelago (Borneo and Sumatra, which comprise western Malesia), Thailand, Indo-China and the Philippines. The occurrence of wild form of *M. indica*, allied species *M. sylvatica* and *M. coloneura*, fossil leaf impressions of *M. pentandra* and presence of numerous varieties in India indicates that *M. indica* had originated in Indo-Burma region. A few other species such as *M. foetida*, *M. caesia* and *M. odorata* are confined to Malaysian region.

India ranks first among the world's largest mango producing countries accounting for about 45% of the world's total mango production. Other major mango producing countries include China, Thailand, Mexico, Pakistan, Philippines, Indonesia, Brazil, Nigeria and Egypt. Worldwide production is mostly concentrated in Asia, accounting for 75% followed by South and Northern America with about 10% share. Major producing states in India are Andhra Pradesh, Uttar Pradesh, Bihar, Gujarat, Karnataka, Maharashtra, Odisha, Tamil Nadu, and West Bengal. Other states where mangoes are grown include Madhya Pradesh, Kerala, Haryana, Punjab etc. As per National Horticulture Board Statistics 2015, India produced 18,431 thousand metric tonnes from an area of 2,516 thousand ha and a productivity of 7.3 tonne/ha.

The fruit is very popular with the masses globally due to its wide range of adaptability, high nutritive value, and richness in variety, diversity, delicious taste, aroma, flavour and diverse end uses. Mango can be eaten raw, as a dessert fruit or processed in to several value added products. Good mango varieties contain around 20% of total soluble solids. The acid content of ripe dessert fruit varies from 0.2 to 0.5% and protein content is about 1%. The energy value per 100 g edible pulp of mango is 60 kCal. Mango contains a variety of phytochemicals and nutrients. The fruit pulp is high in prebiotic dietary fiber, vitamin C, diverse polyphenol and provitamin A carotenoids. In mango fruit pulp, antioxidants, vitamins A and C, Vitamin B_6 (pyridoxine), folate, other B complex vitamins and essential nutrients, such as potassium, copper and amino acids, are present. Mango peel and pulp contain other phytonutrients, such as the pigment antioxidants–carotenoids and polyphenols, omega-3 and -6 polyunsaturated fatty acids.

Climate and soil

Mango is a tropical fruit crop, but it can be grown up to 1,500 m above mean sea level. Mango trees can tolerate a wide range of climatic conditions and perform equally well under sub-tropical conditions. The crop is successfully cultivated under conditions which vary from very humid to cool and dry, to very hot and arid. The trees can survive in swampy conditions for an extended period of time, but will also survive in areas with an annual rainfall of less than 300 mm and temperatures as high as 45°C. The average minimum temperature during the winter should preferably be above 5°C. There should not be high humidity, rain or frost during flowering. The temperature between 24°C and 30°C is ideal for its cultivation. Low temperature when the trees are in full bloom retards fruit development and prompt abortion. High temperature and low-humid conditions result in low carbon accumulation, which lowers the tree's ability to hold heavy crop loads. Low temperature stress is necessary for floral induction.

Higher temperature during fruit development and maturity gives better quality fruits. The areas experiencing frequent showers and high humidity

are prone to many pests and diseases. Thus it can be grown best in regions with a rainfall between 25 cm and 250 cm. Rain or moisture (high humidity, heavy dew, and fog) during the flowering and fruiting period is conducive to the development of fungal diseases that cause flower and fruit drop. Regions having bright sunny days and moderate humidity during flowering are ideal for mango growing. For maximum fruit production a prolonged and severe dry season is necessary. The longer and more severe the dry season, the more regular is the cropping habit. Young trees can be killed outright by the sever frosts, but larger mature trees can regenerate, although defoliation and death of some terminal buds and branches occurs.

Mango can be grown on a wide variety of soils ranging from alluvial to laterite soils except in black cotton soils having poor drainage. It grows well in soils with slightly acidic pH. It does not perform well in soils having pH beyond 7.5. Ideal pH range is from 6.5–7.5. Ideal soil for mango is red loamy with drainage facility. Mango production is best on well drained sandy loam or gravelly soils that dry out rapidly after the wet season, forcing the trees into a dormant period, essential for heavy flowering. Mangoes do not grow or produce well in saline soils, but the polyembryonic rootstock variety 13-1 from Israel and Kurukkan and Olour from India have salt tolerance.

Table 1. Commercial mango varieties grown in different Indian states

State	Commercial mango varieties
Andhra Pradesh	Banganpalli, Suvarnarekha, Neelum and Totapuri
Bihar	Bombay Green, Chausa, Dashehari, Fazli, Gulab-khas, Himsagar, Kishen Bhog and Langra Zardalu
Gujarat	Alphonso, Dashehari, Jamadar, Kesar, Langra, Neelum, Rajapuri and Totapuri
Goa	Alphonso, Fernandina, Hilario, Mankhurd and Mussarat
Haryana	Chausa, Dashehari, Langra and Fazli
Himachal Pradesh	Chausa, Dashehari and Langra
Karnataka	Alphonso, Banganpalli, Mallika and Mulgoa, Neelum, Pairi and Totapuri
Madhya Pradesh	Alphonso, Bombay Green, Dashehari, Fazli, Langra and Neelum
Maharashtra	Alphonso, Kesar, Mallika and Pairi
Punjab	Chausa, Dashehari and Malda
Rajasthan	Bombay Green, Chausa, Dashehari and Langra
Tamil Nadu	Alphonso, Banganapalli, Neelum, Padini and Totapuri
Uttar Pradesh	Bombay Green, Chausa, Dashehari and Langra
West Bengal	Amrapali, Bombay Green, Fazli, Gulabkhas, Himsagar, Kishenbhog and Langra

Varieties

India is home of about 1,000 varieties. Most of them are the result of open pollination arising as chance seedlings. However, only a few varieties are commercially cultivated throughout India (Table 1).

In India, mango is available from December-January to September. Majority of these varieties are alternate-bearer while Totapuri, Banganpalli, Neelum, Mallika, and Amrapali bear regularly. About 20-25 varieties are grown commercially in the Indian sub-continent. These are described here:

Alphonso: Mainly grown in Ratnagiri area of Maharashtra and to a small extent parts of south Gujarat and Karnataka. Fruits are medium sized (250 g), with attractive blush towards the basal end. Pulp is firm, fiberless attractive orange colour. It has good sugar: acid blend and keeping quality is good. Alphonso is considered as one of the most popular mango variety from India. It is susceptible to spongy tissue.

Banganapalli: It is a widely cultivated, early maturing mango of south India. It is the main commercial variety of Andhra Pradesh. Fruits are medium to large sized (350–400 g). The pulp is fibreless, firm and yellow with sweet taste. Fruits have good keeping quality.

Bombay Green: It is one of the earliest varieties of north India. Fruits are medium sized, weighing about 250 g each. Fruits have strong and pleasant flavour. Pulp is soft and sweet.

Chausa: Late- maturing variety of North India, it matures during July or beginning of August. Fruits are large, weighing about 350 g each. Fruits are bright yellow with soft and sweet pulp. It is a shy bearing mango variety.

Dashehari: One of the most popular variety of north India, it is a binneal bearer and mid-season mango variety. Fruits are medium sized, with pleasant flavour, sweet, firm and fibreless pulp. Stone is thin and keeping quality is good.

Fazli: This is indigenous to Bihar and West Bengal. Fazli is a late maturing (August) variety. Fruits are large, with firm to soft pulp. Flavour is pleasant and pulp is sweet and fibreless. Keeping quality is good.

Gulab Khas: It is indigenous to Bihar. It is mid season regular and heavy bearer variety. Fruits are small to medium sized with rosy flavour. Fruits are amber yellow with reddish blush towards the base and one sides. Keeping quality is good.

Himsagar: Very popular regular-bearing variety of West Bengal. Fruits are medium sized, having good quality. Pulp is firm, yellow, and fibreless with pleasant flavour. Keeping quality is good.

Kesar: Popular variety of Saurashtra region of Gujarat. Fruits are medium sized. Pulp is sweet and

fibreless. It has an excellent sugar: acid blend. Fruits ripen to attractive apricot yellow colour with red blush on shoulders. It has good processing quality.

Kishenbhog: Popular mid season variety of West Bengal. Fruits are medium to large with good quality and pleasant flavour. There are traces of turpentine in aroma. Pulp is firm, fibrous. Keeping quality is good.

Langra: An important commercial mango variety of north India, it is a biennial-bearer and mid-season variety, with good quality fruits. Pulp is firm, lemon yellow in colour and scarcely fibrous. It has a characteristic turpentine flavour. Keeping quality is medium.

Mankurad: It is a mid-season popular variety of Goa. Fruits are medium sized with yellow pericarp. Pulp is firm, cadmium yellow in colour and fibreless. Keeping quality is good.

Neelum: A heavy yielding, regular bearing and late season variety of south India. Fruits are medium sized with good flavour. Pulp is soft, yellow and fibreless. Keeping quality is good.

Pairi: A native to coastal Maharashtra including Goa. Early-maturing, heavy and regular bearer mango variety. Fruits are medium sized with good quality. It has good flavour with sugar: acid blend. Pulp is soft and fibreless. Keeping quality is poor.

Totapuri: Widely grown and popular processing variety of south India. It is regular and heavy bearing mango variety. Fruits are medium to large with prominent sinus. Fruit quality is medium. It has a typical flavour and flat taste. Pulp is cadmium yellow in colour and fibreless. It is extensively used for processing of its pulp.

Zardalu: It is a mid season variety of Bihar. Fruits are medium, oblong to oblique, peel is thin and colour of the fruit is golden yellow. Pulp firm to soft, flavour is pleasant and fruit quality is very good. Keeping quality is medium

Clonal selections

Exploitation of natural variability through selection of superior clones of commercial mango cultivars has been undertaken by several research centres. A number of clonal selections of mango have been identified and selected four superior clones from the variety Dashehari at Lucknow, viz. C24, C18, C35 and C45. New clonal selections from Langra and Sunderja have been made at Varanasi and Rewa. Similarly, a clonal selection from Paiyur-1 of Neelum was made at the Fruit Research Station, Paiyur, Tamil Nadu. HAS-4 and NPP-5 superior clones of Alphonso and Raspuri, respectively. At CISH, Lucknow, a superior clonal selection Dashehari-51 having regular bearing and freedom from malformation was identified. An off season selection, Niranjan, has been selected at Parbhani. Besides, a few dwarf polyembryonic selections made in the north-eastern region.

Development of hybrids

As a result of systematic hybridization, over more than half a century in the country, several hybrids have been released by various centres in the National Agricultural Research and Education System (NARES). Of these, Mallika, Amrapali, Ratna and Arka Puneet have become popular varieties released from IARI, New Delhi such as Mallika and Amrapali have assumed commercial status in some mango producing states of the country and Pusa Arunima is gaining popularlity. Some promising mango hybrids and their characters are given in Table 2.

Propagation and rootstocks

Mango can be raised from seed or propagated vegetatively. Several methods of vegetative propagation have been tried with varying degrees of success. Propagation from seed, though easy and cheap, is unable to perpetuate characters of the parent tree because most commercial varieties in India are cross-pollinated and monoembryonic. Plants also take more time approximately, 5-6 years to bear fruit. However, it is essential to raise seedlings to be used as rootstocks for uniform production and quality. Nucellar plantlets of polyembryonic varieties are preferred for vegetative propagation, because they maintain the same genetic background of the rootstock mother-plant, which may present disease resistance or dwarfing or both. Moreover, nucellar plantlets used as rootstock may keep adequate orchard homogeneity. The polyembryonic mango rootstocks such as Ambalavi, Bappakai, Kurukkan, Mylepilian, Nekkare, Olor, Sabre, Vellaikolomban and 13-1 from Israel have been tried as rootstocks with variable success. 13-1 from Israel and *Gomera-1* from Spain proved to be the most adaptable rootstock to saline conditions. So far no suitable rootstock identified for important commercial mango varieties

To achieve a successful graft it is important to have healthy, actively growing rootstocks and select scion wood with swollen buds that are ready to burst. Common propagation techniques employed in mango for commercial propagation are inarching, veener/side grafting, soft wood grafting and epicotyle grafting. Initially, inarching was the commercially adopted propagation technique in mango. Keeping in view the inherent limitation associated with the inarching technique, the side grafting or veener grafting technique was standardized for mass scale commercial propagation. Similarly, Epicotyl/stone grafting and Softwood grafting techniques were becoming popular for propagation of mango grafts. Epicotyle grafting is widely practiced in the Konkan region of Maharashtra.

Table 2. Some important promising mango hybrids and their characters

Hybrid	Place of research	Parentage	Important characters
Mallika	IARI, New Delhi	Neelum × Dashehari	Regular bearer, high TSS, good colour, uniform big-sized fruits, moderate keeping quality.
Amrapali	IARI, New Delhi	Dashehari × Neelum	Dwarf, regular bearer, clusterbearing, small-to medium-sized fruits, good keeping quality.
Pusa Arunima	IARI, New Delhi	Amrapali × Sensation	Semi-vigorous, regular bearer, medium sized fruits having attractive red peel colour, excellent keeping quality.
Ratna	FRS, Vengurla	Neelum × Alphonso	Regular-bearer, free from spongy tissue and fibre.
Sindhu	FRS, Vengurla	Ratna × Alphonso	Regular- bearer, papery thin stone.
Arka Puneet	IIHR, Bengaluru	Alphonso × Banganpalli	Regular bearer, attractive skin colour, medium-sized fruits, free from spongy tissue. Good keeping quality and sugar : acid blend.

The germinated seedlings of 8–15 days old are used for grafting with a success rate of 75–80%.

Micro-propagation of mango has not met with the commercial success so far. However, *in vitro* somatic embryogenesis has been standardized. Techniques like *in vitro* embryo culture and *ex vitro* shoot-tip grafting have been attempted with variable success rates for obtaining large populations of mango hybrids from crosses.

Some important rootstocks having desirable tolerance to abiotic and biotic stresses are listed in Table 3.

Cultivation

Planting/planting density: Different systems of planting like square, rectangular and hexagonal are followed at different places. However, square and rectangular systems are popular. Before planting, pits are filled with well rotten farmyard manure. The grafts should be planted during rainy season. In the *in situ* grafting, rootstocks are planted in the main field and are raised for six months to one year. *In situ* grafting method is very useful for establishment of mango orchards in problematic soils.

High density planting system: Adoption of high density planting (HDP) system along with good horticultural practices is advocated for safe mango production. In north India, Amrapali was found amenable for high density planting system with spacing of 2.5 m × 2.5 m. Later, severe pruning and use of paclobutrazol was suggested for high density planting of Dashehari (2.5 m × 3.0 m) from Pantnagar. The polyembryonic mango Vellai colomban when used as rootstock imparts dwarfing to Alphonso. Under conventional system of planting (10-12 m) 100-70 plants/ha are accommodated. While, spacing of 5 m × 5 m spacing is recommended for semi-intesive or medium density planting. In double hedge row system a spacing of 5 m × 5 m with double rows and 10 m between successive rows accommodates 266 plants per ha. High density planting at a distance of 2 m × 1 m (1,600 plants/ha) is recommended. However, for commercial cultivation only medium density planting accommodating 400 trees per ha (5 m × 5 m) is recommended. With integration of fertigation technology, productivity as high as 14–15 tonnes/ha could be achieved as against 6–7 tonnes/ha under traditional systems.

Table 3. Rootstocks in mango and their potential traits

Country	Rootstock / related species	Traits / characteristics
India	Bappakai	Tolerates salinity levels up to 5.3 d/Sm
	Nekkare	Tolerates salinity level > 4.0 d/Sm
	M. andamanica	Stress tolerance/ water logging
	M. laurina	Resistance to anthracnose
	M. griffiti	Colour genes
	M. zeylanica	Salt tolerance
	M. camptosperma	Tolerance to submergence
	M. foetida	Stress tolerance
	M. khasiana, M. sylvatica	Low temperature tolerance
	Non-descript germplasm from Andaman and Nicobar Islands	Bunch bearing, salt tolerant ; resistance to anthracnose
Israel	13-1	Salt tolerance
South China	*M. Zeylanica; M. odorata, M. pajang and M. foetida*	Salt tolerance
Spain	Gomera-1, *M. zeylanica*	Restricts the uptake and transport of Ca^{++} and Na^{++}
USA/Australia	*M. laurina*	Resistance to anthracnose

Canopy management: Training the plant during juvenile phase is important to get a strong frame. To develop a strong trunk, the trees should be allowed to grow over 1.0 m height initially. The site of first cut is important for the development of a strong framework. After the initial cut, allow 3 or 4 shoots to grow into branches of over one meter long. These are then cut back to about 60–70 cm length, which will give a good strong branch for supporting the growing tree. After this, the trees should start branching by themselves. Young trees can be pruned at any time of the year. Downward and inward growing branches or branches that cross over each other should be removed. Heading back results in the formation of new primary branches (3-7) during March-April. Prune the excess branches and allow 3 to 4 in all the directions to form scaffold limbs developing as primary branches. Thin the excessive secondary shoots retaining 2-3 shoots per primary branch. Tertiary branches (2–3 numbers) can be obtained by pruning the secondary branches at 60–70 cm height.

In fruit bearing trees, it may not be necessary to prune mature trees every year. Mango trees are terminal bearers, i.e., they flower from the ends of the branches and will only flower on mature wood, i.e., shoots that are six weeks or older. Hence, pruning affects the flowering and yield. There are two periods when pruning can be taken up: First pruning should be done immediately after harvest and should be completed by the end of June/July. It includes, removal of low hanging branches as called as skirting. It facilitates the operations such as fertilizer application and controlling of weed. Second pruning in the form of removal of branches inside the tree which cross over or clutter up in the centre of the tree restricting the penetration of sun light and chemical sprays. One or two uprightly growing branches from center of tree are to be removed to reduce tree height significantly and to increase the availability of light inside the canopy for better photosynthesis. During removal of branches, first cut should be given on the lower side of branch, so that a smooth cut is possible which avoids bark splitting. In bearing mango trees, not more than 25% biomass should be removed at a time; otherwise it results in excessive vegetative growth with reduced flowering shoots.

Removal of any diseased or dead branches in the tree, which could be a source of infection is also advocated. However, it is need based and recommended for those trees found to have yield decline. Second pruning may be taken up in the middle of December and, if the timing is right, it is to be followed by a floral flush rather than a vegetative flush. Second pruning should be completed in a short period not exceeding 1–2 weeks.

Canopy management is an essential operation in HDP in order to maintain optimum number of fruiting shoots and contain the canopy. Pruning must be completed as soon as possible after harvest preferably before second week of June-July. Tertiary branches are to be headed back in such a way that the plant height can be maintained at 1.5–2 m and having 10–15 tertiary shoots per tree. About one month after pruning, thinning of newly emerged shoots is essential to avoid excess shoots and overcrowding. On each tertiary shoot, 3–4 new shoots are to be allowed so that 40–60 panicles can be obtained in each tree. Dried panicle shoots or branches must be removed at the time of pruning.

Nutrition and fertilizer management: Nutrition management in mango greatly depends on understanding about deficient, optimum and excessive limits of important nutrients in the plant systems. For majority of essential nutrients, these limits in mango leaves are depicted in Table 4.

Manuring and fertilization: The nutritional requirement of mango varies with the region, soil type and age. A dose of 73 g N, 18 g P_2O_5 and 68 g K_2O/ year of age from first to tenth year and thereafter a dose of 730 g N, 180 g P_2O_5 and 680 g K_2O should be applied in two split doses during June- July and October. Organic manures and phosphate fertilizers should be applied immediately after harvest, whereas ammonium sulphate should be given before flowering. Avoid using too much nitrogen fertilizers to your mango plants during productive stage. The fertilizer recommendation in mango greatly vary from region to region. In Andhra Pradesh, 1,000 g N, 2,000 g P and 500 g K is advocated for bearing trees. However, in Uttar Pradesh 1,000 g N, 500 g P and 1000 g K along with 30 kg FYM is suggested. The fertilizer doses can be modified based on age, variety, region of cultivation and local recommendation. Similarly, application of 50 kg farmyard manure/tree and 1.0 kg each of N and K

Table 4. Deficiency, sufficiency and excess limits of nutrients in mango leaf

Nutrient	Concentration in leaf (ppm)		
	Deficient	Sufficient	Excess
N (%)	0.77-0.99	1.0-1.5	> 1.5
P (%)	0.05-0.07	0.08-0.25	> 0.25
K (%)	0.25-0.39	0.40-0.90	> 0.90
Ca (%)	1.0-1.99	2.0-5.0	> 5.0
Mg (%)	0.15-0.19	0.20-0.50	> 0.50
S (%)	0.05-0.19	0.20-0.60	>0.60
Fe	25-49	50-250	> 250
Mn	25-49	50-250	> 250
Zn	15-19	20-200	> 200
Cu	5-6	7-15	> 50
B	20-49	50-100	> 100
Mo	0.01-0.04	0.05-1.0	> 1

and 500 g P are recommended for mango cv. Dashehari and Chausa. These fertilizers should be placed in 30 cm wide and 20 cm deep trenches dug 2 m away around the trunk. Multinutrient deficiencies especially Zn (36.6–98.0%), Mn (15.0–67.6%), B (10.5–42.8%) and Cu (3.0–40.00%) are observed in the mango orchards in Uttar Pradesh.

Zinc deficiency results in small and narrow leaves with leaf margins bent upward or downward. Internodal length is reduced drastically and the twig with crowded leaves gives rosette appearance. Pale inferential areas and green veins are typical of zinc deficient leaves. The tree with zinc deficiency does not grow well and the yield, size and quality of the fruit are reduced. Small plants with severe zinc deficiency may die. Zinc deficiency is conspicuously seen in alkaline, saline and sandy soils. Zinc deficiency can be rectified by spraying of zinc sulphate 5 g +10 g urea /litre water twice at 15 days interval. Similarly, Two sprays of ferrous sulphate 2.5 g/liter at fornight interval is suggested for correcting iron deficiency. Under boron deficiency, cracking of fruit is the characteristic symptom. Lusterless leathery leaves with thickened veins and conspicuous brown area in pulp are other associated symptoms. Application of 250 g boron/tree (10-15 year old) with recommended dose of manures during July-August was found beneficial in correcting boron deficiency in mango. In the areas having high salt in the soil and irrigation water, leaves show scorching. The leaves lose their natural colour and turn to bronze. Tip burning is also seen in severe cases of salt injury. To cope the situation, use of Dhiancha as green manure with onset of monsoon in the inter-spaces of the orchard and application of adequate Farm yard manure and compost every year is advocated. Gypsum filled gunny bag if kept in flowing irrigation water will reduce salt effect.

Mango leaves absorb nutrients within 24–72 hr after spray. The leaf NPK status is directly correlated with the availability of respective nutrients in the soil profile and their absorption by the plant. It is highly profitable to the grower, considering the moderate investment and easy culture to which its responds. Four sprays of mango special, a foliar formulation containing six micronutrients (Zn, Fe, B, Cu, Mn and Mo) and three secondary nutrients (Ca, Mg and S) developed by the Indian Institute of Horticultural Research, Bangalore is recommended during August–September, November-December, pea stage and marble stages of fruit development for improving yield and quality.

Irrigation: The water requirement depends on the age, soil type and climate. The newly planted grafts need about 30 liters of water every week. Irrigating in grown up trees after fruit set at 10 days interval

Table 5. Irrigation requirements of mango trees

Age (yrs)	Interval between two irrigations (days)			
	Winter		Summer	
	Heavy soil	Light soil	Heavy soil	Light soil
1	6-7	4-5	4-5	2-3
2-3	10-11	8-9	8-9	6-7
4-5	14-15	12-13	10-11	8-9

increases their yield. Watering after fruit set reduces fruit abortion and increases fruit size. In a new planting, trees must be irrigated throughout the year, including dry periods which occur during the wet season, to enable rapid establishment of the tree. Water inputs should be appropriate to tree size. In general up to 100 L/tree/week should be sufficient for the first two years. (Table 5).

Now-a-days use of drip irrgation in mango orchards is very common. Replenishment 40% of evapotranspiration losses (20-25 liters/plant/day when the evaporation is 8 mm and the canopy area covered is around 6.25 m^2) increased the fruit set and yield (up to 12%). Drip fertigation of straight fertilizers (N and K) in the form of Urea and Muriate of Potash at 75% of the recommended dose of fertilizer is found optimum. In bearing orchards, minimum three irrigations are recommended after the fruit set. First irrigation should be given just after fruit set (mustard size stage), second at marble size stage and third in the second week of May prior to fruit maturity. It is advisable to irrigate mango trees in the basins. Drip irrigation is recommended for judicious use of water as it saves 30–40% water and generally gives 50–60% higher fruit yield. Irrigation to the replenishment of 60% open pan evaporation have given the highest fruit yield in mango (119.1 kg, 78.8 kg/tree) cvs Dashehari and Langra, respectively.

Intercropping: Mango orchard provides an opportunity for utilizing inter row space during initial years (up to 8–10 years) of establishment. Due to wider spacing and developing root patterns, the large unutilized inter-space of about 60–70% (land utilization index-'*LUI*') can be gainfully exploited for growing inter and mixed crops. Leguminous crops like green gram, black gram, oilseeds like sesame and groundnut and vegetables crops such as cabbage, cauliflower, tomato, potato, brinjal, cucumber, pumpkin, bitter gourd, bhindi, minor tuberous crops like Colocasia etc. and spices like chillies can be successfully grown as intercrops. The partial shade loving crops like pineapple, ginger, turmeric, ferns etc. can be grown in fully grown orchards. In addition to field crops, some short duration, less exhaustive and dwarf type inter-fillers like papaya, moringa, curry leaf, etc. can also be grown as long as they do not interfere with the main crop. Besides, taking up cover crops like sun hemp,

cowpea, and pea helps in preventing soil erosion and green manuring.

Mulching: Mulching was found to have beneficial effects on tree growth, flowering and yield. Plastic mulching during flower-bud differentiation (October–November) enhanced flowering in mango under north Indian conditions. The mulch stimulates the lateral root growth particularly in nutrient rich upper soil layer and improves nutrient status. Enhancement in flowering and yield (38–70 and 40–60%) was also recorded in *'Off'* and *'On'* year by use of mulches.

Weed management: Most important thing is to keep the area around the base of the tree weed free. In first year after planting, it is important to have an area extending up to about 60 cm away from the tree without weeds. In the intial years of estblishemnt, use of hand tools *(kurpi)* are used for removing the weeds in basins and between rows of plants. When the orchards age progresses, mechanical method of weeding by using small tractors and power tillers with special weeding tool attachments are employed for effective weed control. Cover cropping is another practice followed in mango orchard to suppress the growth of weeds, to bring additional income to the grower until the trees begin to bear and if the intercrops grown are of right type improve the health of trees. The recommended cover crops in mango orchards for summer season are bottle gourd, bitter gourd, onion, chillies, cowpea, black gram, lentils and green gram. For winter season, the intercrops suggested are peas, turnip, cauliflower, carrot, radish and gram.

Use of weedicides is also practiced in mango but utmost care should be taken to avoid spray drift on mango plants. Application of paraquat (3.0 kg *a.i.*/ha) or diuron as pre emergent treatment at 6.67 and 8.9 kg/ha gives good control of weeds. Bromacil and dalapon are effective for controlling dicot and monocot weeds, respectively. One spray of atrazine or diuron at 2.0 kg *a.i.*/ha as pre emergence to soil and one spray of paraquat as post-emergent spray on weeds at 3.0 kg *a.i.*/ha effective for controlling dicot weeds in up to 5 year orchards. Use of glyphosate at 1.8-2.0 kg a.i./ha along with 10% urea is also found effective in managing weeds in pre-bearing orchards.

Mechanization: Harvesting-aids like ladder are aimed at reducing the drudgery of farm labour by the effort and endurance required for the fruit picking operation. Several types of mango harvesting tools have been developed by the research institutions like IARI, New Delhi, CISH, Lucknow; MPKV, Dapoli; and IIHR, Bengaluru. These devices are simple and efficient in harvesting. Mechanized harvesting platforms are also available that facilitate reaching upper portion of the canopies to facilitate harvesting. *Mango harvester* costs ₹ 400 to 600, depending on the length of the bar. Similarly, fertilizer applicator developed at CHES, IIHR regional station, Bhubneswar is also gaining popularity.

Physiological disorders

***Black tip* (Chimney disease):** Symptoms become visible when the mango fruits attain bigger than marble size. Small etiolated area develops near the distal end of the fruit which gradually spreads, turns nearly black and covers the tip of the fruit completely. The black area remains hard and the growth of the fruit is checked.

Reasons for high severity are proximity of orchard-to brick kilns, deleterious effect of gases from brick kilns operating in the vicinity of orchard, wind direction (western winds) and velocity play important role in the severity, and lack of application of timely control measures.

Mode of spread is through toxic gases, viz. sulphur dioxide, ethylene, carbon monoxide and fluoride emitting from the brick kilns operating nearby orchards. It can be can be minimized by the spray of borax (1%) or other alkaline solution like caustic soda and washing soda. The first spray should be done positively at pea stage followed by two more sprays at 15 days interval. Planting of mango orchards in north-south direction and 3 km away from the brick kilns reduces the incidence.

Internal necrosis (boron deficiency): First, water soaked grayish spots develop on the lower side of the fruit. Late, the spots enlarge and develop into dark brown necrotic area. The internal tissue starts disintegrating. The pericarp and mesocarp is disintegrated exposing the flesh. Yellow colored droplets also come out and such affected fruits drop easily.

Foliar spay of borax (1%) at pea stage followed by two more sprays at 15 days interval. Application of 250 g. boron per tree (10-15 year old) around the tree basin.

Fruit clustering (*Jhumka*): This abnormality is characterized by setting of several fruit lets at the tip of panicles. The fruit lets are dark green in colour and their shape is slightly curved than the normal fruit lets. These fruits generally hang for more time as compared to some normal fruits, which subsequently drop due to other reasons of fruit drop. These fruit lets do not however, grow further and subsequently drop as they lack viable embryo.

During flower opening or pollination stages spray of insecticides and fungicides should be avoided. Population of pollinators should be ensured more by keeping bee hives in the orchards during flowering season. Pollinizing cultivars should be planted in the orchards.

Softening of tissue (jelly seed formation): The problem of jelly seed has been recorded in several mango varieties. However, Dashehari is found more susceptible to this disorder as compared to other

cultivars like Chausa and Langra. In this disorder, the integrity of pulp matrix near the stone breaks down and becomes jelly-like with tissue disintegration while the outer pulp near the peel remains normal. The taste of the fruit becomes repulsive and loose quality. From the outer appearance fruits look normal. It incidence is more in Lucknow region especially in the late harvested fruits.

Majority of such orchards with this disorder have been found with the imbalance of nutrients, and P and Zn deficiency were more prevalent. Slow movement of nutrients particularly Ca++ to the fruits from soil and leaf through transpiration stream in Dashehari at maturity was found to be one of the reasons for this disorder. The incidence gets aggravated on exposure of fruits to high temperature and humidity.

An integrated approach is found effective for the control of softening of tissue. This includes application of black plastic mulch (100 micron thick) in the basins of trees during the month of October- November and foliar spray of calcium chloride dihydrate (2.%) and potassium sulphate (1%), one month before harvesting of fruits along with soil application of 250 g Borax per tree during the month of November is also helpful . It is desirable to harvest fruits at proper maturity (not late) and ripen in storage rather than allowing it to happen on plants. Bagging of fruits a month prior to harvest minimizes the incidence of this disorder.

Alternate bearing: Alternate bearing in mango refers to severe fluctuations in yield during 'on' and 'off' years of fruiting. During 'on' year good crop is experienced followed by very low yield in 'off' year. Majority of the south Indian varieties are regular bearers, whereas the north Indian suffer from this phenomenon. Paclobutrazol, a growth retardant and antagonist to endogenous gibberellins biosynthesis has been extensively used in mango for flower induction. It gives early and profuse flowering and more annual yield without affecting fruit size and quality. It has become a commercial practice in Konkan region of Maharashtra. Paclobutrazol applied in mid of July, significantly reduced the number of shoots per terminal in Alphonso, Kesar and Rajapuri. Application of Paclobutrazol in mid of July, August and September under Gujarat condition while during September–October in Uttar Pradesh suppressed the vegetative growth and induced early and profuse flowering. Although the direct effects of Paclobutrazol (PBZ) on early induction of flowering of mango have been well documented, it resulted in reduced vegetative growth without affecting the fruit yield and indiscriminate continuous application of paclobutrazol may cause increase in its residues in fruits.

Application of paclobutrazol @ 3.2 ml/m canopy diameter through soil drenching during the month of September is effective to manage alternate bearing tendency in mango and increase the yields by 25% in 'On' year and 60% in 'Off' year. Application dose is dependent upon the crop load of previous year. Dose of Paclobutrazol can be minimized to half when integrated with plastic mulching (100 μ thick black). Nutritional level of soil and its biological properties are not affected after application of paclobutrazol at standard doses. Residue of applied paclobutrazol in soil (0.462 – 2.535 mg/kg) in the following year has no adverse effect on the soil nutrient status and microbial population and residues were not detected in the fruits with this dose.

Annual tip pruning and Paclobutrazol applications have resulted in overcoming the problem of alternate bearing in mango. The advantage of this procedure is it harmonizes synchronized flowering in selected rows year after year in trees that remained the same size for many years. Although such operations are labour intensive in large trees, mechanical pruners are now available elsewhere that could render the job easier and rapid so that many orchards could be pruned in a shorter period of time.

Smudging is referred as engulfing trees in smoke and allowing smoke to pass through the foliage cover for few days. Ethylene has been identified as the active agent responsible for inducing flowering during smudging. Smudging is done continuously for several days and is stopped if flower buds do not appear within two weeks. The process may be repeated 1-2 months later, but results are uncertain. Smudging is commercially practiced in Philippines for flower regulation in mango.

Similarly, KNO_3 can enhance flowering especially in tropical regions where cold temperature for floral induction may not be sufficient. It is also suggested that induction by potassium nitrate spray occur as a result of ethylene synthesis. Foliar application of KNO_3 (2%) stimulated flowering of mango. Ethylene is usually present in a minute quantity of about 0.1 ppm and causes marked physiological effects in the plants.

Ethephon has also been tried in India for increasing flowering of Langra and Dashehari during "*Off*" years. Precocious bud break and flowering of mango shoots in response to an early October application of 100 ppm 6-Benzyl amino purine (6-BA) has also been noticed. Full flowering was observed one month following application as compared to three months later on non-treated trees.

Mango malformation: It is one of the most important disorders, causing huge losses. Of the two types of mango malformation, vegetative malformation is more common in nursery seedlings and young plants. Floral malformation affects trees at the bearing stage. In vegetative malformation or bunchy top, compact leaves are formed in a bunch at the apex of shoot or in

the leaf axil and growth of shootlet is arrested. Floral malformation directly affects the productivity. The incidence of disorder varies from variety to variety. Deblossoming of early emerged flowers during December and January month alone or coupled with a spray of 200 ppm NAA lowers the incidence of floral malformation significantly. Removal of malformed panicles as and when noticed is another way of reducing the loss caused by this deadly problem.

Spongy tissue: It is a severe problem in Alphonso variety. Fruits though look normal from outside, a patch of pulp matrix turns spongy, yellowish and sour. This disorder has brought down the export prospects of this variety. Germination of stone during fruit growth, inactivation of ripening enzyme due to high temperature, convective heat and postharvest exposure to sunlight are the causes. Use of sod culture and mulching are useful in reducing its incidence. Mango hybrids Ratna and *Arka Puneet* which have Alphonso as one of the parents are found not suffering from this malady. Harvesting mangoes when they are three-fourth matured rather than at full maturity also reduces the incidence of this malady.

Diseases and pests

The major pests are discussed here. Hoppers (*Idioscopus clypealis*, *I. nitidulus* and *Amritodus atkinsoni*), mealy bug (*Drosicha mangiferae*), inflorescence/leaf/twig midge (*Erosomyia indica*), *Dasineura amraramanjarae*, *Procystiphovra mangiferae* and *Procontarinia matteriana*), fruit flies (*Bactrocera dorsalis*, *B. correctus* and *B. zonatus*), leaf webber (*Orthaga euadrusalis*), shoot gall psylla (*Apsylla cistellata*), stem-borer (*Batocera rufomaculata*), shoot-borer (*Chlumetia transversa*), bark-eating caterpillar (*Inderbella quadrinotata*), scale (*Chloropulvinaria polygonata*, *Aspidiotus destructor*), stone weevil (*Sternochetus mangiferae*), thrips (*Coliothrips indicus*, *Rhipiphorothris cruentatus*, *Scirtothrips dorsalis*), fruit borer (*Deanolis albizonalis*), leaf miner (*Acrocercops syngramma*), red tree ant (*Oecophylla smaragdina*), inflorescence caterpillars [*Eucrostus* sp. (Geometridae); *Argyroploce* aprobola/Meyrick (*Eucosmidae*); *Euproctis fraterna* (*Lymantriidae*)], termites (*Odontotermes* sp.).

Mango can be attacked by many diseases which reduce production, quality and yield. Major disease affecting mango are anthracnose (*Colletotrichum gloeosporioides*), powdery mildew (*Oidium mangiferae*), die back (*Lasiodiplodia theobromae*), sooty mould (*Capnodium mangiferae*), phoma blight (*Phoma glomerata*), bacterial canker (*Xanthomonas campestris* pv. *mangifera eindicae*), gummosis (*Botryodiplodia theobromae*), scab (*Sphaceloma mangiferae*), black banded (*Rhinocladium corticolum*, perfect stage *Peziotrichum corticolum*), ganoderma root-rot (*Ganoderma lucidum*), root rot and damping off (*Rhizoctonia solani*), red rust (*Cephaleuros virescens*).

The important post-harvest diseases are anthracnose (*Colletotrichum gloeosporioides* syn. *Glomerella cingulata*), stem end rot (*Diplodia natalensis*) and black rot (*Asperigillus niger*).

Harvesting and post-harvest management

Maturity indices: Selection of right stage of maturity for harvest is an important aspect, which has considerable influence on storage life and quality and final acceptance by the consumer. Mangoes should be harvested at right stage of maturity. Some of the maturity indices developed in mango are discussed here:

Outgrowth of shoulders: The area around the stem of the fruit, known as the shoulder is generally flat. As the fruit reaches the final stage of maturity, the shoulder portion starts bulging forming a depression at the point where the fruit is connected to the stem. This is a reliable test to identify the mature fruit which is ready for ripening. However, in varieties having long or oval shape fruits, such as Kesar, Totapuri, Dashehari etc., prominent shoulder outgrowth is not seen.

Colour of the pericarp: These fruits become light green as they mature. In some varieties, grey powdery deposit can be observed on the skin of the mature fruit.

Smoothness of the pericarp: Tender and immature fruits have a rough skin surface, which are prominent even from a distance. The skin becomes smooth as the fruit matures.

Spotting on the pericarp: At the final stage of maturity, white cork cells develop on the skin, at the shoulder or bottom of the fruit. These cells look like white spot with a reddish ring around.

Specific gravity of fruit: The mature fruits with a specific gravity of 1.01 to 1.03 are heavier than the immature fruits. Thus the immature fruits float in water, while the mature fruits sink in water. Mangoes are generally harvested at physiologically mature stage and ripened for optimum quality.

Fruits are hand picked or plucked with a harvester. During harvesting, the latex trickles down the fruit surface from the point of detachment causing burning of exposed tissues and imparting a shabby appearance to it upon storage. Therefore the fruits should be harvested with a 10–20 cm stem attached. For efficient harvesting of mangoes a simple, low cost and portable mango harvesting device has been developed at the CISH, Lucknow. Fruits are taken into the pouch and held between the divider and knife and as the device is pulled, the blade cuts the stalk. The fruits are then conveyed through a nylon chute to collecting boxes without bringing down the device every time. This saves time and protects fruits from mechanical damage due to impact. It also protects operator's hand from the sap, which oozes out from the point of detachment. On

an average, a man can harvest about 800–1000 fruits per hour, depending on the skill of the worker, fruiting and height of the tree. It consumes 50% less energy as compared to local methods.

Yield: Grafted plants though begin flowering in the very second year of planting, de-blossoming is resorted till fourth year in order to facilitate training and pruning for development of good framework. Yield varies with variety, tree age, agronomic practices and agro-climate. Normally economic yields start from the eighth year of planting which progressively increases up to 25 years after which yields plateau. The variation in yield of mango plants as per the age of orchards are depicted in Table 6.

On an average, mango yields 8 tonnes/ha. The productivity of mango is higher in Andhra Pradesh, Bihar and Uttar Pradesh. With the adoption of high density planting, the yield of mango orchards can be increased many fold.

The post harvest losses in mangoes have been estimated in the range of 25-40% from harvesting to consumption stage. If proper methods of harvesting, transportation and storage are adopted, such losses could be minimized.

Grading: The fruits are graded according to their size, weight, colour and maturity benefits to both the producer and consumer. Grading according to size plays an important role in packaging of the fruits. During grading, the immature, overripe, damaged and diseased fruits should be discarded. The grades vary with variety. For Alphonso and Kesar the commercially accepted grades are A$^+$ grade (>300 g), A grade (250-299 g), B grade (200-249 g), C grade (150-199 g), D grade (<150 g). Grade designations and definitions of quality have been prescribed under voluntary Agricultural Produce (Grading and Marketing Act, 1937), for Alphonso, intended for marketing within the country as well as for export markets, separately.

Packaging: For exports, the stem of the fruits is cut approximately at a length of 1 cm from the fruit with the help of sharp scissors. Then the fruits are kept upside down for 2 h so that the latex flows out from the fruit completely (Desaping). For this operation, special knitted pallets should be prepared to keep the fruit upside down. Utmost care should be taken while cutting the stem of the fruit so that latex drop does not fall on the fruit.

Wooden boxes are commonly used for packaging and transportation. CFB Boxes of 5 kg and 10 kg capacity for packing and shipping of mango fruits are also available. For export purposes, packaging in CFB boxes is essential. Paper scraps, newspapers, etc., are commonly used as cushioning material for the packaging of fruits which prevents bruising and spoilage during storage and transportation. Polythene (LDPE) lining has also been found beneficial as it maintains humidity, which results in lesser shrinkage during storage. Wrapping of fruits individually (Unipack) with newspaper or tissue paper and packing in honeycomb nets helps in optimum ripening and less spoilage.

Table 6. Age-wise yield and productivity of mango trees

Age (years)	Fruit/plant (numbers)	Productivity (tonnes/ha)
5-10	50-500	5-8
11-20	500-1,500	8-12
Above 20 but below 40	1,500 and above	15 and above

Shrink-wrapping is a new technique and trend for packaging mangoes. Shrink-wrapping with an engineered plastic wrap can reduce shrinkage, protect the produce from disease, reduce mechanical damage and provide a good surface for stick-on labels. Fiberboard Box developed at CISH, Lucknow with proper vents at top, sides and bottom for Mango Packaging, Double Fruit Foam Net.

Vapor Heat Treatment (VHT) of mangoes at 46°C for 10 min helps in reduction of incidence of anthracnose and stem end rot. Standardized grading has become imperative for better economic returns in global market. Bigger size fruits take 2-4 days more time in ripening than smaller ones. Hence, packaging of smaller fruits with larger ones should be avoided to achieve uniform ripening.

Handling and storage: Mango is harvested during hotter part of the year in India i.e. April to August. This results in huge postharvest losses. Removal of field heat, cold storage and application of skin coatings to control the ripening processes and reduce ageing and water loss are established to reduce losses. Mangoes are highly susceptible to low temperature injury. Loss of flavour and development of undesirable softening are major symptoms of chilling injury. The most critical factor affecting the postharvest shelf life of mangoes is their temperature management. The temperature range of 20–23°C will result in fruit of the best appearance, palatability, and decay control when ripening mangoes. Mangoes can be held at 10–13°C to extend their shelf life. Relative humidity of 90–95% should be maintained during all postharvest handling steps to minimize water loss and shrivelling of mangoes. Several methods have been evaluated to extend the shelf life of mangoes that rely on the control of the availability or action of O_2 and CO_2 and ethylene during ripening to delay ripening by 2–10 days.

Storage is essential for extending the consumption period of fruits, regulating their supply to the market and also for transportation to long distances. The mature green fruits can be kept at room temperature for about 4–10 days depending upon the variety. For

exports, the harvested fruits are pre-cooled to 10–12°C and then stored at an appropriate temperature. The fruits of Dashehari, Mallika and Amrapali should be stored at 12°C, Langra at 14°C and Chausa at 8°C with 85–90% relative humidity. The fruits could be stored for 3–4 weeks in good condition at low temperature. Controlled atmosphere (CO_2 3–4% and O_2 4–5%) storage of Alphonso, under a continuous flow system held at 13–15°C indicated that Alphonso could be kept for 30 days with a post-storage ripening period of 4–5 days.

Ripening: Ripening of mango is commonly done in the field right after harvest and before packaging, by increasing the temperature of the fruit. This may be done by either leaving the fruit exposed in a shed for up to two days on the ground, or wrapping fruits in newspaper and again in plastic. Temperatures above 35°C slow-down the ripening process by inhibiting the enzyme ACC oxidase that is responsible for the formation of ethylene. These high temperatures increase water loss and decay incidence very significantly. The ripening rate can be accelerated by the treatment of mature-green mangoes with ethylene.

Calcium carbide, a banned chemical is used for forced ripening posing health and environmental risks. Use of calcium carbide for ripening of mango is strictly not recommended. Uniform ripening of mango is possible with the use of ethylene, which is accepted world over. The procedure involves dipping of fruits @100 kg in 100 liters of water containing 62.5–187.5 ml ethrel / ethepon at 52 ± 2°C for 5 min. Concentration of ethrel to be used depends upon maturity of fruits; less mature ones require higher concentration. Solution prepared once, can be repeatedly used for four times. Ethrel treated fruits ripen uniformly with attractive yellow colour without any spoilage within 4–5 days of treatment. Low cost ripening chamber (one ton capacity-7 × 7 × 7 ft) for the purpose of using ethylene gas (available in 200 ml canister) can also be used.

Value addition and uses: Mangoes are put to diverse end uses. Raw fruits of local varieties are used for preparing various traditional products like raw slices in brine, amchur, pickle, murabba, chutney, panna (sherbet) etc. Presently, the raw fruit of local varieties of mango are used for preparing pickle and raw slices in brine on commercial scale while fruits of Alphonso, Banganapalli, and Totapuri are used for preparation squash in different regions. Sour, unripe mangoes are used in chutneys, athanu, pickles, side dishes, or may be eaten raw with salt, chili, or soy sauce. A summer drink called aam panna comes from mangoes. Mango lassi is popular throughout South Asia. Aamras is a popular thick juice made of mangoes with sugar and milk. Mangoes may be used to make juices, mango nectar, and as a flavouring and major ingredient in ice cream. It is also used to make fruit bars, and sweet chili sauce, Ready-to-serve beverages such as squash, nectar, cordial juice, and preservation of mango pulp, mango powder, jam, and jelly.

The wood is used as timber, and dried twigs are used for religious purposes. The mango kernel also contains about 8–10% good quality oil which can be used for saponification and finds use in the preparation of cosmetics. Kernel starch could be used in confectionery.

Utilization of processing-industry waste for value added products: Mango consists of 33–85% edible pulp, with 9–40% inedible kernel and 7–24% inedible peel. A huge amount of waste is produced during mango processing which is a rich source of many bioactive compounds. Waste can be converted to value added by-products such as Kernel flour, starch/fat from kernel, Pectin from peel, biogas production from peel. Utilization of mango waste properly can earn large amount of foreign exchange. Two types of waste are – solid waste of peel/skin, seeds, stones, etc. and liquid waste of juice and wash waters. In mango fruits the discarded portion is very high (30–50%). These wastes are rich in organic constituents like, cellulose, starch, pectin, vitamins, minerals, etc. and these can be profitably utilized. The waste could be used for the production of fertilizers, fuel and value added products through processing, extraction, hydrolysis or fermentation and as animal feed such as fermented edible products such as cider, beer, wine brandy and vinegar and animal feedsand production of alcohol. ■