Pomology-II

Student Handbook

CLASS-XII

CENTRAL BOARD OF SECONDARY EDUCATION, DELHI
Shiksha Kendra, 2 Community Centre, Preet Vihar, Delhi-110 092 (India)

नया आगाज़

आज समय की माँग
आगाज़ नया इक होगा
निरंतर योग्यता के निर्णय से
परिणाम आकलन होगा।

परिवर्तन नियम जीवन का
नियम अब नया बनेगा
अब परिणामों के भय से
नहीं बालक कोई डरेगा।

निंरतर योग्यता के निर्णय से
परिणाम आकलन होगा।

बदले शिक्षा का स्वरूप
नई खिले आशा की धूप
अब किसी कोमल–से मन पर
काई बोझ होगा।

निरंतर योग्यता के निर्णय से
परिणाम आकलन होगा।
नई राह पर चलकर मंजिल को हमें पाना है
इस नए प्रयास को हमने सफल बनाना है
बेहतर शिक्षा से बदले देश, ऐसे इसे अननाए
शिक्षक, शिक्षा और शिक्षित
बस आगे बढते जाएँ
बस आगे बढते जाएँ
बस आगे बढते जाएँ.....

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POMOLOGY-II
for Class XII

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Preface

In india, fruits are grown extensively under varying climatic conditions from temperate to arid zones. Fruits are regarded as protective food as they are rich source of essential minerals, vitamins and antioxidants, which protect us from several fatal diseases. In India, fruit crops are grown on an area of 6,329 (000' ha) area with an annual production of 71,516 (000' MT). Of total fruit production, 90% of share is being contributed by major fruit crops like banana, mango, citrus, papaya, guava, apple, pineapple, sapota, grapes, litchi and pomegranate. These fruits are unique in their own taste, platability and nutritive value and are incomparable with any other food commodity. However, their production is encountered with several complex problems, which if not addressed in time, may result in complete crop failure.

Considering the importance of horticulture, CBSE has introduced advance vocational course on horticulture entitled '**Pomology II**' for class XII students with the following objectives:

- This is an advance course on horticulture, which will enlighten the students with the latest knowledge and skills in the area of modern fruit production. Major topics in this course are production of temperate, tropical and subtropical fruits, fruit-based processing units, rootstocks for fruit crops and their management, fertigation, role of biotechnology in fruit production, maturity standards, mechanical harvesting, pesticide residue and safety, high density planting, orchard rejuvenation, packing and storage of fruits etc.
- After studying this course, students will get an exposure to modern production techniques of fruits, which will help them in motivation to come up as entrepreneurs in the area of fruit production, as an orchardit, as a consultant or establishment of a fruit based processing industry.
- This course has been developed as an aim to sensitize the students in the field of fruit production so that students think of choosing this subject for their higher studies.
- This course has been designed to provide entry level job skills to th students, which will help to meet th human resource requirements for fruit production sector.

Vineet Joshi, IAS
Chariman, CBSE

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CHAPTER

1

IMPORTANCE OF FRUIT CULTURE AND SETTING UP OF FRUIT BASED INDUSTRY

OBJECTIVES

After studying this chapter, students will be able to:

- Understand the economic and health benefits of fruits
- Understand the problems faced by entrepreneurs for setting up of a fruit based industry
- Know the points to be kept in mind while setting up a fruit processing unit
- Start a fruit based processing unit

INTRODUCTION

You must be eating several fruits, sometimes in bulk, when available at a cheaper rate. Have you ever thought about their cultivation? What benefits can you draw by cultivating fruits? Have you ever thought of fruit based product, which you eat almost daily that where they come from, where are these produced, who produces them? Perhaps not, but it is clear that fruit cultivation is a gentlemen's job. It is an art as well as science, which has several benefits to mankind. In this chapter, you will come to know that fruit culture is highly beneficial to us as fruits not only generate income but they also possess several vitamins, minerals, antioxidants that have several health benefits. In addition, they provide raw material for processing industry, which generates rural employments and helps in increasing our earning manifolds.

Fruit culture: Economic preposition and health benefits

Economic preposition

Cultivation of fruits is considered as one of the most lucrative enterprises, which provides very high net income in comparison to cereal crops. Fruit crops provide a base for several agro-industries, which again becomes a source of good money. Similarly, by producing value added products, a farmer can earn a lot of money. At present, export of fresh fruits and their processed products is a major source of foreign exchange in our country. Moreover, fruit cultivation provides employment to rural, skilled and technical personnel, which becomes the base for survival of a mass population as described briefly hereunder.

Source of employment: Fruit cultivation is a labour intensive preposition, which offers higher employment opportunities to us. Cultivation of fruits can generate employment to the tune of 860 man days as compared to merely 150 man days in cereals. In contrast to cereal crops, which are harvested once in a season, fruit crops are harvested for a longer time period as fruits mature in flushes, which ensures additional employment opportunities. Some fruit crops like grape, banana and pineapple generate much large employment ranging from 1,000 to 2,500 man days per hectare.

Source of raw material for agro-industry: Fruit cultivation is a mother for many auxiliary industries like canning industries and processing industries etc. Several agro-industries, based on fruit products are being established, thereby solving the unemployment problem to some extent. For instance, coir (coconut) industry. Further, owing to change in food habits, there is an increasing demand for factory made jams, jellies, fruit beverages, dehydrated foods, pickles etc., in the domestic market. Fruits like mango, citrus, guava, pineapple, banana, litchi, apple, strawberry etc., provide raw material for their processing into value added products. This not only provides employment to rural and urban population but also becomes a source of foreign exchange .

Export earnings: There is a considerable demand for fresh and processed fruit products in foreign markets e.g. mangoes both fresh and canned, fruit juices, salted cashew and other fresh fruits etc. Mangoes, walnuts, grapes, bananas, pomegranates account for larger portion of fruits exported from the country. These fruits are mainly exported to the countries like Kuwait, Dubai and Saudi Arbia. West Asia, the Far East and West Europe are the main export markets for Indian fruits. Fruit juices, fruit pulp and pickles are mainly imported by the USSR, Yemen, Arab Republic. The other markets for processed fruits are UK, UAE, Saudi Arabia, Kuwait, Germany, USA, Holland and Switzerland. Nearly half of India's processed fruit exports are mango based fruit juice, canned and bottled fruits, of which, mango pulp is mainly exported to countries like Saudi Arabia, The Netherlands, UAE, Yemen Republic etc. Thus, fruit cultivation offers great opportunities for earning foreign currency.


Fruits as a source of export earnings

Health benefits of fruits

Fruits were thought to be an ill man's food about 4 decades back and were being given to a person when he was not feeling well. At that time, more emphasis was put on foods providing energy such as carbohydrates and fats. However, the importance of fruits for human nutrition was known which is obvious from the famous proverb" An apple a day keeps the doctor away". The per capita availability of fruits is about 70 g per day, which is just sufficient for a balanced human diet. Requirement of fruits for different groups is different (children 50 g, men 30 g and women 30 g per day). Hence, to meet the requirements of fruits for our increasing population, the production potential need to be increased besides reducing post harvest losses.

Fruits rich in anlioxidants

Chart showing health benefits of some fruits

In general, fruits are good source of vitamins and minerals and hence termed as protective foods. Vitamins and minerals are required in minute amounts and hence known as micronutrients. They help in better utilization of other nutrients such as carbohydrates, fats and proteins by affecting their metabolism and hence in better assimilation in the body.

Reduced intake of fruits in the diets by a large segment of our population due to socio-economic reasons is largely a contributing factor for prevalence of different types of nutritional deficiency diseases. Many of the common fruits found or grown locally could make a major difference in not only supplying vitamins and minerals but also in efficient utilisation of other food constituents. In the absence of adequate supply of vitamins and minerals, utilization of other nutrients particularly proteins is poor.

The most common vitamin deficiency symptoms among our population include night blindness due to carotene/vitamin A deficiency, scurvy due to vitamin C deficiency, beri beri due to thiamin deficiency and

pellagra due to niacin deficiency. In addition, many common symptoms appear like soreness of tongue, cracking at the angles of mouth, redness of eye, burning of feet, anemia etc., due to deficiency of one or the other vitamin in the diet. Goitre is quite prevalent in hilly regions due to deficiency of iodine in the diet.

Vitamin A is needed for the synthesis of a pigment present in the retina called 'rhodopsin' which helps in night vision. Therefore, vitamin A deficiency leads in night blindness. This is the earliest sign of vitamin A deficiency. If not remedied, further deficiency of this vitamin can lead to total blindness. Appearance of a white plaque on the white of the eye called 'Bitot's spot' is also an indication of vitamin A deficiency. Vitamin A deficiency is an important problem particularly in preschool children and yet it can be totally prevented by the inclusion of cheap vitamin A rich fruits such as mango and papaya.

Vitamins are very sensitive to heat and light and get easily destroyed when food is cooked in open vessels for a long time. Vitamins also get destroyed on storage, and hence from the point of view of nutrition, it is best to consume fresh fruits. After cutting, fruits should not be washed as water soluble vitamins are lost.

Fruits contain several minerals such as calcium, iron, zinc etc. Calcium is the major component of bones and teeth. Iron is a part of the red pigment of blood called haemoglobin. Iron deficiency leads to anemia. Vitamin C helps to improve iron absorption. Unlike vitamins, minerals are not easily destroyed by heat and light but they can be washed away if fruits are cut and washed.

Fruits are also rich source of pigments. The chief pigments of fruits are carotenoids, chlorophylls, anthoxanthins and anthocyanins. The carotenoids are a group of yellow, orange and orange red fat soluble pigments widely distributed in nature. These pigments are present in mango, papaya, peach, apricot, tomato, red pepper, carrot, squash etc. The chlorophylls are fat soluble pigments like carotenoids. They are important in photosynthesis, and occur in the plants in the ratio of 3:1 as chlorophyll a and chlorophyll b. Anthoxanthins are flavonoids, which are yellow in colour, and anthocyanins are also flavonoids which consists of red, blue and purple pigments and are water soluble. These pigments are widely distributed in the fruits such as grapes, plum, cherries, berries, *jamun*, *phalsa* etc.

Different types of fruits vary in their contents of vitamins. Some of them are rich in vitamin C (Barbados cherry, *aonla*, guava) while others are rich in vitamin A such as mango, pineapple and papaya. In India, due to different types of climatic zones, a large number of fruits are grown and available in different seasons

Grouping of fruits on the basis of their nutrients is as follows:

Carbohydrate- Raw or ripe banana or mangoes and other sweet fruits.

Fat- Avocado, olives, figs, seeds of muskmelon, watermelon, apricots, almonds etc.

Protein- Seeds of muskmelon, watermelon, apricots, almonds, avocados etc.

Avocado: rich source of fats

Vitamins

Carotene (Vitamin A) : Mango, pineapple, papaya, apricots.

Vitamin C: *Aonla*, citrus fruits like lemons, limes, orange, guava, papaya, strawberries.

Thiamine: *Avocado*, mango, orange.

Riboflavin: *Bael*, avocado, mango, papaya, strawberries.

Niacin: *Avocado*, Blackberry, mango.

Mango: rich source of vitamin A

Minerals

Calcium: *Amla*, guava, Mosambi orange.

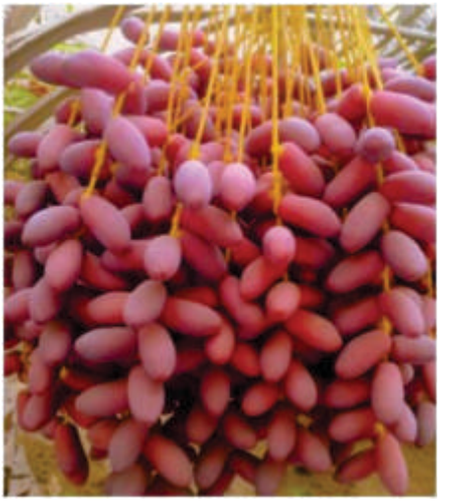
Iron: *Amla*, blackberry, guava, *jamun*, mango, dates, strawberries.

Phosphorus: Avocado, banana, grapes, dates, litchi, Mosambi.


Papaya: rich source of vitamin A

Fruits contain simple sugars such as glucose fructose etc. and also organic acids such as citric acid, malic acid, tartaric acid etc. which gives instant energy to the body. Hence intake of fruit provides a feeling of freshness. Organic acids also increase the availability of some mineral elements by solubilizing them.

As most of the fruits are eaten in the fresh form, some of the digestive enzymes such as proteolytic enzymes (Papain from papaya; bromelin from pineapple; ficin from figs) or starch digestive enzymes (amylase may) help in better digestion of the nutrients in foods and therefore, containing stomach problems. Although in some fruits, for example apple, composition is poor but still they have beneficial effects on human body due to the presence of dietary fibre or flavonoids, which act as antioxidants. Dietary fibres not only help in bowel movement but also help in reducing the absorption of antinutritional factors and in reducing incidence of ulcers. Many fruits such as apple, guava, citrus are rich in pectin, which is a component of dietary fibre.


Dates: rich in P and Ca

In recent years, emphasis is being put on the use of antioxidants for control of cancer and heart diseases. In this regard, fruits play a vital role in providing antioxidants in the form of vitamin C, carotenoid pigments and flavanoids.

Thus, fruits occupy an unique position in human diet. To meet the requirement, the production potential of all the fruits needs to be increased besides reducing post harvest losses.

Health benefits of fruits are due to:

- **Hydrating Effect -** Fruits, eaten raw or consumed as fresh juice, are excellent ways to retain and balance the moisture level in the body. The water absorbed by sick persons in this manner has an added advantage of supplying sugar and minerals at the same time. Patients are frequently advised to take mosambi or grape juice as fructose is readily available to body.

- **Diuretic Effect -** Consumption of fruits lowers the urine density and thereby acceleratea & the elimination of nitrogenous waste and chlorides. Fruits contain a very low level of sodium, they make a valuable contribution to a salt-free diet.

- **Alkalinizing Effect -** The organic acids of the salts in fruits produce alkaline carbonates, when transformed within the organism, which alkalize the fluids. All fruits promote intestinal elimination. This keeps the body free from toxic wastes, which creep into the blood from an overloaded, sluggish intestinal tract.

- **Mineralizing Effect -** Fruits furnish minerals to the body. Dried fruits such as apricots, raisins and dates are rich in calcium and iron. These minerals are essential for strong bones and good blood, respectively.

- **Laxative Effect -** The fibrous matter in fruits such as cellulose, aids in the smooth passage of the food in the digestive tract and easy bowel action. The sugars and organic acids contained in fruits also increase the laxative effect. Hence, regular use of fruits prevents and cures constipation. One or two fruits a day clean the digestive tract and aids easy bowel action.

- **Antioxidative Effect -** Fruits have been referred in ancient text as the best medicines to prevent aging. These are very strong rejuvsenants, which is believed to be due to natural presence of antioxidant,

vitamin C and E. These are substances that defend our body against the ravages brought on by harmful free radicals. Although antioxidant capacity varies greatly among fruits and vegetables, it is better to consume a variety of commodities rather than limiting consumption to a few with the highest antioxidant capacity.

- **Therapeutic Values -** The active principals present in fruits, leaves, bark and other plant parts of fruit crops have been used since ages in curing different ailments. For example, *aonla* is effective for respiratory complaints. It is used in Ayurveda as a cardiotonic, aphrodisiac, antipyretic, antidiabetic, cerebral and gastrointestinal tonic. A tablespoonful each of fresh gooseberry juice and honey mixed together forms a very valuable medicine for the treatment of several ailments. Likewise, bark of mango, the extracts of *bael* leaves and preserve and banana fruits are used to prevent diarrhea and *jamun* seeds and leaf extract are used to cure diabetes. Another disorder, which is slowly attaining an alarming position with the change in the life style is obesity, particularly in urban areas. Fruit have also find their role in combating this disorder as they are high in nutrition, low in fat and calorie. These attributes are quite effective for long term weight loss.

Establishment of fruit based processing units

Location: The following are some of the basic factors that must be considered in the establishment of a food processing business:

- **Available raw materials -** Primary fruit processing plants are generally located in areas of the production of the individual fruit or vegetable crop. Production applies sufficient yields to attract growers to want to produce a crop that meets specific quality standards. Adequate quantities of right type of horticultural produce from contract farming should be readily available in the locality, as horticultural crops are highly perishable and deteriorate in long distance transport.

- **Handling, storage and transportation facilities -** There should exist proper handling, storage and transport facilities for the safe and easy movement of raw material and finished product.

- **Adequate water supply -** There should be continuous potable water and electricity supply. The water must be potable and low in mineral salts such as calcium, magnesium, sulphur and iron.

- **Clean environment -** The environment should be clean and free from debris, dust and disagreeable odours.

- **Sewage disposal facility -** Wastes from fruit and vegetable processing facilities are high in organic matter, consequently the BOD is high and this must be lowered before discharging into the municipal systems. Proper waste disposal mechanism should be there to prevent environmental pollution.

- For frozen products, cold chain facility should be available.

- **Adequate labour supply -** Ample labour should be available at all times for efficient working of the plant.

- **Adequate markets -** The processing industry should look beyond the borders of its own local area and think globally. It requires good transportation facilities. There should be scope for future orderly expansion of the factory.

Present position, scope and future prospects of fruit processing

At present, we are not able to process even 1% of total fruit produced in our country, whereas, several advanced countries use to process about 70-80% of their produce. The following are the major reasons for low processing of fruits in India:

- Non-availability of modern processing technologies.
- Availability of machinery and equipments at a high cost.
- Lack of information about improved technologies.
- Lack of sufficient capital.
- Lack of information about loaning schemes.
- Excessive burden of work and responsibility.
- Lack of recognition and appreciation in the family.
- High cost and distant place for the availability of raw material.
- Difficulty in getting money from buyer after sale.

There is a great scope for processing industry based on fruits as discussed hereunder:

1. Due to perishable nature, about 30-40 of fruits are lost due to improper handling after harvesting. Processing of fruits in times when production is very high or when there is a glut of fruits in market, will reduce these losses to minimum.
2. Sometimes, surplus can't be stored for sale in off season because of inadequate storage facility. With processing, the surplus can be utilized effectively.
3. Fruit based industry will require raw material for which farmers will come forward to grow fruits, which will help in generating employments for rural youth and farm women.
4. With rapid urbanization, there has been significant increase in middle class families, which demand for processed products.
5. In the recent years there has been a change in food habits of the people in Inida. Our children demand for processed products rather than those made at home. Hence, to meet this demand, there is a great scope in expanding this industry in our country.
6. There is a considerable demand for processed fruit products in foreign markets, which can be only bemet after boosting our fruit processing industry.
7. We, in India, are not using much advanced techniques of food processing, whereas, there is a great scope for using several advanced technologies to boost the quality production of such processed products.
8. The rural homemakers who play a considerable role processing at homecale, have not been exposed to modern methods of preservations/processing. We need to disseminate the technology in accordance with the need of locality. Such technologies for rural areas should meet the criteria of low cost, low input, low risk and should be suitable for small scale applications.

Equipments required for setting up of a processing unit

The various types of equipments used in the processing industry are as follows:

1. **Raw material preparation (before processing):** Washing machines, peeling machines, cutting machines, preparation tables, pitting knives, coring knives.
2. **Preparation of pulp / juice extraction:** Continuous simple crusher, horizontal pulper, turbo refiner, continuous extractor, hydraulic press.

3. **Blanching / cooking / concentration / evaporation:** Cooking kettle, steam jacketed pans, continuous water blancher, large stainless steel tank, steam generator, double bottom tank for scalding / blanching.

4. **Pasteurization / deaeration:** De-aerator, pasteurizer, horizontal sterilizer, steam heated processing retort, plate heat exchanger.

5. **Drying / dehydration:** Cabinet dryers, SO_2 generator / chamber, sulphuring box, solar dryer, tunnel dryer, drum dryer, spray dryer, freeze dryer.

6. **Packing machines:** Pouch filler, bottle filling machines, seaming machine, pouch sealing machine, crown corking machine, semi-automatic capping machine.

7. **Canned products:** Can reformer, flanger, double seamer, exhausting tunnel, water sprays, brining/syruping tanks, vacuum gauge, retorts, seam testing machines, salometer, hydrometer.

8. **Quality control equipments:** Refractometer, retorts (autoclaves), hot oven, pH meter, penetrometer, texture analyzer, microscope, incubation oven, analytical balance, working tables, BOD incubator, refrigerator, spectrophotometer/colorimeter, electronic balance, jars vacuum detector, various thermometers, hand refractometer, vortex shaker, colony counter, gas stoves.

9. **Miscellaneous equipments:** Mobile product wagons, storage tank, mixing tank, rotating tank, hot plate, magnetic stirrer, weighing machine, water bath, boilers, exhausts, fans, blowers, illumination and control equipments, waste water treatment equipments, weighing scale, jelmeter, rubber gloves, filter cloth, dusters, aprons, bottles, jars, cans.

EXERCISES/ACTIVITIES

- Go to fruit market. Make a list of fruits and group them on the basis of nutritional composition.
- Take a appointment from a nutritionist. Ask him to list the health benefits of fruits.
- Go to a processing unit. Make a list of positive and negative points of that unit.

CHECK YOUR PROGRESS

1. Describe the health benefits of fruits. Write two fruits rich in Vitamin A, C and minerals such as Ca and Fe.
2. Describe the points which you will keep in mind while setting up a processing unit.
3. Explain why India's could not make a dent in processing of fruits.
4. Write important instrument required for processing of fruits.

WRITE TRUE (T) AND FALSE (F) FOR THE FOLLOWING STATEMENTS

i. Guava is a rich source of B complex group of vitamins

ii. Mango can be helpful in curing night blindness.

iii. Processing units can be set up anywhere in the country.

iv. Our country process about 50-60% of the total fruit we produce.

v. Avocado is a rich source of carbohydrates.

SUGGESTED FURTHER READINGS

- Chattopadhyay, T.K. (2003). A textbook on pomology. Volume 1. Kalyani Publishers, Ludhiana.
- Sharma, S.K. (2010). Postharvest management and processing of fruits and vegetables. NIPA, New Delhi.
- Siddappa, G. and Tandon, D.K. (1998). Presrvation of Fruits and vegetables. ICAR, New Delhi
- Singh, A. (2000). Fruit physiology and production. Kalyani Publishers, Ludhiana.
- Singh, S.P. (2000). Commercial fruits. Kalyani Publishers, Ludhiana.
- Srivastava, R.P. and Kumar, S. (2001). Fruit and vegetable preservation: Principles and practices. International Book Distributing Co., Lucknow, India.

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CHAPTER

2

TEMPERATE FRUITS AND THEIR CULTIVATION

OBJECTIVES

After studying this chapter, students will be able to:

- Identify the temperate fruits and know their importance
- Explain the cultural requirements of temperate fruits
- Identify the problems of temperate fruits and their management
- Identify the major insect-pests and diseases of temperate fruits and their integrated control measures
- Start growing temperate fruits if they belong to hilly areas (temperate zone)
- Start agribusiness in temperate fruit plant nursery or development of value added products

INTRODUCTION

Whenever you go to fruit shop or a market, you might have seen several types of fruits in the shops. Have you ever thought about their areas of production, and specific climate in which they grow? I don't think you have ever thought about it. You may have several such queries in your mind. In this chapter, you will come to know about temperate fruits i.e. the fruits which are grown in cooler climate in hills or areas where the winter temperature is quite low. Most of these fruits require chilling temperature (below 7.2^{o}C) to break bud dormancy. If specific chilling requirement is not met, there will be low flowering in the spring, and hence the crop will also be low. The major temperate fruits grown in India are apple, pear, peach, plum, cherry, apricot and walnut. These fruits contain ample amount of carbohydrates, proteins, vitamins and minerals and thus protect our body from several ailments. In this chapter, we will discuss about the cultural requirements and production technology of important temperate fruits grown in India.

What are temperate fruits?

The fruits, which can be successfully cultivated under temperate climatic conditions i.e. areas where winter temperature is very low and summer temperature is not so high, are called as temperate fruits. Most of the world's temperate fruit production is confined to northern hemisphere, which has over 80 per cent terrestrial area unlike in southern hemisphere where major area is covered by oceans. In general, temperate fruits are grown in regions where winter temperatures are not so cold that would kill the plant but are low enough to provide the buds adequate chilling to break winter rest.

Most of these fruits require chilling temperature (below 7.2^{o}C) to break bud dormancy. If specific chilling requirement is not met, there will be low flowering in the spring, and hence the crop will also be low.

Most of the temperate fruits belong to the family Rosaceae, except the nuts (e.g. walnut, pecan nut, hazel nut) and other minor fruits like persimmon and gooseberries, etc. The temperate fruits can be broadly classified into three main groups, viz. i) pome fruits, ii) the drupes, and iii) nuts. The pome fruits are usually false fruits as the edible part develops from the extra ovarian tissues of thalamus. Apple and pears are major pome fruits. The drupe fruits are characterized by stony hard pit (e.g., plum, peach, almond etc.). Nuts have hard shell, and most of the temperate nuts (walnut, pecan nut, hazel nut) belong to the family Juglandaceae.

In India, temperate fruits are mostly confined to west Himalayan ranges i.e, Jammu and Kashmir, Himachal

Pradesh and Uttrakhand. Their cultivation has been extended to east Himalayan ranges in Sikkim, Nagaland and Arunachal Pradesh. Limited cultivation is also done in Nilgiri hills of south India. Although, the temperate fruit growing areas in India do not fall in typical temperate zone but the prevailing temperate climatic conditions due to the vicinity of snow covered Himalayas and high altitude has made their cultivation possible.

APPLE

Apple is the most important fruit among the temperate fruits grown throughout the world. It belongs to genus *Malus,* family Rosaceae with basic chromosome number of x = 17. Most of the cultivated apple varieties are diploid with chromosome number, 2n = 34. Some cultivars are triploids and tetraploids as well. For example, Suntan, Jupiter and Janagold are triploid and Alpha-68 is a tetraploid cultivar. The cultivated apple is usually referred as *Malus pumila* L., although, the exact name is *M. domestica* Borkh. The origin of apple is considered to be the Caucasus, Asia Minor and Soviet Central Asia. Ambri, a dessert apple variety, is considered indigenous to Kashmir. China, USA, Turkey, Poland, Russian Federation, France, Italy, Germany and Argentina are major apple producing countries. In India, apple is cultivated in Jammu and Kashmir, Himachal Pradesh, Uttarakhand, Arunachal Pradesh, Nagaland and Sikkim. Some low chilling varieties are also cultivated in Nilgiri hills and eastern Himalayan ranges.

Soil and climatic requirements

Apple can grow on a wide range of soils. Well-drained, deep, fertile, slightly acidic, clay loam soils with pH 6.0-6.8 are considered ideal for apple cultivation. Sites with gentle slope are generally more suitable than too steep areas. Windy locations, ridge tops and skylines should be avoided for apple cultivation.

Apple requires about 1,000 to 1,500 hours of winter chilling for breaking the bud dormancy. Abundant sunshine is necessary for proper growth and colour development in fruits. Spring frost and hails are the major limiting factors in apple production. Therefore, areas experiencing frequent spring frosts and hails coinciding flowering and fruit set should be avoided. Well distributed annual rainfall of 100-125 cm is favourable for good productivity. Excessive rains and foggy conditions near fruit maturity result in poor fruit quality, poor colour and development of black fungal spots on the fruit surface.

Planting

The methods of planting apple in flat areas are square, rectangular, quincunx and hexagonal systems. However, in hilly areas, contour or terrace planting is convenient. The planting distance of apple depends on variety, rootstock, soil type and cultural practices, which influence the size of the canopy. However, in general, a planting distance of 8 x 8 m for vigorous and 5 x 5 m for dwarf cultivars is recommended in India. In general, pits of 1 x 1 x 1 m size are dug and filled at least one month before planting by mixing 40-50 kg FYM or compost, 500 g superphosphate and 50 g insecticidal dust like metacid dust or folidol dust at the time of filling. Early planting should be done preferably in December. Care should be taken that the graft union remains at least 25 cm above ground in order to avoid scion rooting and collar rot incidence.

Commercial varieties

Important commercial varieties of the world are Delicious, Golden Delicious, McIntosh, Rome, Beauty,

Top and Red Golden Delicious cultivars of apple

Jonathan, York Imperial, Golden Delicious, Stayman Winesap, Yellow Newton, Baldwin, Grimes Golden, Wealthy, Cox's Orange Pippin and Rhode Island Greening.

According to the time of harvesting, apple varieties can be categorized as early, mid season and late.

Early : Red June, Tydeman's EarlyWorcester, Kings Pippin, Summer Queen

Mid season : Starking Delicious, Red Delicious, Richared, Black Ben Davis, Red Gold, Mclntosh, Golden Delicious, Lord Lambourne

Late : Granny Smith, Ruspippin (yellow, winter banana)

Flowering, pollination and fruit set

Most of the apple cultivars especially of the Delicious group and its colour and spur mutants being self-infertile, require cross pollination for satisfactory fruit set. Therefore, pollinizing varieties, having overlapping flowering period should be planted with the main varieties. Tydeman's Early Worcester, Red Gold and Golden Delicious are good pollinzers. For the spur types, like Golden Spur, Wellspur, Top Red etc., can be inter-planted as pollinizers. Crab varieties such as *Malus floribunda*, Red Flesh, Crimson Gold, Yellow Drop, Manchurian, Snow Drift and Golden Hornet can also be introduced into the orchard apart from standard pollinizers to ensure pollination.

Attractive fruits of Red Delicious cultivar

Delicious group of apple varieties were introduced in India at Shimla (HP) by S.N. Stocks, which revolutionized apple cultivation in our country as well.. These varieties require polliniser variety in commercial orchards. Placement of 25-30% pollinisers has been recommended for Delicious group of apples.

Twenty five to 30 per cent pollinizer trees are adequate for Delicious varieties. In areas having poor set, the proportion of the pollinizer trees can be increased to 30 to 50 per cent. Since honeybees carry out cross pollination in apple, 4-5 bee hives per hectare should be placed in the orchard before flowering.

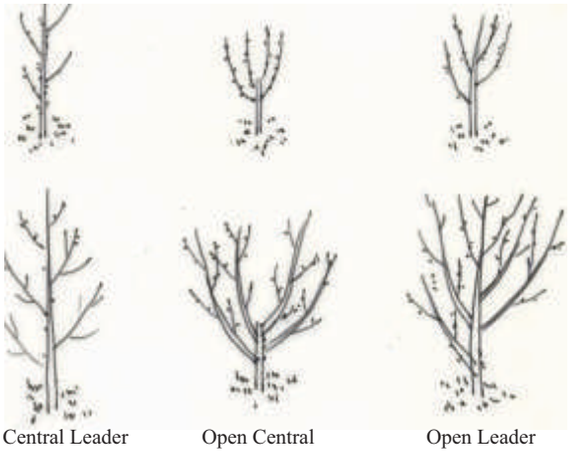
Rootstocks and propagation

Traditionally seedling rootstocks are used. These provide strong and well developed root system with good anchorage in shallow sloppy hilly conditions. In western countries, now standard clonal rootstocks such as Malling (M) series and Malling Merton (MM) series rootstocks developed at East Malling Research Station and John Inn's Research Institute, Merton, are used. MM series rootstocks are resistant to woolly apple aphid. EMLA series virus free rootstocks have also been developed by screening the M and MM series rootstocks. Based on their effect on the scion, clonal rootstocks of apple have been classified in four groups viz., dwarfing (e.g. M 9, M 26), semi-dwarfing (e.g. MM 106, M 7), semi-vigorous (e.g. MM 104, MM 111) and vigorous (e.g. M 16, M 25, MM 106).

Clonal rootstocks (e.g. M series) could not be successful in India because of low fertility status of soil, poor anchorage of stocks and bad suckering rate in such rootstocks.

Training and pruning

Modified central leader system of training is most suitable for developing framework of the tree in standard plantations on seedling rootstock. The proportional heading back and thinning out system of pruning is adopted to maintain the balance between the reproductive and vegetative growth. Apple requires regular moderate annual pruning. In the aged plantations, spur



Central Leader Open Central Open Leader

Some training systems in apple

pruning is advisable to encourage the vegetative growth and new spur development. In high density plantations on clonal rootstocks, the most suitable methods of training are spindle bush, dwarf pyramid or cordon. Espalier system induces *dwarfing effect* and improves spur development and fruit quality. All the size controlling training systems facilitate use of anti-hail nets in hail prone areas.

Manures and fertilizers

In general, 10 kg FYM, 70 g N, 35 g P_2O_5 and 70 g K_2O should be applied to one-year-old plants. The dose should be increased in the same proportion till the plant gains the age of 10 years when the doses are stabilized. A mature tree requires 100 kg FYM, 700 g N (2.8 kg CAN), 350 g P_2O_5 (2.0 kg single superphosphate) and 700 g K_2O (1170 g muriate of potash) in an 'on' year. In the 'off' year, the fertilizer doses should be reduced to 500 g N, 250 g P_2O_5 and 400 g K_2O.

NPK fertilizers should be broadcasted in the tree basin 30 cm away from trunk to tree dripline and mixed well in soil. FYM, P_2O_5 and K_2O should be applied during the winter before snowfall at the time of basin preparation whereas nitrogenous fertilizers should be applied one month before bud break. If irrigation facilities are available, nitrogen should be applied in two split doses, first half dose should be applied 2-3 weeks before flowering and the second half dose should be applied one month later. Apple trees also respond to foliar application of nitrogen in the form of urea (0.5 per cent), which can be sprayed twice after fruit set at one month's interval.

Orchard floor management

Mulching followed by herbicidal application has been the most effective for floor vegetation management and soil moisture conservation. Oak leaves and hay mulch has been found beneficial. Black polyethylene mulch in cooler conditions is the most effective in weed control, moisture conservation, reduction in fruit drop and improvement in size, colour and quality of fruits. However, in warmer conditions, black polyethylene mulch has adverse effect on root growth due to rise in soil temperature.

Gramaxone (1,000 ppm) or mixture of 2,4,5 T (100 ppm) and Gramaxone (500 ppm) is effective in controlling shrubby weeds. Diuron @ 2 kg/ha, Tok E-25 @ 4 litre/ha and Trafazine at 4 kg/ha can be used to check weed growth in apple nurseries.

Fruit thinning

The judicious thinning at proper stage of fruit development can regulate cropping and improve fruit size and quality. Hand thinning is cumbersome, hence chemical methods should be employed. Carbaryl (1,500 ppm) applied 3 weeks after petal fall induces 60 per cent thinning in Red Delicious. 2,4,5-T can induce 35-40 per cent thinning. In Golden Delicious, application of NAA (10 ppm) and Carbaryl (750-1000 ppm) at petal fall is effective for optimal fruit thinning.

Fruit drop and its control

Fruit drop is one of the most serious problems in apple. Most of the commercial varieties of apple have 3 waves of fruit drop : (i) early drop, (ii) June drop, and (iii) pre-harvest drop. Pre-harvest fruit drop results in serious economic losses as full grown marketable fruits abscise before harvest. This is caused due to hormonal imbalances, especially reduction in the levels of auxins. This drop is very high in early ripening cultivars like Tydeman's Early Worcester, Red Gold and Pippins and range from 40 to 60 per cent of crop load. Application of NAA (10 ppm) before the expected time of fruit drop or 20-25 days before harvest can check the fruit drop effectively.

Colour improvement and enhancement of ripening

In Delicious varieties of apple, colour development is generally poor in marginally warmer areas and thereby produce fetches poor price in the market. Application of 1,000 ppm 2-chloroethyl phosphonic acid (ethrel/ethephon), an ethylene releasing hormone, about 10 days before harvest improves fruit colour

substantially but impairs shelf life. Since this chemical accelerates fruit abscission, 10 ppm NAA is added to check drop.

Physiological disorders and their management

In apples, physiological disorders like cork spot, bitter pit, Jonathan spot, water core, internal breakdown, and storage scald can cause damage. Of these disorders, bitter pit is quite serious. Its symptoms appear as small, dry, brown pockets usually spherical in shape below the peel and also in the cortex. Delicious group is more prone to bitter pit. Early picked apples are more prone to bitter pit. In addition, unbalance or high nitrogen promotes its incidence. However, calcium deficiency is the primary cause of bitter pit in apples. Spraying calcium chloride (0.4%) or dipping harvested apples in calcium chloride (2%) is effective in reducing bitter pit. Similarly, boron and zinc sprays increase the Ca content of fruit and reduce the incidence of bitter pit effectively.

Maturity and harvesting

It is important to harvest the fruits at proper stage of maturity. Immature fruits are of poor flavour and quality and shrink during storage. Over mature fruits are also poor in quality and are more prone to storage disorders. The important picking indices for apple are, change of seed colour to brown, change of ground colour from green to pale or red, TSS of 11 to 14.5, firmness of flesh (16-18 lb/square inch), easy separation of fruit from the spurs and 90-180 days from full bloom to maturity, depending on variety. Now-a-days, starch-iodine index (SII) is being followed as a reliable maturity index.

Change of ground colour from green to pale or red, TSS of 11 to 14.5, firmness of flesh (16-18 lb/square inch), SII (4.5/10) and 90-180 days from full bloom (DFFB) to maturity depending on variety are major maturity indices for harvesting apples at a right stage of maturity.

The harvested fruits are graded according to size and colour. In India, apples are graded in seven size grades *viz.* super large (85 mm diameter), extra large (80 mm), large (75 mm), medium (70 mm), small (65 mm), extra small (60 mm) and *pittoo* (55 mm and below). The fruits can be packed in telescopic fibre board cartons or wooden boxes for transportation and storage. Apple fruits can be stored at -1.1 to 0 ^{0}C at 85-90 per cent relative humidity for 4-6 months. Controlled atmospheric (CA) storage is also becoming popular in advanced countries. Apples can be kept for about 9 months in CA storage. In India also, some CA storage facilities have been created by Adani group and Reliance Industries in Himachal Pradesh. Apple has the longest shelf life in cold storage than any other fruit and thus is available all the year round.

Plant protection

a. Insect pests and their control

Insect-pests	Control measures
San Jose Scale (*Quadraspidiotus perniciosus*)	Application of 2 per cent miscible oil or 5 per cent summer oil during February-March efficiently controls the pest. The summer oil formulations, e.g. Orchex 796, Caltex 1, POL Summer oil, etc. can be applied at the rate of 1 per cent at petal fall stage. *Coccinella septempunctata* and endoparasitoid, *Encarsia perniciosi* have been found to contain scale population effectively.
Woolly apple aphid (*Eriosoma lanigerum*)	Soil application of phorate or carbofuran granules during May and October-November checks its incidence and spread of this pest. The foliar spray of chlorpyriphos (0.02%), fenitrothion (0.05%),

	dimethoate (0.03%) or phosphamidon (0.03%) also controls the pest effectively. Rootstocks like MM 106, MM 109, and MM 111 are resistant to this pest. Endoparasite, *Aphelinus mali* is quite promising, and must be encouraged in apple orchards for the control of woolly aphid.
Root borers (*Doresthenes hugelii*)	Drenching tree basins with chlorpyriphos (0.04) or dusting with folidol dust at the rate of 25 kg/ha during September is quite effective for the control of root borers.
European red mite (*Tetranychus sp.*)	Spray of dicofol (0.05 per cent) followed by malathion (0.05 per cent) provide some control of red mites.
Blossom thrips (*Thrips flavus*)	Spray of chlorpyriphos (0.04%) or fenitrothion (0.05%) at pink bud stage is recommended for the control of thrips.

b. Diseases and their control

Apple scab: The disease is caused by *Venturia inaequalis* and it occurs throughout the apple growing belts of the world. The first severe epidemic of apple scab in India occurred in 1973 in Jammu and Kashmir. The disease was reported in Himachal Pradesh in 1977 and in 1982-83 severe epidemic occurred. In this disease, olive green spots appear on leaves and fruits, which causes severe losses to the growers.

Apple twig infested with woolly apple aphid

Symptoms of scab on apple leaves

The recommended spray schedule to control apple scab is given below:

Stage	Fungicide (per/100 litre water)
Green tip	Dodine (100 g), Captan (300 g) or Ziram (300 ml)
Pink bud	Benomyl (50 ml), Carbendazim (50 g) or Thiophanate methyl (50 g)
Petal fall	Fenarimol (40 ml), Hexaconazole (30 ml) or Penconazol (50 ml)
Pea stage	Mancozeb (300 g), Dodine (75 g) or Zineb (300 g)
Fruit development (20 days after pea stage)	Benomyl (250 g), Carbendazim/Thiophanate methyl [20 (50 g] + Mencozeb (250 g) or Dithianon (50 g)
Fruit development (after 20 days of previous)	Mancozeb (300 g), Captan (300 g), Carbendazim (50 g), Mancozeb (300 g), Zineb (300 g) or Propineb (300 g)

Pre-harvest (20-25 days before harvest)	Mancozeb (300 g), Captan (300 g) or Ziram (300 g)
Before leaf fall	Urea (5 kg)

Powdery mildew : In this disease, whitish powdery mass grows on leaves and other ariel parts. It can be kept under control by pruning and destroying affected terminals and spraying of wettable sulphur (0.2-0.3%), carbendazim (0.05%) or karathane (0.05%) during late dormancy, bud swell, petal fall and two weeks later. In nursery, spraying of fungicides at 7 days interval is recommended.


Powdery mildew affected apple branch

White root rot: White mass grows on roots, casing them to rot. Proper drainage, removal of infected roots and application of Chaubattia paste on cut ends of roots and soil drenching of the tree basins with carbendazim (0.1%) at 15 to 20 days interval during monsoon has shown recovery of the plants at an early stage of infection.

Collar rot: Rotting takes at the collar region of plant. The removal of soil around collar portion during November-December and exposure to sun, removal of affected bark and application of Chaubattia paste and soil drenching around trunk with mancozeb (0.3-0.4%), copper oxychloride (0.5%) or ridomil MZ (0.3%) has shown appreciable control. Clonal rootstocks like M 2, M 4, M 9 and MM 113 are resistant to collar rot, whereas, MM 106 is susceptible to the disease.

Cankers: A number of cankers like pink canker, European canker, smoky blight, nail head, stem black, silver leaf and stem brown cankers have been observed in apple plantations caused by various fungi. Scarification of cankered portion and application of Chaubattia paste or copper oxychloride controls the cankers effectively. Cow dung paste (1 part fresh cow dung + part clay soil + water) has also been found to give good healing of scarified portions. Spray of copper oxychloride (0.3%) or captan (0.2%) after harvest and at bud swell stage is recommended in severe canker prone areas.

PEAR

The cultivated pear, *Pyrus communis* L., belongs to the family Rosaceae with basic chromosome number, X= 17. The primary centre of origin of pear is the region including Asia Minor, Caucasus, Central Asia and Western Himalayas. Major pear producing countries are USA, Canada, Mexico, Argentina, Brazil, Chile, Italy, Russia, Germany, France, Switzerland, Spain, Austria, Poland, UK, Australia, New Zealand, Japan, China, Korea and South Africa. In India, pears are cultivated mainly in Jammu and Kashmir, Himachal Pradesh, Punjab, Arunachal Pradesh, Meghalaya, Mizoram, and Western Uttaranchal. Low chilling pears can be grown in Punjab and Nilgiri hills.

Soil and climatic requirements

Pears grow best in fertile, deep, medium textured and well drained clay loam soils. Pears are more tolerant to wet conditions but more susceptible to drought. Pears prefer neutral soil (pH 6.0 to 7.5). There should not be any hard rock or pan within two meters of soil depth, which may restrict proper root growth of the trees.

Conference pears

Pear is adaptable to a wide range of climatic conditions but European varieties require 1,000-1,200 chilling hours. The oriental pears require as low as 200-500 chilling hours below 7 ^{0}C during winters. A well distributed annual precipitation of 100 cm is desirable for successful pear cultivation in rainfed areas.

Commercial varieties

The leading pear varieties of the world are William Bartlett, Anjou Bose, Flemish Beauty, Conference, Hardy, Comice, Winter Nellis, Seckel, Kieffer and Clapp's Favourite. European varieties of pear are cultivated in high hills of India having cooler climate. These are categorized as early, mid - season and late as follows:

Early : Early China, Laxton's Superb, Fertility and Seckel

Mid - season : Bartlett, Conference, Starking Delicious, Max Red Bartlett, Dr July Guyot

Late : Doyenne Du Commice, Easter, Beurre Hardy, Winter Nellis, Clapp's Favourite and Flemish Beauty.

In lower hills and valley areas, which have warmer climate, the varieties belonging to oriental group are grown, which require low winter chilling. The important varieties for these areas are Sand Pear (*Pathar Nakh*), Kieffer, China, Gola, Le Conte and Smith. William Bartlett is the leading variety of pear in Indian conditions. The coloured strains of Bartlertt, viz. Max Red Bartlett, Red Bartlett and Starking Delicious are gaining popularity due to fancy red colour of fruits.

Fruits of Max Red Bartlett

Flowering and pollination

Most of the pear varieties are self-fruitful and do not require pollinizers. However, the provision of pollinizers increases productivity. Most of the varieties are cross-compatible. Bartlett, Burre Hardy, Winter Nellis, Flemish Beauty and Kieffer are pollinizers for other commercial pear varieties.

Plant propagation and rootstock

Pear varieties are propagated by budding or grafting on the seedling rootstocks. Tongue grafting and 'T' budding are most successful methods. Seedling rootstocks such as *P. communis* are compatible with all pear cultivars. The seedling rootstocks such as *P. pashia* (*Kainth*) and *P. serotina* (Shiara) are used in India. Quince (*Cydonia oblonga*) strains are used as size controlling rootstocks.

Planting and spacing

Pear plants are planted in winters when these are dormant. The standard plants on seedling rootstocks are planted at a spacing of 5 meters in normal soil conditions. The spacing can be reduced to 3 meters for plants on clonal rootstocks. In hills, pear is planted on terraces or contours in square or hexagonal system.

Training and pruning

Most of pear varieties are upright in growth habit and need a training system, which would induce spreading habit. Modified central leader system is most appropriate for training the standard trees. Usually, 2 to 3 scaffold branches are selected around the trunk every year for 3 to 4 years in a spiral stair case fashion. The central leader is headed back every year during winters and a terminal side branch is allowed to develop as modified central leader in order to check the upright growth and develop spreading habit.

Pear plants need regular but moderate pruning during winters. Both heading back and thinning out of branches are followed. All the shoots need to be headed back and about ¼ to ½ length should be removed to encourage spreading habit. Crowding branches should be selectively thinned out. Dead, broken or diseased branches should also be removed. Since pear is a spur bearer, renewal of spur is done after 8 to 10 years in order to encourage new healthy spurs.

Nutrition and manuring

Usually one-year-old plant requires 10 kg FYM, 70 g N, 35 g P_2O_5 and 70 g K_2O, which can be increased

annually till 10th year and the levels of fertilizers are maintained thereafter. Thus, a 10-year-old mature tree requires 60-100 kg FYM, 700 g N, 350 g P_2O_5 and 700 g K_2O. FYM, P_2O_5 and K_2O should be applied during December at the time of basin preparation. N is applied usually in February-March in single or in split doses. Pears are also sensitive to boron deficiency, and a single spray of borax (0.4%) during active growth period helps to correct B deficiency in plants.

Orchard floor management

Usually, the basins of pear plants should be kept weed-free. In the inter basin spaces, permanent sod may be allowed to develop. In areas where moisture conservation is important, plant basins can be mulched with hay, at least 10 cm in thickness, after spring rains and retained throughout the summers. The mulch should be removed before onset of monsoon in order to avoid excessive soil moisture and root suffocation. In cooler areas. black polyethylene mulch is better since it also helps in weed control.

Maturity, harvesting and storage

Pears are harvested when the seeds start to turn brown. For distant marketing and processing, fully mature, firm, green pear fruits are harvested as the ripe pears are delicate and do not withstand long transportation and have poor shelf life. However, for domestic or short distance markets, the picking can be delayed till green colour of peel starts turning pale. Pear fruits are graded as extra large (dia. 8 cm), large (dia. 7 cm), medium (dia. 6.5 cm) and small (5 cm). The fruits should be properly packed in 10 or 20 kg wooden boxes or corrugated fibre board cartons. Average yield of pears in proper management conditions is about 30-40 tons per hectare. Pears can be stored at –1 to 0 ^{0}C at 80-85 per cent relative humidity for 30 to 45 days. In controlled atmospheric storage, pears can be stored at 2 per cent O_2 and 1 per cent CO_2 level at –1 to 0 ^{0}C for 2-3 months.

Plant protection

Insect-pests	Control measures
Pear psylla (*Pyrylla pyricola*): Most serious pest of pear. It is known agent for spread of pear decline.	It can be controlled by restricting vegetative growth of the trees, summer pruning of water sprouts, use of overhead tree sprinklers to wash out the honeydew and spraying fenvelrate or fenoxycarb (0.05%) before flowering initiation.
Disease	**Control measures**
Fire blight (*Erwinia amylovora)*	Keep the orchard clean and destroy the affected plant parts. Spray, Bordeaux mixture (8:8:100) along with 2-3% oil at green tip stage and during dormant season or streptomycin (100 ppm) after rains, throughout the spring and early summer.
Blossom blight (*Pseudomonas syringae)*	Spray of Bordeaux mixture (4:4:50) at the onset of leaf fall and later at bud burst is quite effective in controlling it.

EXERCISES/ACTIVITIES

- Go to market and purchase several types of fruits from the vendors. Now identify those which areproduced in temperate regions. Also find the difference between their edible parts.
- Plan a visit to some hilly state during summer vacations (e.g. Himachal Pradesh, Uttrakhand, Jammu

and Kashmir), meet some fruit growers there. Make a list of fruit crops in different orchards and enquire about the different cultural practice used for different fruits.

CHECK YOUR PROGRESS

1) What are pome fruits? Name major temperate fruits grown in India. Write important varieties of apple.

2) Name major insect-pests of apple and pear. Write their control measures.

3) Name major diseases of apple and pear. Write their control measures.

4) Write short notes on grading, bitter pit, and colour development in apple.

FILL IN THE BLANKS

1. The basic chromosome number of apple is ……..
2. In commercial cultivation of Delicious apples varieties, about …… trees should be of polinizer variety.
3. For vigorous apples varieties, a planting distance of ……is recommended.
4. ……. is sprayed for enhancing colour improvement in apple.
5. ……is used for fruit thinning in apple.
6. ……is the major storage disorder of apple.
7. The smallest grade of apple is called as …….
8. Wooly apple aphid infests…… and ……. of apple trees.
9. Sand pear is grown in …… (lower/high hills).
10. Red Bartlett is a variety of …….. (apple/pear).
11. In India, ……rootstock is commonly used in pear propagation.
12. The best time for pruning apple and pear is…… (Dec-Jan, Feb-March, March April)

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PLUM

Plums belong to family Rosaceae, and genus *Prunus* with basic chromosome number, X = 8. Most of the plum species belong to section Euprunus e.g., *P. domestica* (European plums), *P. insititia* (Damson plums), *P. cerasifera* (cherry plum) and *P. salicina* (Japanese plums). The fruit of plum is drupe, glabrous usually having bloom on the surface. The varieties of plums may be diploids, tetraploids and hexaploids with somatic chromosome number of 16, 32 and 48, respectively. The five different centres of origin for plums have been identified, which include Europe for European plums, Western Asia for Damson plums, Western and Central Asia for Cherry plum, China for Japanese plums and North America for American plums.

Santa Rosa plums

The USA, Germany, Romania, Russia, China, Bulgaria, Hungary, France, Poland, Italy, Austria, Turkey, Japan, Mexico, Argentina, Australia, New Zealand, Spain, Afghanistan, India and Pakistan are major plum producing countries. In India, the plums are grown in Jammu and Kashmir, Himachal Pradesh, Uttarakhand, Nilgiris, eastern Himalayan ranges and sub-mountainous parts of Punjab.

Soil and climatic requirements

Plums require deep, fertile and well-drained sandy loam soils for successful cultivation. However, European plums prefer heavy and rich clay-loam soils. Plums perform well in slightly acidic soils with pH 6.5 to 7. Alkaline or saline soils are undesirable for all types of plums.

Plum are successfully cultivated from temperate to subtropical zone. It can thrive well in areas with cold winters as well as hot summers. Plum can thrive in very high rainfall as well as in dry areas. Most of its varieties require 800 to 1,000 chilling hours to break winter rest. Plum tress bloom early in the season, and hence are prone to spring frost injury. About 50 to 100 cm well distributed annual rainfall is enough for quality production of plums.

Commercial varieties

European plum: European plum varieties are grouped in to following 5 sub-groups:

a) Prune: The popular varieties in this group are French, Sugar, Italian, German, Imperial and Stanley.

b) Reine Claude: This group is also called as Green Gage. Varieties like Reine Claude, Jefferson, Washington, Imperial Gage and Green Gage are included in this group.

c) Yellow Egg: It is comparatively a small and relatively unimportant group, suitable for canning purpose only. Yellow Egg and Golden Drop are important varieties of this group.

d) Imperatrice: Important varieties are Grand Duke, Diamond, Tragedy and President.

e) Lombard: Important varieties of this group are Lombard, Bradshaw and Pond.

Japanese plum: The Japanese plums require less winter chilling as compared to European plums. Under Indian conditions, the Japanese group varieties are predominantly cultivated. Important varieties of this group are Santa Rosa, Meriposa, Beauty, Methley, Burmosa, Red Ace (Florida), Formosa, Kelsey, Red Heart, Elephant's Heart, Burbank and Frontier. This group is suitable for both table as well as processing purposes.

American plums: This group is mainly used as rootstock or culinary purposes as the fruit quality is not good. The important species are *P. Americana* (cold resistant), *P. hortulana* (vigorous, resistant to brown rot, good for processing), *P. munsoniana* (resistant to spring frost and fruit brown rot).

Display of plums and peaches by shopkeepers

Important varieties of plums for different elevations are:

High hills:	Early	:	Sweet Early, Methley, Kelsey, Early Transparent, Gage
	Mid - season	:	Santa Rosa, Starking Delicious, Satsuma, Burbank, Elephant's Heart
	Late	:	Meriposa, Frontier, Prunes
Mid - hills :		:	Beauty, Santa Rosa, Meriposa, Frontier
Low hills and valley areas :			Alucha Purple, Titron, Alucha Black, *Alubukhara*, Kala Amritsari
Dry temperate zone		:	Prunes, Local Mansons

Flowering and pollination

In European plums, both self-fruitful and self-unfruitful varieties exist. In self-fruitful varieties, usually 30

per cent fruit set occurs, which is enough for a good crop. However, in self-unfruitful varieties, fruit set is less than 1.5 per cent without the provision of pollinizers. Thus, 10 to 20 per cent inter-plantation of pollinizers is required.

Important self-fruitful varieties are California Blue, French Damson, German Prune, Giant, Stanley, Prune, Victoria and Yellow Egg. The self-unfruitful varieties are Belgian Purple, Diamond, Grand Duke, Hall, Italian Prune, Jefferson, Imperial Gage, President, Reine Claude, River's Early, Sultan, Tragedy, Transparent and Washington.

Most of the Japanese plum varieties are self-fruitful but provision of pollinizers can improve production. Red Roy, Red Rose, Santa Rosa, Climax, Beauty and Methley are self-fruitful varieties. Meriposa, Formosa, Kelsey, Burbank and Satsuma are self-unfruitful varieties. Wickson, Larodo, Santa Rosa and Beauty are good pollinizers for both self-fruitful and self-unfruitful varieties.

Planting

The plums are planted in winters when the plants are dormant. In flat areas, square, rectangle or hexagonal system of planting are followed. In hills, planting or terrace planting is most desirable. The plants on vigorous seedling stocks can be planted at 6 meter distance in well prepared pits. Size of the pit should be at least 1 x 1 x 1 m. For proper root development, any hard pan in subsoil or the rock should be removed while digging pits. The grafting point should be kept at least 15-20 cm above ground level at the time of planting.

Rootstocks and propagation

Seedlings of plums, apricots or peach can be used as rootstock for plum varieties. In Indian conditions, wild apricot and wild peach seedlings are considered good rootstock for plums. Some rootstocks selections from different species are Brompton, St. Julien A, Damson (*P. insititia*), Myrobalan (*P. cerasifera*) and Mariana (*P. cerasifera* x *P. munsoniana*).

The most common method of propagation is tongue grafting, which is done at bud break in spring. 'T' budding is also a good method of propagation, which should be done at the onset of rainy season. The grafting/budding success is more than 90 per cent in plums. The clonal rootstocks of plums are propagated by normal layering or hardwood cuttings.

Training and pruning

In general, modified central leader system of training is followed in plums as in case of apple. However, in mid-hills and valley areas, open centre system can also be followed. Burbank and spreading type Japanese plum varieties should be trained in open centre system, whereas, upright growing varieties like Santa Rosa, Stanley and Wickson can be trained in modified central leader system.

In general, plums require moderate pruning, relatively more than in apple but less than in peach. In plums, it is important to encourage 45 to 60 cm of average extension growth in young stage and 25 to 30 cm in bearing trees, which can be regulated by pruning. Heavy heading back encourages vigorous growth. Hence, the undesirable, diseased, broken limbs and water sprouts should be thinned out. The Japanese plum varieties have the tendency of over bearing, hence these should be pruned harder to improve fruit size and quality.

Manuring and fertilization

One-year-old plum plant requires about 50 g N, 25 g P_2O_5 and K_2O, which can be given in the form of calcium ammonium nitrate, single super phosphate and muriate of potash. These doses can be increased annually up to the age of 10 years when the plants are mature. The fully grown fruiting trees should be given 500 g N, 250 g P_2O_5 and 600 g K_2O along with about 60 kg well rotten farm yard manure (FYM). FYM should be applied during winter along with P_2O_5 and K_2O at the time of basin preparation. Half dose of N fertilizer should be applied in spring before flowering and the rest half dose a month later. Foliar application of nitrogen in the form of urea (1 per cent) is quite effective in plums and 2 to 3 sprays during fruit development stage can improve the fruit size as

well as the plant growth.

Weed control

The manual weed control in plum is quite laborious and expensive. Simazine or atrazine (6 kg/ha) at pre-emergence stage, followed by grammaxone (2 L/ha) at post emergence stage of weed growth can effectively control the weeds for 4 to 5 month in plum orchards. Care should be taken that foliage of the tree should not come in contact with the herbicides.

Maturity and harvesting

Plums develop best dessert quality on the tree but for long distance marketing, plums should be picked a few days in advance when the fruits are still hard but have attained proper colour in at least 50 per cent of fruit surface. Change in fruit surface colour is good maturity index. The fruits with 10-12 psi pressure at fruit maturity are fit for harvesting. Usually, Santa Rosa takes about 104 days after full bloom to maturity whereas Beauty requires only 84 days.

Packing of pulms

Plant protection

Main pests of plum are San Jose Scale, plum scale, tissue borers, plum fruit moth, European red mite, two spotted mite, plum saw flies and nematodes. The diseases infecting plums and causing economic losses are bacterial canker, oak root fungus, brown rot and collar rot. Some of viral diseases affecting plums are plum pox, plum line pattern, prune dwarf and plum decline. The integrated pesticides and fungicide spray schedule suggested for peach can effectively control most of plum pests and diseases.

PEACH

Peach [*Prunus persica* (L.) Batch.] belongs to family Rosaceae, with basic chromosome number, X = 8. Botanically, the fruit of peach is a drupe, and called as stone fruit. Peach originated in China and primarily grown in the temperate zone but has lower chilling requirements than pome fruits. Low chilling varieties are grown in subtropical and tropical zones as well. The peaches are commercially cultivated in USA, Italy, China, France, Spain, Greece, Japan, Argentina, Australia, Mexico, Korea, Russia, Germany, Portugal, New Zeeland, South Africa, Turkey, Canada, Chile, Austria and India. In India, peach is cultivated in Jammu and Kashmir, Himachal Pradesh, sub-mountainous tracts of Punjab and Western Uttar Pradesh hills. Limited cultivation of peach is also done in Nilgiri hills and to some extent in northern eastern states.

Soil and climatic requirements

Peach thrives on a wide range of soil types but does best on light, gravely clay loam soils, which are fairly fertile, deep and well drained. Peach does not do well on water-logged conditions. It is highly susceptible to logging condition among the temperate fruits. Very fertile and heavy clay soils are hazardous to peach because such conditions induce heavy vegetative growth, which is susceptible to winter injury. Well distributed rainfall of 80-100 cm per year or assured irrigation is desirable for a good peach crop. Dry climate with low humidity for 2-3 weeks before harvest is ideal for development of a good quality fruit.Peach requires the warmest climate amongst the temperate fruits. Peaches can be successfully grown in areas experiencing 750 to 800 chilling hours during winters. However, the low chilling peaches of Florida group require only 300 to 550 chilling hours to break winter rest. Peach is very sensitive to low temperature injury after bud break. The swelling buds are injured if the temperature falls below -6.5 ^{0}C for few hours.

Floridared peach

Commercial varieties

Peach varieties, in general, are classified into two groups: i). Flat peaches (*P. persica* var. *compress*) and ii). Nectarines (*P. persica* var. *nectarina*). Nectarines are identical to peach in tree and flower characteristics but differ in the absence of fuzz or pubescence on the fruits. Nectarines are usually small in size, having greater aroma, less melting flesh but are more susceptible to thrips attack than peaches. The peach varieties are divided in two groups based on separation of pit from flesh as under:

Nectarine is a mutant of peach. It is very difficult to differentiate peach and nectarine tree as they are identical in tree and flower characteristics but differ in the absence of fuzz or pubescence on the fruits.

Clingstone: The flesh adheres with the stone even at maturity and is not easily separated. Important varieties of this group are Sun Haven, Red Haven, Shimizu Hakuto and Kanto-5, Sharbati, Flordaquir.

Free stone: These are the varieties in which the stone freely separates from flesh at maturity. The varieties of this group are July Elberta, Rich Haven and Elberta, Flordasun.


Nectarine fruits

The peach varieties for the Indian hilly conditions are as follows:

Mid hills: Early ripening : Word's Earliest, Early White Giant, Red Haven, Sun Haven

Mid season : Alton, July Elberta, Kanto-5, Shimizu Hakuto

Late ripening : J.H. Hale, Elberta, Helberta Giant

Low hills and valley areas : Sharbati, Sun Red, Shan-e-Punjab, Totapari, Matchless, Sufeda, Honey, Sweet, Florida Red, Floidasun.

Low chilling varieties : Some of the low chilling varieties with low chilling requirement are Floridasun (300 hours), Sun Red (300 hours), Sun Gold (550 hours), 16-33 (300 hours), Florida Bell (200 hours) and Floridared (75 hours).

Rootstocks and propagation

Peach is easily grafted or budded on seedlings of peach, plum or apricots; however, peach varieties are usually propagated on wild peach or peach x almond hybrid seedling stocks. Peach scion varieties are usually grafted by tongue grafting during February-March with more than 90 per cent success. Peach x almond hybrid rootstocks like GF 556 and GF 677 are popular in Europe, which are suitable for alkaline soil conditions. Root-knot nematode resistant rootstocks are Nemagaurd, Nemared, Shalin, and Yunnan.

Planting

The peach is planted in winters when the plants are dormant. In flat areas, square, rectangle or hexagonal system of planting can be followed. In hills, planting or terrace planting is most desirable. The plants on vigorous seedling stocks can be planted at 6 meter distance in well prepared pits. Size of the pit should be at least 1 x 1 x 1 m and for proper root development, any hard pan in subsoil or the rock should be removed while digging pits. The grafting point should be kept at least 15-20 cm above ground level at the time of planting. The planting distance depends on several factors, however, 5 x 5 m planting distance is ideal in any system of planting.

Flowering and pollination

Practically, all the commercial varieties of peach are self-pollinated. Thus, most peach plantations do not require elaborate cross-pollination provisions for assured crop. However, a few male sterile/self infertile varieties like J.H. Hale, June Elberta, Halberta and Chinese Cling etc., need male fertile varieties as pollinizers. For such varieties, every third row should be of a pollinizer (e.g. July Elberta). The pollination in peach is

accomplished by honeybees.

Training and pruning

Peach usually requires moderate to heavy pruning annually. The pruning in initial years of plantation is done to shape the framework of plants and is termed as training. Usually the modified central leader system or the open centre system of training is adopted in peach. Modified centre leader system can be followed in areas with plenty of sunshine or in areas of heavy snowfall where risk of limb breaking is more. Another method of training peaches is 'V' shaped *Tatura Trellis*, which is becoming popular because of high yield efficiency. Peach trees should be pruned every year to produce new growth for regular and good fruiting. All the shoots should be headed back to one-half to two-third to maintain the balance in fruiting and vegetative growth.

Manuring and fertilization

In general, the mature tree of over 6 years requires 60 kg FYM, 500 g N, 250 g P_2O_5 and 600 g K_2O annually. However, for the exact fertilizer scheduling, the leaf and soil analysis should be carried out. FYM, P and K fertilizers should be applied at the time of basin preparation in fall. Peach does not respond favourably to foliar nutrient sprays.

Maturity, harvesting and storage

The best time for harvesting peach is when ground colour of fruits starts changing from green to pale. The fruit should be firm at the time of harvesting in order to stand transportation. Peach should be graded according to size and quality. The fruits are packed in 5 or 10 kg wooden or corrugated fibre board (CFB) cartons for marketing. Firm and unripe peaches can be cold stored for 2-4 weeks at –1 to 0 ^{0}C at 85 per cent relative humidity.

Insect-pests	**Control measures**
Peach leaf curl aphid (*Brachycaudus helichrysi*)	Spray methyl demeton 25 EC (0.025%) or dimethoate 30 EC (0.03%) or monocrotophos 36 EC (0.04%) or fenitrothion 50% EC (0.05%) or formothion 25% EC (0.038%) 7-10 days before flowering (pink bud stage).
Peach fruit fly (*Dacus dorsalis*)	Spray neem oil/horticulture tree oil in April-May. Spray of bait consisting of malathion (0.1%) + sugar/gur (1%) is also very effective. Provision for bait station (25g gur + 10 ml malathion + water) can also be made to attract and kill the adult flies.
Nematodes like root knot (*Meloidogyne* sp.), and root lesion (*Pratylenchus sp.*)	Use resistant rootstocks (Nemagaurd, Shalil, Nemared). Use nematicides such as furadon, @ 100-300 g/tree or follow soil fumigation.
Diseases	**Control measures**
Peach leaf curl (*Taphrina deformans)*	Spray with Bordeaux mixture/ lime sulphur at leaf fall stage and bud swell stage. Spray insecticides to kill peach curl aphid, which are vectors for this disease.
Bacterial gummosis *(Pseudomonas syringae)*	Spray streptocycline @ 10g/100 L water before the onset of rainy season or alternatively spray copper oxychloride/Bordeaux mixture @ 0.3% after leaf fall
Brown rot (*Monilinia fructicola)*	Remove all rotten fruits after harvest. Apply fungicide sprays during bloom and as fruit ripens. In addition, hot water treatment (50^{o}C) for 3 minutes and refrigerated storage of the fruits should be done in time.

Leaf curl of peach

A view of gummosis in peach

Plant protection

ALMOND

Almonds are rich in vitamins and minerals and can be used for a wide variety of home remedies. Take care of your heart, brain, and digestive system with this superfood. It lowers our Cholesterol, regulates blood pressure and protects from diabetes

Almond is cultivated for its energy rich kernels. Almonds belong to family Rosaceae, and genus *Prunus*. The cultivated almond is *Prunus amygdalus* Batsch with basic chromosome number, X= 8. Most of the cultivars are diploids with somatic number, 2n = 16.

Almond is a native of western Asia and Mediterranean region, and is mainly cultivated in Italy, Iran, Morocco, China, Portugal, Turkey, France, Algeria, Greece, Afghanistan and Persia. In India, almonds are grown in Jammu and Kashmir and dry temperate zone of Himachal Pradesh (Kinnaur and Lahaul Valley). However, green almond cultivation is done in wet temperate zone of Himachal Pradesh (Shimla and Kullu districts), Uttarakhand and sub-mountainous areas of Punjab.

Almonds, a super food

Soil and climatic requirements

Usually, light sandy soils are suitable for almond cultivation but deep fertile, well-drained, light-loam soils are most suitable for commercial cultivation. It is more resistant to dry soils than most other temperate fruits, yet it shows good response to summer irrigation. Very heavy clay soils are not desirable. Commercial almond growing is limited to the areas having little or no frost hazard during flowering period. It is susceptible to injury by rainy weather in spring and summer. Almonds prefer dry and low humid conditions during fruit ripening

Planting

The planting of almond is done is winter as in case of other stone fruits. Usuallly, planting distance is 6 m in flat fertile soils, but it can be reduced to 4-5 m in less fertile and shallow soils, which restrict plant growth.

Commercial varieties

Prominent varieties grown worldover are Non Pareil, Mission, Ne Plus Ultra, Peerless, Eureka, Kapreil, Thompson, Ballico and Merced. The promising varieties for Indian conditions are:

Dry temperate zone	:	Ne Plus Ultra, Texas (Mission)
High and Mid - hills	:	Merced, Non Pareil, IXL, Nauni Selection, (wet temperate zone) Nikitskyi, White Brandis
Low hills and valley areas	:	Drake, Katha, Peerless, Ne Plus Ultra

Mid sub-tropical areas : Hybrid No. 15, NB 258, JK 39, JK 55, JK 57 and JK 75

Flowering and pollination

Most of the commercial cultivars of almond are self-incompatible and some combinations are even cross-incompatible. So it is necessary to interplant pollinizing varieties with the standard commercial varieties. Pollination is entirely dependent on honeybees activity. Unfavourable weather (e.g., very high or low temperature) for honeybees adversely affects normal fruit set. Provision of 4-6 bee colonies per hectare must be made for assured cross pollination.

Rootstocks and propagation

Almond seedlings, bitter almond and wild peach seedlings can be used as rootstock. Although, bitter almond is considered as a better rootstock than sweet almond. Almond trees on peach rootstock have short life especially in soils, which are high in lime and sodium. Other important rootstocks for almond are Behmi (suitable for cool high hills), Marianna 2624 (resistant to oak root fungus) and Nemaguard (suitable for nematode infested areas).

Training and pruning

Almond plants can be trained either by modified central leader system or by open centre system. The fruits are borne on short spurs or on one-year-old shoots. Since, the spurs remain productive for 5 years, it may be a good practice to prune one fifth of old bearing wood every year so as to encourage 20 to 30 cm annual extension growth. Almonds do not require heavy pruning. Hence, thinning of branches rather than heading back is recommended. Larger but fewer cuts are more desirable than numerous small cuts, which encourage the problem of gummosis. This practice is called bulk pruning.

Manuring and fertilization

Almond has high nitrogen requirement similar to peach, however, it can tolerate lower available potassium content of soil than apple and plum. A mature bearing tree of almond above the age of 7 years requires 40 kg FYM, 2.0 kg CAN, 1.5 kg single super phosphate and 1.2 kg muriate of potash annually. Almond is sensitive to boron deficiency, which affects flowering and fruit set and may cause stem gummosis. Spray of boric acid (0.1 per cent) before flowering and after petal fall is recommended to overcome boron deficiency.

Maturity and harvesting

The mature well-filled nuts should be harvested. Harvesting starts when almond in shady portion of the tree show shriveling and cracking of the hulls. The harvested fruits should be stacked for few days for easy de-hulling. In wet temperate zone, mid and high hills, the green almonds are harvested before onset of rains. The kernels of green almonds are used for confectionery, healthy foods and fresh consumption as green almonds cannot be stored for long time.

Plant protection

Major diseases of almond are bacterial gummosis, almond rust, root rot, collar rot, crown gall, twig blight, shot hole, oak root fungus and almond rust. Important insect pests of almond are leaf curl aphid, twig borer, San Jose scale, root knot nematode and defoliating beetles. These can be controlled by following measures recommended for peach or plum.

Cherries, a high value fruit crop

CHERRY

The cherries belong to the family Rosaceae, and genus *Prunus*. The cultivated cherries are divided into three groups, *viz*. Sweet cherries (*Prunus avium* L.), Sour cherries (*Prunus cerasus* L.) and Duke cherries (*Prunus avium x Prunus cerasus*). The sweet cherries are mainly used for table purposes and most of the varieties are diploid (2n = 16). The sour cherries and duke cherries are

mainly used for processing purposes and are not popular commercially. Most of these are tetraploids (2n = 32) but few cultivars are diploids also. The cherries are native of south-east Europe, western Asia and Asia Minor. The major cherry producing countries are Italy, USA. Germany, France, Russia, Hungary, Spain, UK, Denmark, Poland, Turkey, Rumania, Bulgaria, Greece and Japan. In India, the sweet cherries are cultivated on a commercial scale in Jammu and Kashmir and to a limited extent in Himachal Pradesh.

Soil and climatic requirements

Sweet cherries are more exacting in climate and soil requirements as compared to other stone fruits. Cherries require fertile, well-drained, chalky or deep sandy-loam soils. Soil should not be waterlogged as cherries can't tolerate wet areas in root zone. The cherries are well adapted to cooler climates and require 1,000-1,500 chilling hours below 7 ^{0}C during winters. Cherry blossom is badly damaged by spring frosts. Cherries require about 100 cm of fairly well distributed rainfall throughout the year; however, the flowering and fruit ripening period should be dry.

Commercial varieties

Early Winkler, Black Heart, Red Heart, Early Purple, Coe, Ida, Lambert, Stella, Bing, Van Windsor, Schmidt, Napoleon, Emperor Francis, Ranier, Yellow Spanish and Lambert and Elton are important varieties of sweet cherries.

Flowering and pollination

Most of the sweet cherry varieties appear to be self-unfruitful as well as cross-incompatible. So, the cherry varieties must be inter-planted in proper combinations. Stella, Vista, Vega and Seneca are universal donors for cross-pollination. Most of the sour cherry varieties are self-fruitful and can be planted in solid blocks. Sour cherry varieties can't be used as pollinizers for sweet cherries as their flowering period does not overlap each other.

A branch full of cherries

Rootstocks and propagation

The most common seedling rootstocks for cherries are Mahaleb (*P. mahaleb*) and Mazzard (*P. avium*), and Paja (*P. cerasoides*). The Bird cherry (*P. padus*) seedlings are also used as rootstock but it results in delayed graft-incompatibility. F12/1 is a good clonal rootstock of cherry, which is resistant to bacterial canker and vigorous in growth. Colt is easy-to-root, semi-dwarfing rootstock suitable for high - density plantings but it is susceptible to bacterial crown gall. The clonal rootstocks are usually propagated by mound layering or hardwood cuttings. The scion varieties are propagated by 'Tongue' grafting or 'T' budding on seedling or clonal rootstocks.

Planting

Cherries are planted in winters when the plants are dormant. Pits of 1 x 1 x1 m are dug and filled one month prior to planting. In flat areas, the square or hexagonal system of planting should be followed, however, in hills the planting is done in terraces or contours. For standard plants on seedling rootstock, the plant-to-plant spacing should be 6 m, but in case of plants on dwarfing rootstocks or the compact cultivars (Compact Stella or Compact Lambert), the planting distance can be reduced to 3-4 m.

Cultural practices and manuring

Cherries are very responsive to nitrogen application and clean cultivation. Ten-year-old full grown tree requires 60 kg FYM, 2.0 kg calcium ammonium nitrate (CAN), 1.6 kg single super phosphate and 1.0 kg muriate of potash annually. The fertilizers should be broadcasted in tree basin, 30 cm away from trunk up to tree drop line. Clean basin with legumes or permanent sod between the basins is a good management practice. Mulching with 10-15 cm thick layer of dry grass after spring rains helps in soil moisture conservation, weed control and

improvement in soil structure and fertility.

Maturity and harvesting

There is no recognized maturity standard for picking cherries. Cherries are picked manually when mature, which is reflected by sweetness and change in fruit colour. The fruits are graded according to size and packed in corrugated cartons or baskets of 2 to 5 kg.

Plant protection

Cherries are attacked by bacterial canker, verticillium wilt, crown and root galls, leaf spot, brown rot and viral diseases. Amongst the insect pests, flat headed tree borer, black cherry aphid and San Jose Scale are serious pests. The control measures for these pests and diseases are the same as suggested for other temperate fruits.

APRICOT

Dried apricot, a product of high preference

Apricot is an attractive, delicious and nutritious temperate fruit rich in vitamin A, carbohydrates, proteins, phosphorus and niacin. Apricot belongs to family Rosaceae, and genus *Prunus.* The domesticated apricot is *Prunus armeniaca* L. with basic chromosome number, n= 8 and somatic number, 2n = 16. Apricots hybridize with plums to produce plumcots. *Prunus dasycarpa* is a plumcot resembling purple apricot produced by the cross of apricot and myrobalan plum (*P. cerasifera*).

The primary centre of origin of apricot is considered to be western China and secondary centre of origin is western Asia. Wild Indian apricots like *Zardalu* and *Chulli* are considered indigenous to western Himalayan ranges of India. Major apricot producing countries are Russia, USA, Spain, France, Turkey, Italy, Greece, Hungary, Australia, Morocco, Syria, Iran, Algeria, Afghanistan, Bulgaria, Rumania, China, Iraq, Pakistan, Israel and India. In India, apricots are grown in Jammu & Kashmir, Himachal Pradesh, Uttrakhand and to some extent in NE states.

Soil and climatic requirements

Apricots can establish well in deep fertile clay-loam and well-drained soils. It is a quite hardy plant and can withstand both drought and waterlogged conditions slightly. The climatic requirement of apricot is similar to peach but it needs slightly more winter chilling (800-1,000 chilling hours) than peach. Apricot flowers are as tolerant to spring frost as peach. The annual rainfall of 50-100 cm, long cool winters and uninterrupted warm springs are suitable for apricot fruiting.

Rootstocks and propagation

The common rootstocks used for commercial apricot plantation are seedlings of apricots, plums and peaches. However, the wild apricots such as *Zardalu* and *Chulli* seedlings are most suitable as they form the strong graft union with most of scion varieties and can withstand the adverse soil and climatic conditions. The apricot varieties are propagated by 'Tongue' or 'cleft grafting' and 'T' budding with more than 90 per cent success.

Commercial varieties

The most important varieties of apricot in the west are New Castle, Blenheim, Royal, Tilton, Early Montgamet and Moorpark. In India, varieties suitable for different agro-climatic conditions are:

Dry temperate zones	:	Charmagaz, Suffeda, Shakarpara, Kaisha
High hills	:	Nari, Kaisha, Nugget, Suffeda, Charmagaz, Shakarpara, Moorpark, Turkey, Royal and St. Ambroise
Mid hills	:	New Castle, Shipley Early, Zardalu

Planting

The planting of apricots is done is winter. Usual planting distance is 6 m in flat fertile soils, but it can be reduced to 4-5 m in less fertile and shallow soils, which restrict plant growth. The planting can be done on square or rectangular system of planting. In hills, contour system may be followed.

Training and pruning

Apricots tend to develop large and heavy branches. Therefore, modified leader system of training is advisable. However, open centre system is also satisfactory for most areas. Apricots require relatively less pruning than peaches but heavier pruning than apple. The fruits are borne on short one-year-old spurs largely towards the tip of last year's growth. Spurs bear fruits for three-to-four years. The objective of pruning in apricot is to induce new growth for quality fruit production. The young trees require light pruning, only sufficient for proper training, as the heavy pruning delays bearing.

Manuring and cultural practices

Mature apricot plants above 10 years of age, require 60 kg FYM, 2.0 kg calcium ammonium nitrate, 1.6 kg single super phosphate and 1 kg muriate of potash annually. Apricots respond well to foliar nitrogen spraying in the form of urea (0.5 to 1.0 per cent). A pre-fall spray of 2.5 per cent urea improves fruits set and yield.

The tree basins should be kept weed free by manual weeding or herbicidal treatments. Atrazine or diurone (4 kg/ha) is effective for control of weeds for 4-5 months. Mulching of tree basins with 10-15 cm thick layer of grass is useful not only to conserve soil moisture but also to keep the weed growth in check.

Maturity and harvesting

A full grown apricot tree can yield about 50 to 80 kg fruits. The fruits are usually plucked at change of fruit colour from green-to-yellow or white and loose flesh firmness. Apricot fruits should be graded according to size and packed in 5 kg wooden boxes for transportation and marketing. The fruits are delicate and have poor shelf life. Apricots can be stored at 5 ^{0}C at 85 per cent relative humidity for a week.

Plant protection

Major diseases of apricot are leaf spot, stigmina blight, collar rot, root rot and shot hole. Major insect pests affecting the apricots are blossom thrips, peach fruit-fly, plum fruit moth, tissue borers and defoliating beetles. The control measures for these pests and diseases are the same as suggested for other temperate fruits.

WALNUT

Walnut belongs to family Juglandaceae and genus *Juglans,* having basic chromosome number, n = 16 and somatic chromosome number, 2n=32. Genus *Juglans* includes 20 species. All the *Juglans* species are edible but English walnut or Persian walnut, *Juglans regia* L. is the most important.

The walnuts are considered to be the native of North America, South America and south east Europe to East Asia. Major walnut producing countries are France, Italy, USA, Romania, China, Portugal and Germany. In India, walnut remained confined to Kashmir and spread to Himachal Pradesh and Uttarakhand during the last century only and is yet to gain popularity in east Himalayan ranges and hills of south India.

Soil and climatic requirements

Walnut prefers well-drained, silt loam soils rich in organic matter. Coarse and sandy soils with hard pan should be avoided for walnut plantation. Fluctuating water table is also not suitable for walnut cultivation. Walnuts are most sensitive to alkaline soils.

Main climatic limitations of walnut cultivation are spring frost, extreme summer heat and insufficient winter chilling. Walnut requires more than 1,000 chilling hours during winters. An annual rainfall of 80 cm is

considered sufficient for the cultivation of walnut. High temperatures in spring or summers above 40 ^{0}C accompanied by humidity may cause sunburn of exposed tissues. Such conditions early in the season may cause blank nuts, but if occurs later, kernels may be shriveled. In warm areas, walnuts do not receive adequate chilling, causing delayed bud break and flowering, which result in poor fruit set.

Thin shelled walnuts

Rootstocks and propagation

Generally, walnut seedlings are used as rootstocks. The seedling stocks are vigorous in growth and susceptible to oak root fungus but make smooth graft union, free from constriction with scion varieties. Some of the important rootstocks suitable for walnut are Manregian seedlings, *J. hindsii* and Paradox. Side-veneer grafting, patch budding, annular budding and chip budding are the recommended methods of propagation.

Planting

Planting of walnut is done any time from December to March during dormancy but an early planting is advisable for successful field establishment of plants. In warmer areas without irrigation facilities, walnuts should be planted during rainy season with earth ball or seedlings raised in polythene bags to ensure better establishment of the plants. For *in situ* grafting, 3 to 4 seeds are sown 10 to 15 cm deep during winters at one location and the desirable scion is grafted on the selected seedling during July-August. Since the walnut plants on seedling rootstock are vigorous in growth, plant-to-plant spacing of 8 m is suitable.

Commercial varieties

Eureka, Placentia, Wilson Wonder, Prolific, Franquette, Howard, Pedro, Chandler, Hartley, Payne and Serr are important varieties of walnuts grown worldover. The promising varieties of walnut in India are Govind, Kashmir Budded, Eureka, Pratap, Placentia, Wilson and Franquette.

Flowering and pollination

Walnuts are monoecious plants having male and female catkins separately on the same tree. The male catkins are borne on lateral buds of last year growth whereas the female catkins are borne terminally on current season's growth. Some of the varieties are lateral fruiting as well having high yield potential like Sunland, Chico, Howard and Tehma. Walnut is a wind pollinated fruit and most of the varieties are self-compatible. But the plantation of different varieties is useful as the anthesis of male and female catkins may not synchronize in one tree due to dichogamy (maturation of male and female parts at different times of the day). Pedro is a good pollinizing variety.

Training and pruning

Modified central leader system of training is followed in walnuts with 5 to 6 laterals developed around the stem. After the initial frame of the tree is developed, walnut plants require minimal pruning. Some thinning out of branches is desirable in heavy bearing varieties.

Manures and fertilizers

Annual application of nitrogenous and phosphatic fertilizers is required for regular fruiting. In practice, the walnut plantations are scattered and seldom manured resulting in alternate bearing habit. The fertilizer doses depend on age, yield, size and the fertility of soil. Usually 60 kg/ha each of N, P and K is sufficient for fully grown up trees. Walnut trees are sensitive to zinc deficiency, which can be corrected by foliar application of 0.4 per cent zinc shulphate.

Maturity and harvesting

Walnuts are harvested when 10-15 per cent fruits have dropped themselves, indicating fruit maturity. The

harvested nuts are de-hulled by keeping in a heap under wet leaves. Bleaching of nuts is a practice to give attractive appearance by dipping nuts for 5-10 seconds in a mixture of 8 kg each of Salsoda (sodium carbonate) and lime dissolved in 227 litre of water. Yield of walnut trees varies with the variety, age and size, however, the average yield is about 40 kg/tree.

Plant protection

Main diseases of walnut are leaf blotch, dieback and powdery mildew. Walnut weevil and stem borer are the main pests.

EXERCISES/ACTIVITIES

- Go to fruit market. Purchase several types of temperate fruits available there and classify them into pome, stone fruits and nuts. Among stone fruits, write about their edible parts and differentiate between stone fruits and nuts.

CHECK YOUR PROGRESS

1) What are stone fruits? Name major stone fruits grown in temperate region in India. Write important varieties of peach grown in India.
2) What are major insect-pests of stone fruits?. Write their control measures.
3) What is the importance of rootstock? Write the rootstocks used for peach, plum and apricot.

FILL IN THE BLANKS

1. J.H. Hale is a variety of …….
2. Leaf curl is a major problem in……..
3. Nectarine is a mutant of ……
4. Walnut belongs to family ……
5. Which one is a monoecious fruit plant? (apple, peach, walnut)
6. Charmagaz variety of apricot is grown in …….(dry temperate zone / mid hills/ low hills / plains)
7. Sand pears are mainly grown in …… (dry temperate zone / mid hills / low hills / plains)
8. Fruit cracking is a serious problem in ……..(apple / cherry / peach/almond)
9. Dichogamy is found in …… (apple / peach / walnut / cherry)
10. Sweet cherries are used for table purpose, whereas ……. and …….cherries are used for processing purposes.

SUGGESTED FURTHER READINGS

- Chadha, K.L. and Awasthi, R.P. (2005). Apple. Malhotra Publishing House, New Delhi.
- Chadha, T.R. (2000). Textbook of temperate fruits. ICAR, New Delhi.

- Bose, T.K., Mitra, S.K. and Rathore, D.S (1991). Temperate fruits. Naya Prokash Publishers, Kolkata, India.
- Bal, J.S. (2007). Fruit growing. Kalyani Publishers, Ludhiana, India.
- Chattopadhyay, T.K. (2006) A textbook on Pomology, Vol. 4 (Temperate fruits), Kalyani publishers, Ludhiana, India.,
- Sharma, R.R. (2006). Fruit production: Problems and Solutions. Intl. Book Distributing Co., Lucknow, India.
- Sharma, R.R. (2009). *Adhunik phalotpadan*. Kalyani Publishers, Ludhiana, India.

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CHAPTER

3

TROPICAL FRUITS AND THEIR CULTIVATION

OBJECTIVES

After studying this chapter, you will be able to:

- Identify tropical fruits, describe their importance and their main production sites
- Describe major cultural requirements of tropical fruits
- Identify major problems of tropical fruits describe their management
- Enlist major insect-pests and diseases of tropical fruits and their integrated management strategies
- Start growing these fruits after examining soil and climatic conditions of your locality
- Start business of import or export of these fruits

INTRODUCTION

In the previous chapter, you have learnt about temperate fruits, their production problems and management. In this chapter, you will come to know about tropical fruits i.e. the fruits which are grown in areas, which experience warmer climate throughout the year. This type of the climate prevails in the southern states of our country where there is no much variation in the winter or summer temperature. The major tropical fruits grown in India are mango, banana, papaya, pineapple, sapota, and guava. These fruits contain ample amount of carbohydrates, proteins, vitamins and minerals and thus protect our body from several ailments. Few fruits like sapota are very useful for patients and few (e.g., guava, papaya) are good for getting rid of constipation. Guava is a very rich source of vitamin C as well. In this chapter, we will discuss the cultural requirements of fruits, major production problems and their management.

Fruits of Mallika

What are tropical fruits?

The fruits, which are cultivated successfully in areas which experience high temperature during winter as well as summer are called as tropical fruits. Most of the world's tropical fruits are grown in southern hemisphere which has over 80 per cent terrestrial area near to oceans.

MANGO

Mango *(Mangifera indica* L.), the choicest fruit of India, is said to be the king of fruits. No other fruit is so intimately connected with the history, literature and life of Indians as mango. It is an outstanding source of vitamin A, a good source of vitamin C, apart from normal minerals and other vitamins. In India, it occupies the same position as apple does in temperate countries and grapes in certain regions.

Mango is indigenous to Indo Burman region. It belongs to family Anacardiaceae and genus *Mangifera* with basic chromosome number, X = 20. There are 41 species in genus *Mangifrea*, of which *M. indica, M. caseia, M. sylvatica* and *M. odorata* produce edible fruits.

Soil and climatic requirements

Mango can be grown in a variety of soils but clay-loam, well-drained soils with a pH range of 5.7 to 7.5 are considered to be the best for its cultivation. It has very deep tap root system and thus the presence of any hard pan or calcareous layer in the sub-soil is harmful. Similarly, black cotton soils are also considered unsuitable for commercial mango orcharding. A temperature range of 24-27°C throughout the growing season is the best for its cultivation. It is highly sensitive to frost especially at pre-bearing stage. Its cultivation is limited in areas located above 1,000 m mean sea level. Rainy and cloudy weather at flowering time is considered the limiting factors for its cultivation as these conditions may favour the incidence of many insect-pests and diseases.

Commercial varieties

Fruits of Pusa ArunimaIn India, there are several varieties of mango but only 10-12 are grown commercially. For example, Dashehari, Langra, Chausa and Bombay Green are grown commercially in north, Banganpalli/Baneshan, Neelum, Totapuri in south, Alphonso and Kesar in west and Langra, Himsagar, Zardalu, Kishenbhog, etc. in east. On the basis of embryos, mango varieties have been classified as monoembryonic (Most of the varieties) and polyembryonic (Bapakai,Vellary, Chandrakaran,Kurrukan, Goa, Olour, Carabao, Paho, Peach, Apricot, Strawberry etc.)

Fruits of Pusa Arunima

Some institutions have developed some interesting hybrids. For example Indian Agricultural Research Institute, New Delhi has developed Amrapali, Mallika, Pusa Surya and Pusa Arunima, Pusa Pratibha, Pusa Shresth, Pusa Pitambar, Pusa Lalima etc.. IIHR, Bangalore has developed Arka Puneet, Arka Anmol, Arka Neelkiran, RHRS, Vengurle has developed Ratna and Sindhu (Seedless) and CISH, Lucknow has developed Ambika. All these hybrids have one or the other special characteristics.

Plant propagation

Mango can be propagated both by sexual and asexual means. Rootstocks are propagated by seeds and stooling. Scion varieties are propagated by veneer grafting, stone grafting and soft-wood grafting in different parts of India.

Veneer grafting: The preparation of scion is the most important factor for getting high success by veneer grafting. For this, disease - free, healthy mother plant should be selected. Scion can be prepared from 4-6 months old round shoots. Defoliation of the selected shoots about a week before the grafting is essential for forcing of buds. One-year-old seedlings (pencil thickness) are considered most suitable for using as rootstock. For grafting purpose, 4-6 inch scion should be taken from mother plant and then a slanting cut is given both on the stock and the scion and then scion is fitted on the cut of stock and wrapped with 150 gauge alkathene tape of one inch width. When the scion begins to sprout, the upper part of stock is cut step-by-step. All the sprouts below the graft union should be removed regularly.


A view of side veneer grafting in mango

The best time for grafting under north Indian conditions is March-April. It can be done in May-June also but success is limited owing to high temperature during these months. The added advantage of this method over inarching is that one can prepare his own plants from the desired scion variety, obtained from anywhere, within the country or abroad. Moreover, the orchards established with inferior varieties or old seedling trees can be converted into superior varieties by top-working. In top-working, old/inferior plants are headed back up to secondary branch level during February. The new shoots arising from the beheaded branches are 'Veneer grafted' with a desired variety during June-July. Such plants will start bearing within two years of grafting.

Stone grafting: In addition to inarching (now hanging inarching) and veneer grafting, epicotyl (stone) grafting is the successful propagation method of mango in region with moderate temperature and high relative

humidity. In this method, germinating seeds of less than two-weeks-old are wedge or splice-grafted with a mature scion. A slanting cut of 2-3 cm length is given on 2-week-old epicotyl with a matching cut on the proximal portion of the scion and then these are tied firmly with a alkathene strip. In wedge grafting, the selected 2-weeks-old seedlings are headed back by retaining 6-8cm long stem with the stone. The longitudinal transverse cut running 4-6cm centrally down on the beheaded rootstock is made for fixing a wedge shaped scion prepared by giving a slanting cut from both sides on the lower side of scion stick. The scion stick is then inserted into the saddle-like cut made on the rootstock, pressed properly and tied with the help of 150 gauge - polyethylene strip so that cambium tissues of the rootstock and scion stick and overlap each other.

Mango trees are commercially propagated by stone grafting in Konkan region of India. In north, side - veneer grafting is best while in west, softwood grafting is better.

In some localities like south and western part of India, soft-wood grafting is followed for its commercial propagation.

Planting distance and time

Planting distance varies from variety-to-variety and locality-to-locality. In general, a planting distance of 10-12m is recommended for commercial varieties like Dashehari, Langra, Chowsa, Alphonso, Banganpalli etc. However, for Amarpali, a planting distance of 2.5 x2.5 m is recommended with annual pruning after harvest. Usually, square system of planting is followed but, triangular system has been found useful for Amrapali. Pits of 1 x 1 x 1 m size are dug out and kept open during May, which are refilled by the end of the June with the mixture of top soil and Farm Yard Manure in the ratio of 1: 1. The best time for planting mango is the monsoon season. However, in areas of heavy rainfall, planting should be done at the end of raining season. The planting can be done throughout the year in areas having mild type of tropical climate.

Manures and fertilizers

The application of manures and fertilizers in mango depends on several factors like soil, climate of the area, variety, nutrient status of the soil, etc. It is always advisable to get the soil tested before application of fertilizers. In general, ammonium sulphate, super phosphate arid sulphate of potash should be mixed in the ratio of 1: 3: 1 with the following quantities of farm yard manure (FYM) should be applied as given in the table below:

Age of the plant (year)	Fertilizer mixture to be applied (kg)	Quality of Farm Yard Manure (kg)
One	½	10
Two	1	20
Three	1	30
Four	1.5	40
Four	1.5	50
Six year to 10 year	2 to 2.5	40
11 year to 15 year	3 to 5	60
Above 15	6 to 10	60

Farm yard manure (FYM) is generally applied in September-October every year. In pre-bearing young plants, manuring should be done in March and June in two split doses. However, for bearing plants, half quantity of fertilizers should be applied in July after harvesting and the rest during October along with FYM. A dose of nitrogen may be given a month before initiation of flowering i.e., in the first week of February.

Mango trees should not be irrigated between October-March because plants take rest in this period. During flowering, minimum water should be applied, as heavy irrigation may result in excessive flower drop .

Irrigation

Young plants should be irrigated at weekly intervals in summer and at fortnightly intervals in winter. However, the bearing plants should be irrigated at 10-15 days interval from fruit set stage to maturity. It is, however, advised to withheld irrigation during flowering as it may result in shedding of flowers.

Intercropping and interculture

During the early years of establishment (up to 10 years of age), the vacant space between trees can be profitably utilized by growing intercrops. Apart from giving good returns, intercropping prevents weed growth, reduces nutrient loss through leaching and surface run off, and keeps harmful diseases and pests under control. Vegetables like onion, tomato, radish, carrot, beans, cauliflower, cabbage, leafy vegetables and dwarf, short duration fruit crops like papaya, pineapple, *phalsa*, strawberry etc., can easily be grown in the vacant space of a mango orchard.

Problem of alternate bearing and its management

Most of the commercial varieties of mango bear heavily in one year with very low or no crop in the following year. This phenomenon is known as alternate or biennial bearing. The year of heavy or good crop is called as "on" year and the year of low or poor crop as "off' year. As a result of this habit, a mango orchardist gets less net returns as compared to other fruit crops. However, now farmers can take a regular crop of mango by adopting the following measures:

I. Grow regular bearing varieties like Amrapali, Mallika, Pusa Arunima, Pusa Surya, Ratna, Sindhu, Arka Puneet, Arka Anmol, Arka Neelkiran etc.

2. De-blossomimg in "on" year so as to get some flowers in "off"' year.

3. Drench paclobutrazol (3.5-4.5 a.i. per metre canopy diameter) around tree trunk every alternate year. It makes the plant dwarf and regulates the cropping pattern to a greater extent.

Plant Protection

Insect-pests	**Control measures**
Mango leaf hopper (*Amaritodus atkinsonii*)	Mango hoppers can be controlled by two sprays of carbaryl (0.1%) or Diazinon (0.2%) during January-February at fortnightly intervals.
Mango mealy bug (*Drosicha mangiferae*)	Kill nymphs and females by spraying metasystox (0.2%). Follow banding of tree trunks with 30 cm wide alkathene.
Stone weevil (*Stenochytes mangiferae)*	Difficult to control, however, bagging of fruits, destruction of affected fallen fruits and disposal of refuse debris etc., can bring reduction in the insect number
Fruit fly (*Dacus dorsalis*)	Collect and destroy the affected fruits. Use baits (malathion (0.05%) + jaggery+eugenol) at 4-5 places in open containers. It attracts the adult flies, and control them effectively. Raking of soil in May-June is equally useful as it helps in the killing of pupae.
Diseases	**Control measures**
Powdery mildew *(Oidium mangiferae)*	Two sprays of karathane (0.1%) at fortnightly interval completely control this disease. One preventive spray of karathane (0.1%) as soon as cloudy weather appears during flowering time.

Anthracnose (*Collectotrichum gloeosporioides)*	Spray zineb (0.2%). However, a preventive spray of Bordeaux mixture (4:4:50) is always useful in humid areas before panicle emergence.
Gummosis (*Botrypodiploidia theobromae)*	Remove affected parts and apply Bordeaux paste. Spray copper oxychloride (0.2%).

Physiological disorders

Malformation: It is most dreaded disorder of mango in northern parts of India, the causal agent of which is still unknown. Most of the commercial varieties in sub-tropical parts of India are affected by malformation and southern parts are virtually free from it. Plants both in nursery and field are affected by this malady. The symptoms of this malady are characterized by the transformation of inflorescence into compact mass with predominating male flowers. This disease is commonly related to the prevailing environmental temperature. Panicles emerging during late-December or early-January (when the environmental temperature is comparatively low) are worst affected by malformation. The following control measures reduce the incidence of malformation:

1. Remove and burn all the affected malformed panicles and branches as and when they emerge.
2. Follow up de-blossoming in January.
3. Application of methanol leaf extract of *Ruelia tuberosa* L. 12 g leaf per litre solution reduces malformation in cv. Dashehari. However, the concentration is variety specific, which needs to be standardized.
4. Spray NAA (200 ppm) in October.

Mango malformation is the most dreaded malady of mango in north India; its causes are not yet known, however, temperature plays a vital role. De-blossoming of malformed panicles during December-January is most useful solution.

Malformed mango panicle

Powdery mildew in mango panicle

Spongy tissue: Spongy tissue disorder accounts for more than 30 per cent loss in Alphonso mango. In this disorder, a non-edible, sour, yellowish and sponge like patch develops in one part of the fruit during ripening. The fruit pulp remains unripe but the fruits look normal in external appearance. On cutting, the fruits emit bad odour and are unfit for human consumption. The precise cause of this malady is still unknown. However, recent studies indicate that fruits low in Ca content are worst affected by spongy tissue disorder and the convecteric heat of the soil adds more to this disorder. Use of sod culture, green vegetation, leguminous crop cover or mulching at pre-harvest stage are some measures to reduce this disorder to some extent.

Spongy tissue is one of the most serious disorders of Alphonso mango, which hinders its export from India.

Maturity, harvesting and yield

Depending on variety and growing environment, mango fruits take 90-120 days to reach harvest maturity. Various indices have been suggested to determine the harvest maturity of mango, e.g., change of skin colour, natural falling of some fruits from the tree (*tapka*), formation of abscission layer at pedicel joint, specific gravity of fruits (1.01-1.02), etc. Harvesting is done manually. The most useful tool for this purpose is a long bamboo pole fitted with a cutting shear and a collecting net below it at the distil end of the pole.

Yield varies widely depending on cultivars, age of tree, climatic conditions, alternate bearing, general health of the orchard, etc. In general, grafted plants start bearing at the age of 4-5 years, while seedlings may take at least 8-10 years to come to bearing stage. Initially, the grafted plant (5 years old) may bear 15-20 fruits which will increase to 400-600 fruits by the 10th year; Normally, the yield will go on increasing up to 40 years (2,500 fruits) after which it may decline.

BANANA

Fully ripe banana fingers

Banana is one of the oldest and most popular fruits. The Indo-Malayan region is believed to be the place of origin. It is a good source of carbohydrates and minerals like potassium and sodium. It is widely used as a fresh fruit, but several value added products like chips, puree etc., can also be made from it. The central core of the pseudostem is used as a vegetable, and also for manufacturing paper and boards. India ranks second among the banana growing countries after Brazil. In India, Kerala, Maharashtra and Tamil Nadu account for major share in area and production of banana.

Banana belongs to family Musaceae and genus *Musa* with basic chromosome number, X = 11. *Musa* has been divided into five groups like Eumusa (x = 11), Rhodochlamys (x =11), Callimusa (x =10), Australimusa (x = 10) and Enserte Sedis (x =9). On the basis of genomic constitution, banana has two species, *Musa acuminata* and *M, balbisiana.* All edible bananas have been developed from these two species.

Soil and climatic requirements

Banana can be grown on a variety of soils ranging from clay to sandy clay-loam. However, the best soil is medium textured soil, uniform, reasonably deep and fertile, having good internal drainage and pH between 5.5 - 8.0. Banana is essentially a humid tropical plant, coming up well in regions with a temperature range of 10 ^{0}C to 40 ^{0}C with an average of 23 ^{0}C. In cooler climate, the duration is extended, sucker production is affected and bunches are smaller. Low temperatures (less than 10 ^{0}C) are unsuitable since they lead to a condition called 'choke' or impede inflorescence and bunch development. Banana comes up well from sea level upto an altitude of 1,800 m above sea level. Banana is well adapted to areas with temperature between 21-32 ^{0}C, and annual rainfall between 1,000-2,000 mm.

Commercial varieties/clones

Based on *Acuminata* and *Balbisiana* proportion, varieties of banana have been classified as AA, AAA, AB, AAB, ABB, AAAA or AAAB groups. However, only few varieties could become commercial. The major varieties are Poovan (AAB) , Monthan (ABB) , Harichal (AAA), Rasthali (AAB), Hill Banana (AAB), Nendran (AAB), Sevazhai (AAA) and Kunnan (AB).

Plant propagation

Bananas are propagated from offshoots (suckers or keikis) or corms (bullheads). If enough buds are present, large bullheads can be halved or quartered. Planting material should be treated for nematodes.

Planting system

Square, rectangle and triangle systems are recommended systems for banana planting. For mono-cultured

cropping system, the recommended planting distance is 3.0 x 1.5 m. When intercropped with other permanent crops, the recommended planting distance is 2.4 x 2.4 m. However, it can be modified to 1.9 x 1.9 m & 1.2 x 1.2 m for high - density planting of tall & dwarf varieties, respectively.

Cultural practices

Thinning of suckers: Thinning of suckers aims at maintaining of good of vigour of the plant, obtaining desired number of plant per clump and to enhance production of good quality fruits. Thinning involves removal of unwanted suckers; normally weak unhealthy, mainly water sucker using sharp knife at the ground level, leaving one bearer, one follower and one sucker per clump at any time.

Weeding: During early years of growth, weeds should be controlled manually or using a weedicide. Weeds between rows can be controlled by using contact herbicides or by planting cover crops. As banana roots are superficial, care is taken during weeding to ensure that root damage does not occur. Weeds in between rows are controlled with herbicides using sprayer with a protective cone to the spray nozzle.

Banana bunch covered with blue polythene bag

Fertilizer application: Banana requires high fertilization due to its rapid and vigorous growth and high fruit yield. It removes nearly 250-300 kg N, 25-40 kg P and 800-1200 kg K, 150-180 kg Ca, 40-60 kg Mg and 14-20 kg S per hectare. Usually, 300 Kg N, 40-50 Kg P and 250-300 K should be given per ha.

Water management: Banana plant should be irrigated to encourage development and healthy growth especially in the early years of growth. Micro-sprinkler or drip irrigation system is recommended. Areas with frequent flash floods, construction of in-field drainage is recommended.

Wrapping of fruit bunch: To have a good quality fruit, wrapping of fruit bunches is recommended. For wrapping, strong polyethylene bag with size 75 x 120 cm is used and should be done after the shooting of inflorescence has completed.

Panama wilt affected banana plants

Plant protection

Insect-pests	Symptoms	Control measures
Corm weevil (*Cosmopolites sordidus*)	Larvae feed and tunnel the corm of plant. Affected corm is riddled with tunnels. The leaves of infected plant are dull yellow - green and floppy. Young suckers often wither and fail to develop.	Use healthy material and treat with hot water for 5-10 minutes. Good sanitation. Drench with dieldrin.
Stem borer weevil (*Odoiporus longicollis*)	The weevil bores into the stem and the leaves of infected plant turn yellow and the plant becomes susceptible to wind damage.	Good sanitation. Spray with dieldrin.
Nematode (*Radopholus similis*) and Fruit fly (*Bactrocera musae*)	The infected root turns reddish-brown and later become black. The roots become short, blackened and reduce in number	Use hot water treatment. Provide sanitation. Drench with fenamiphos. Wrap fruits with polyethylene bags.

	and thus, susceptible to wind damage. Larva feeds on the fruit. Evidence of attack is indicated by black spot on the skin.	
Diseases	**Symptoms**	**Control measures**
Leaf spot (Sigatoka) (*Mycosphaerella musicola*)	Small pale yellow or greenish-yellow streak, parallel to the leaf veins. Later the streaks darken and expanded laterally to form elliptical brown spots. The centre of each spot eventually dries upto form light grey structure, like "eyespot" or scorching appearance.	Use resistant cultivar. Spray with benomyl (0.03%).
Panama disease (Fusarium wilt) (*Fusarium oxysporium*)	Soil-borne disease. The first symptom is yellowing of older leaves or collapse of the petiole while the leaves are still green. All leaves eventually collapse and die, hanging on the pseudostem. Later, pseudostem may split.	Use resistant variety. Good sanitation. Used diseases free material.
Bunchy top	It is a viral disease. Symptoms appear as prominent dark green streaks on petioles and along leaf veins. In badly diseased plants, leaves bunch together, margins of lamina become wavy and slightly roll upwards. Banana aphid (*Pentalonia nigronervosa)* acts as vector for its spread.	• Adoption of strict quarantine measures. • Destroy infected plant material. • Control aphid by spraying metasystox or dimecron (0.01%).

Maturity, harvesting and yield

Depending on the variety, banana starts to bear fruit, 6-8 months after planting and is ready for harvesting in about 7-11 weeks later. The 'follower' plant will produce 3-4 months later, thus about four harvests from I clump per year is possible. The average yield per year for a 3 year-cycle is 12.0 tonnes per hectare for Rasthali. The general average yield is about 7 tonnes for the first year, 12 tonnes for the second year and 10 tonnes for the third year per hectare.


Papaya plant laden with fruits

PAPAYA

Papaya (*Carica papata* L.) is a widely cultivated tropical fruit of the world.

Papaya is one of the important quick growing fruit crops, which is a rich source of Vitamin A. It improves digestion and said to cure chronic constipation, piles and enlarged liver and spleen. Papain is a valuable enzyme prepared from the latex of papaya. The papaya is a native of tropical America and was introduced to India in the 16th century. It is now grown in almost all tropical and subtropical countries of the world like Australia, Sri Lanka, South Africa, Tropical America, Indonesia, Pakistan, India and Bangladesh. In India, it is largely grown in Bihar, Assam, Maharashtra, Madhya Pradesh, Tamil Nadu and Andhra Pradesh.

Papaya belfongs to family Caricaceae and genus *Carica* with somatic chromosome nunmber, 2n=24. The other important species of genus *Carica* are *C. monoica*, *C. candamarcensis, C. pentanda*.

Soil and climatic requirements

Papaya is adapted to practically any well drained soil. The plant is shallow rooted and will not tolerate excessive wetness or standing water. Well drained medium black to red loamy soils are suitable, and does not thrive well in calcareous and stony soils, which contain little organic matter.

Papaya thrives best under warm, humid conditions. It is generally intolerant to strong winds and cold weather. Temperatures just below freezing can kill small plants to the ground. Dry climate during flowering often causes sterility, while dry climate during fruit maturity adds to the sweetness of fruit. Plant can be grown from sea level to elevation of 1,000 m above mean sea level. It cannot withstand frost.

Pusa Nanha papaya

Commercial varieties

Papaya is polygamous, with three primary sex types: female, male and bisexual. Female flowers are borne along the trunk and can be identified by that location and the presence of a miniature papaya fruit inside the base of the flower petals. Male flowers are borne in long sprays that originate along the trunk. Varieties have been classified as Dioecious (produce male and female plants) and gynodioecious (produce female and hermaphrodite flowers. Honey Dew, Coorg Honey Dew, Washington, Solo, CO-1, CO-2, CO-3, CO-4, CO-5, CO-7, Pusa Dwarf, Pusa Delicious, Pusa Majesty, Pusa Nanha, Pant Papaya-1, Pink Lady, Red Lady, Sun Rise Solo etc., are important varietes of papaya.

Due to sex variations, about 40-60 per cent of the plant may turn to be male in the cases of dioecious varieties. Thus, in such case, 2-3 seedlings should be planted per the pit, and lastly population ratio of one male plant for every 8-10 female plants should be maintained. In the case of gynodioecious varieties (Pusa Delicious, Coorg Honey Dew, Pusa Majesty, Pink Lady, Red Lady, Sun Rise Solo) plant one seedling/pit. The ideal seasons for it planting are June to October and January to March as the other months are either too hot or rainy.

Male papaya plant

Female papaya plant

Plant propagation

Most papayas are grown from seed because of the impracticality of vegetative propagation methods. For this, seeds are extracted from fully ripe fruit, washed to remove gelatinous material and planted several per pot of soil or potting medium. Germination is accomplished in approximately two weeks under full sunlight. The plants can be set out as soon as they are large enough (about 1 foot tall) to survive with minimal care. The pots of plants should be spaced 8 to 10 feet apart. Papaya seedlings should begin flowering in five to six months, at which time they can be thinned to a single female or bisexual plant at each site. In the absence of bisexual plants, one male plant is needed for every eight to ten females.

Planting

Plough the land thoroughly and dig pits of 40 x 40 x 40 cm. size at about 1.8 -2.4 m apart either way depending on variety and fill them with topsoil and compost. Place the seedling in the centre of the pit and provide support. For Pusa Nanha a planting distance of 1.2 X 1.2 m is recommanded.

Manures and fertilizers

Application of 25 tonnes of FYM per ha and 250 g N, 250 g P and 500 g K/plant/year is recommended. Apply the entire quantity of N, P_2O_5 and K_2O in split application once in 2 months commencing from the 2nd month of planting. Fertilizer at the rate of one-quarter pound of ammonium sulfate (21-0-0) per plant should be applied a month after planting, increasing to one half pound six months after establishment.

Weed control

Weeds and grass control within 3 to 4 feet of the papaya is essential for optimum growth and fruiting. Cultivation for weed control should be quite shallow, as the papaya's roots are concentrated near the soil surface. The use of organic mulches is highly recommended.

Irrigation

Papaya responds well to copious irrigation in well-drained soils. Regular irrigation helps fruit development and induces the tree to bear larger sized fruits. Water stagnation should be avoided. In most parts of India, papaya is irrigated once in 8 to 10 days. Irrigation should be applied to thoroughly wet the soil periodically as needed through the year. A fluctuating irrigation regime may retard growth and cause poor fruit set. The ring system of irrigation is better than bed or basin system because the ring system prevents runoff water.

Anthracnose affected fruits of papaya

Plant protection

Diseases	Symptoms	Control measures
Foot rot (*Phytophthora sp*.)	The leaves turn yellow and drop off. The plant may collapse with a breakdown at the bottom.	Uproot and burn the affected plants. Avoid water logging. Spraying the stem and drenching the soil around the stem with Bordeaux mixture.
Powdery mildew (*Oidium caricae*)	Whitish patches appear on lower surface of leaves. Corresponding upper surface appears yellow. The affected leaves turn yellow and dry up.	Dusting sulphur 10 kg/acre or spraying of Karathane (0.05%) or any wettable sulphur (0.05%) is effective.

Leaf curl	Severe curling, crinkling and deformation of the leaves. Other symptoms may be vein clearing, reduced leaf size inward rolling of the leaves and petioles are twisted	Spraying of metasystox (0.1%) at an interval of 10-15 days for controlling the vectors.
Papaya mosaic	The top young leaves of the diseased plants are much reduced in size and show blister patches of dark green tissue alternating with yellowish green and puckering. The leaf petiole is reduced in length and twisted	Removal of infected plants and destroying them. Control aphids and other vectors by periodical spraying of systemic insecticides.

Maturity, Harvesting and Yield

The change of colour from green-to-yellow and the consistency of the latex from milky to watery indicate that the fruit is ready for harvest. The fruits should be harvested individually by hand picking taking care to avoid all possible injuries.


Symptoms of leaf curl in papaya

Papaya fruits will be ready for harvest in about 9-10 months after planting. Fruits are borne throughout the year. Yield varies from 75 to 100 tonnes per hectare. The economic life of papaya plant is only 2½ to 3 years. A papaya plant with good management produces 25 to 40 fruits weighing 40 to 60 kg in the first 15 to 18 months.

Papain extraction

Papaya fruits, which are about 90-100 days old (fully grown but not mature) are selected for tapping. In the morning hours, four longitudinal incisions are given on the four sides of the selected fruits from the stalk end to the top of the fruit. The depth of the incision should be 3 mm. On incising, latex starts flowing, which is collected in a suitable container. (Areca nut spates, aluminum trays or glass vessels). Care should be taken not to use any other containers for papain collection since it will react with papain, rendering it unfit for any use. The latex that solidifies in the cuts should also be scrapped carefully and added to the liquid latex. This process of making four incisions in the untapped fruit surface at 3-4 days interval is repeated thrice or four times over a period of 12 to 16 days. The latex thus collected every time should be dried in the sun or in dryer at temperature ranging between 50 ^{0}C to 55 ^{0}C. Potassium metabisulphite (0.05 per cent) is added to the liquid latex in small quantities before it is dried since this helps to extend the storage life of papain. The drying is continued until it comes off in flakes having a porous structure. The dried papain is powdered, sieved in a 10 mesh sieve and stored in polyethylene bags or any other suitable container. After papain extraction, fruits can also be used for consumption.

SAPOTA

Sapota (*Achras zapota*), sapodilla or *Chiku* is another delicious tropical fruit of India, tropical America, south-east Mexico, Guatemala and other countries. Immature fruits are astringent, while ripe-fruits are sweet and used as desert. Now the crop has attained the status of major fruit industry in India. Sapota fruits are

nutritious, rich in minerals, carbohydrates and mostly eaten as fresh fruit. Sherbets, milk shakes and ice cream can be made from fresh pulp. In Chile, the latex obtained from the bark of the tree, was for many years, the principal ingredient of chewing gum. It is a very good fruit for patients suffering from fever and febrile attacks.

Bearing tree of sapota

It belongs to the family Sapotaceae and genus *Achras* with somatic chromosome number, 2n = 26. Sapota is believed to have originated in Mexico and Central America and being a tropical crop, grows throughout the tropics. In India, it is cultivated in Maharashtra, Gujarat, Andhra Pradesh, Karnataka, Tamil Nadu, Kerala, Uttar Pradesh, West Bengal, and some parts of Rajasthan, Punjab and Haryana.

Soil and climatic requirements

Sapota tree is well adapted to a wide range of soils but grows best in well-drained, light soils. Trees are especially well adapted to the rocky, and highly calcareous soils. It comes up well in alluvial soils of the riverbanks, sandy loams near coastal areas, red laterite soils of the heavy rainfall area and medium black soils.

Sapota prefers a warm and moist weather and grows in both dry and humid weather. Coastal climate is best suited. Sapodillas are adapted to tropical and warm sub-tropical climates. Young trees may be killed or injured at temperatures of 30 to 32 $^{\circ}$F (-1 to 0 $^{\circ}$C). Large trees can withstand temperatures as low as 26 $^{\circ}$F (-3 $^{\circ}$C) for a few hours with only minor damage. Optimum temperature is between 15 to 35 $^{\circ}$C and at higher temperature above 43 $^{\circ}$C during summer, the flower and fruitlets may drop. Areas with an annual rainfall of 125 to 250 cm are highly suitable.

Commercial varieties

Many varieties are popular among the growers. Most important being Cricket Ball, Baramasi, Badami, Thagarampudi, Dwarapudi, Kirtibharathi, Oval, Pala, Guthi and Culcutta Round. Some varieties produce fruits in winter and other in summer. Similarly some produce round fruits and others produce oval fruits.

Plant propagation

Although, seeds can be used for propagation and for selection of superior types, they should not be used for commercial plantings. Side veneer and cleft grafting on to seedling rootstock are the most common grafting methods. Chip budding can also be used. Inarching in sapota is the commercial method of propagation practice over forty years. One of the advancements in propagation of sapota has been the use of softwood grafting. For this, one year old rootstocks of pala (*Manilkara hexandra*) are selected and all side branches are removed. The stock is then cut down to a height of 20 cm above soil level. Scions should be 8 to 10 cm long and of pencil thickness with bulging tips. The colour of the scion should be turning from green to brown. For pre-curing, leaf blades are clipped off seven-to-ten days before grafting. When the petioles dry and drop off, the scions can be detached from the tree and used for grafting. Longitudinal cut of 3-4 cm is made and the scion wedge is inserted to the softwood portion of rootstock and tied with a polythene strip of 200 gauge thickness. The grafts are kept in shade or mist chamber for 15 days and later transfer the successful grafts to open place. Treating the scion with IAA (750 ppm) increase the percentage of success. Higher percentage of (more than 95) success can be obtained from this method.

Planting

Planting is done in July-August or February-March in well prepared field in a square or rectangular system of planting, The planting distance is usually 10 m x 10 m in light soils and 13 m x 13 m in heavy soils.

Manures and fertilizers

S. No.	Age of the tree (Yrs.)	Nitrogen	Phosporus	Potas
1.	1-3	50	20	75
2.	4-6	100	80	150
3.	7-10	200	40	300
4.	11 Years onwards	400	160	450

Irrigation

When plants are young, irrigation should be given throughout the year, depending upon the soil conditions, However, when plants grow, these should be irrigated once in a week during summer and at fortnightly interval during winter.

Weeding

Weeds compete for water and nutrients. Weeds may be controlled by herbicide applications of registered materials and/or by mulching. Weeds and lawn grass should be removed within a 2 to 4 ft (0.6-1.2 m) radius around the trunk and under the canopy. A 2 to 4 inches (5-10 cm) thick layer of mulch may be used to reduce soil drying and weeds. Keep mulch 8 to 12 inches (20-30 cm) away from the trunk.

Plant protection

Insect-pests	Damage	Control measures
Leaf webber (*Nephopteryx eugraphella*)	Feeds on buds, leaf and young fruits	Spray phosalone 35 EC (2 ml/l)
Hairy caterpillars	Flowers and flower buds are damaged	Spray chlorpyrifos 30 EC or endosufan 35 EC (2ml/l)
Diseases	**Symptoms**	**Control measures**
Sooty mould (*Capnodium* sp.)	Photosynthetic functions of the leaves get affected and fruits get disfigured	Spray starch or maida (1 kg boiled in 5 liters of water and diluted to 20 liters)
Leaf spot (*Phaeophleospora indica*)	Pinkish to reddish brown spots are seen, resulting in drying and shelding of leaves.	Spray mancozeb (0.2%) if defoliation occurs.

Maturity, harvesting and yield

Indicators of maturity are fruit size, loss of peel scruffiness and a change in peel color from brown - to - amber. Another test is to lightly scratch the peel; if it is tan,fruit can be picked, but if it is green or oozes latex, the fruit is not fully mature.

Fruits can be harvested by hand, using a pole with a basket, or using machines or platforms that place the picker close to the fruit. Removing the fruit with a hook is not advisable as many of them hit the ground before they can be caught in the air. Fruit should be handled carefully during harvesting, packing and shipping.

Sapota starts bearing from 4th year onwards and economical yields can be obtained from 7th year onwards. Plants flower almost throughout the year. It takes 4-6 months from flowering to fruit maturity. March-to-May and September-to- October are the two distinct seasons of harvest. A full bearing tree may produce about 2,500-3,000 fruits/season.

GUAVA

Guava (*Psidium guajava* L.) is also known as the 'apple of tropics' and 'poor man's fruit' in India. Guava has wide adaptability to varied types of soils, climatic and cultural conditions. It is a rich source of vitamin C and pectin, and good source of other vitamins like thiamine and riboflavin, and minerals like calcium and phosphorus. Being rich in pectin, excellent jelly is made from guavas. The fruits can also be utilized for making nectar and ready-to-serve (RTS) drinks.


Allahabad Safeda guavas

Guava is native of tropical America. It is commercially cultivated in India, Pakistan, Bangladesh, Philippines, Hawaiian Islands, Myanmar and Cuba. In India, it is mainly grown in Uttar Pradesh, Madhya Pradesh, Bihar and Maharashtra. In Uttar Pradesh, Allahabad region has the reputation of growing the best quality guavas in the world.

Guava belongs to family Myrtaceae and genus *Psidium* with basic chromosome number (n) = 11. Other species of *Psidium* are the mountain guava (*P. montanum*), *P. friedrichsthalianum* (Chinese guava) and *P. cateinum* (Cattley guava).

Soil and climatic requirements

Guava is a hardy fruit plant and can thrive on all types of soils ranging from heavy clay to light soils. However, the clay loam, deep, friable and well drained soils are best. It can be grown in soils having pH up to 9.0, though the optimum range is 4.5 to 7.5. Under highly waterlogged, saline and alkaline conditions, its cultivation is adversely affected.

Guava grows successfully in tropical and sub-tropical regions and even under adverse climatic conditions. However, both yield and fruit quality are better in areas with distinct winter. It grows well even at an altitude of 5,000 feet. The areas receiving a rainfall of 40 inch between June-to-September, are considered ideal for its cultivation. The young plants are susceptible to drought and frost. Dry atmosphere at the time of flowering and fruiting are favourable but high temperature during fruit development may cause excessive fruit drop.

Commercial varieties

Important varieties of guava are Allahabad Safeda, Sardar (Lucknow-49), Behat Coconut, Seedless, Apple Colour, Banarasi Surkha, Chittidar, Harijha and Red Fleshed. Some hybrids/ varieties such as Safed Jam, Kohir Safeda, Hisar Lalit, Hisar Surkha, Hisar Safeda, Arka Amulya, Arka Mridula etc., have also been developed by different institutes.

Plant propagation

Guava can be propagated both by seed and asexual means. Most important methods of vegetative propagation are air layering/gootee, stooling and budding. Now-a-days, stooling is preferred. In this method, the plants are headed back during December-January and allowed to grow new shoots. These shoots (stools) are ringed, treated with IBA (2,500 ppm) made in lanolin paste and earthed up to induce rooting. Profuse rooting occurs within a month. The rooted stools are separated from the mother plant and planted in the nursery during July-August. Rooting is better if the soil in the stool bed is kept moist all the time. 40-50 plants can be prepared from one mother plant per year by performing stooling twice a year.


Vegetatively propagated plants of guava

Planting

Before planting, the field should be thoroughly ploughed and leveled. The pits of 1 x 1 x 1 m size should be dug out at appropriate distance in a square system before monsoon. The pits are refilled with 25-30 kg well decomposed farm yard manure, mixed with top soil and irrigated. The best planting time is onset of monsoon. However, planting can be done during March-April also. The planting density depends on factors like variety, rootstock and climatic and soil conditions. Guava is usually planted at a distance of 7 to 8 m.

Irrigation

Guava is a hardy fruit plant and requires very less water. However, in the early stages of orchard establishment, plants require frequent irrigation. Later, more frequent irrigation (fortnightly interval) is required from April-to-June, for good growth and fruit yield. Irrigation during winter is beneficial to obtain quality crop. Usually, no irrigation is given during winter. Due to regular growth, flowering and fruiting in south India, guava requires irrigation throughout the year.

Manuring and fertilization

The amount of manure and fertilizers to be given, depends upon the variety, age of plant, soil and climatic conditions and type of the fertilizer to be applied. Although, it is difficult to give one general fertilizer schedule, but a ten-year-old guava tree should be given about 80 kg of FYM, 1 kg of ammonium sulphate or 800 g of calcium ammonium nitrate, 3kg of super-phosphate and 2 kg of potassium sulphate.

The fertilizers should be applied in two split doses (June and October) when there is sufficient moisture in the soil. 50 per cent of nitrogen and full dose of potash should be applied in June and the remaining the N and entire phosphorus in October. Foliar application of nitrogen in the form of urea (4-6%) has been found to be very effective in increasing growth, flowering, yield and quality of guava. The best time for foliar application is January and July. A fertilizer schedule is given below:

Age (Yrs)	FYM (kg)	Nitrogen (g)	Phosporus (g)	Potash (g)
1-2	10-15	60	30	30
3	20	120	60	60
4	30	180	90	90
5	40	240	120	120
6	50	300	150	150
7 and above	60	360	190	190

Flowering and crop regulation

Guava flowers twice a year in north India. First flowering takes place in April-May, which gives fruits in rainy season. The second flowering takes place in August-September to give fruiting in winter season. The rainy season crop is generally avoided as most of the fruits are infested by fruitfly and the fruits are insipid and of very poor quality. The winter crop is virtually free from fruitfly and the fruits are of high quality. Winter crop is therefore, preferred as it gives very high returns to the farmers. In central-southern India, guava flowers thrice a year, with flowers appearing in October also. In West Bengal, flowering once in April-May and again in September-October has been reported.

Under certain climatic conditions, guava plants may flower twice or thrice a year. Under these conditions, regulation of flowering is required, to get fruits of desirable quality in a desired *bahar*. Regulation of flowering can be achieved by exposure of roots, root pruning and with chemicals, which is called as bahar treatment.

In areas where guava flowers twice or thrice a year, we need to regulate guava crop in such a way that only quality crop is harvested. In this process, rainy season crop is avoided. This can be done by forcing the plants to

take rest in the undesired season by stopping irrigation, and then applying fertilizers and manures in the desired season. De-blossoming can be done by spraying NAA (100 ppm) or 2,4-D (30 ppm) in summer.

Plant protection

Insect pests	Damage	Control measures
Fruit fly (*Chaetodacus* sp.)	Most serious pest of rainy season crop, renders whole crop unfit for consumption. Adult flies lay eggs on fruit, maggots on hatching, enter the fruits, and feed inside.	Soil raking, destruction of infected fruits, use of baits (sugar + malathion) and spraying plants with malathion (0.05%) or dimecron (0.03%) during oviposition period are some useful measures.
Mealy bug (*Cryptolemus* spp.)	Causes damage by sucking cell sap from tender leaves, shoots, flowers and fruits. The affected leaves dry up and the fruits drop off, resulting in poor yield.	The banding of the tree trunk with polyethylene film or Ostico-sticky bands is the best method to prevent them climbing up the tree. Further, treatment of soil with malathion is also effective.
Bark eating caterpillar (*Indarbela* spp.)	Feeds on bark under silken galleries. The infested trees are visible from a distance as the winding silken galleries full of frass faecal matter are seen on the trunk.	Remove the silken galleries, plug the holes with cotton soaked in diesel/petrol or monocrotophos.
Diseases	**Symptoms**	**Control measures**
Wilt: Several fungi like *Fusarium solani, F. oxysporum, Marophomina phaseoli* are associated.	This disease is characterized by yellowing of leaves, followed by drying of the leaves. The twigs start drying from tip downwards. The plant may collapse slowly in several or within 15-20 days.	Remove and burn the infected plants, maintain proper drainage, grow wilt resistant varieties (L-49, Banarasi), avoid planting in highly alkaline soils, disinfect soil with 2 per cent formaldehyde solution before planting, and drench soil with brassicol or spray bavistin (0.1%) at an interval of 15 days at early stages of disease infection.
Anthracnose (*Gloesporium psidii*)	Die-back starts from top of the branch. Other plant parts, like shoots, leaves and fruits are readily affected. High humidity and frequent rains favour the spread and intensity of disease.	Spray dithane-Z-78 or phytolan (0.2%) at fortnightly interval.

Maturity, harvesting and yield

Seedling guava plants have 5-6 years juvenile phase whereas the grafted or layered plants start bearing after 2-3 years. Change in fruit colour is usually taken as harvesting index. As soon as colour starts turning from

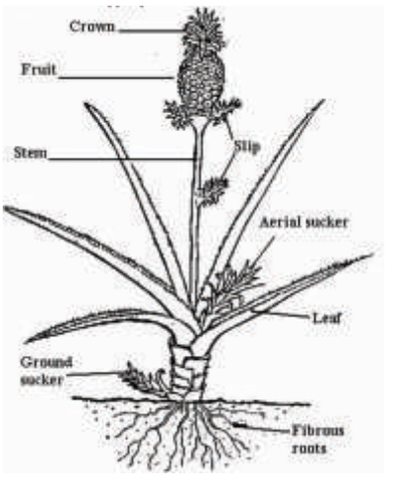
greenish-to-yellowish, the fruits should be harvested. Hand picking of fruits at regular intervals is preferred. Harvesting by shaking of tree may cause severe damage to fruits and the tree. Guava starts giving economic yields after 8-10 years of planting. In general, grafted plant of 8-10 years age can yield 400 to 800 fruits weighing 80 to 100 kg. Guavas are highly perishable and must be marketed immediately after harvest. It is possible to keep ripe but firm fruit in good condition for about 4 weeks at 8.3 to 10 ^{0}C and 80-90 per cent relative humidity.


Wilt affected guava tree

PINEAPPLE

Pineapple (*Ananos comosus*) is a tropical fruit plant known for its juicy and fragrant fruit. It probably received its name because the fruit looks like a large pinecone. Many people enjoy drinking the juice of the pineapple and eating the fruit as a dessert or in salads. Thailand grows more pineapples than any other country of the world. It belongs to family Bromeliaceae and genus *Ananas* with somatic chromosome number, 2n = 50. Many scientists believe that pineapples originated in Brazil. Today the world's chief pineapple producing countries are Brazil, China, Indonesia, Malaysia, Mexico, Philippines, South Africa, Thailand, and the United States. In India, it is mainly grown in NE states, West Bengal, Assam, Kerala, Karnataka, Bihar, Jharkhand etc.

It is a very good source of vitamin A and B_1. It is mainly consumed as fresh fruit but processed products like jelly, jam, juice, snack food, canned fruits, wine, and vinegar also made from it. In addition, several parts of the plant are used to make cattle feed, meat tenderizers and medicines. In the Philippines, people weave the fibers of the plant into a cloth called *ping*.



Parts of a pineapple plant

Soil and climatic requirements

Medium-to-heavy loams, rich in humus and having slightly acidic reaction are more suitable. Plant prefers soil pH of 5.0-6.0. Soils with a higher pH are unsuitable owing to the development of lime induced iron chlorosis. Too much water can harm it , but irrigation is necessary in some dry regions but plant is particularly sensitive to waterlogged conditions.

Pineapple needs a warm climate. Extremes of climates such as occurrence of frost and intense solar radiations associated with very low humidity are not favourable for pineapple cultivation. The optimum temperature range for successful pineapple cultivation is between 15.6 ^{0}C and 32.2 ^{0}C. High temperature over 35 ^{0}C is unfavourable for the development of fruits, especially if the relative humidity is low. In general, pineapple needs a sunny climate, though there are no exact figures on hours of sunshine or of solar radiations required for flowering and higher productivity.

Commercial varieties

Varieties of pineapple are divided into 3 main groups-I) Cayenne, 2) Queen and 3) Spanish. The first group is by and large, is the most important group. Most of the varieties in India may be accommodated into anyone of these three groups. For example, Kew or Gaint Kew, synonymous with Smooth Cayenne, grown most extensively in India, represents Cayenne group, and Queen another popular variety belongs to Queen group.

Varieties of Cayenne group are - Smooth Cayenne or Cayenne, Hilo, Kew, Giant Kew, Charlotte, Rothschild.

Varieties of Queen group are - Mauritius, Ripley Queen, Alexandra, Mac Gregor, Queen.

Varieties of Spanish group are - Red Spanish, Singapore Spanish, and Masmerah.

Other varieties : Abacaxi and Cabezona.

Plant propagation

Propagation of pineapple is exclusively done by vegetative means. In case of hybrids, progenies evolved through seeds are also vegetatively propagated. Propagation can be done from any four parts of a pineapple plant: (1) *shoots,* (2) *slips*, (3) *crowns* and (4) *suckers*. Shoots grow from the main stem. Slips grow from the flower stalk just below the fruit. Crowns are the groups of leaves at the top of the pineapple. Suckers arise from the roots below ground. Among the types and sizes of propagules tried, slips and suckers weighing around 350 g and 450 g are best in terms of yield and quality.

Planting and after care

The planting system depends on the topography of land and rainfall. There are four planting system in vogue, viz. flat-bed planting, furrow planting, trench planting and contour planting. Workers insert the shoots, slips, crowns, or suckers through the plastic strips by hand. They punch holes in the plastic with a planting tool. After planting, pineapple plants require careful cultivation.


A view of high density plantation of pineapple

Plant spacing or density of pineapple depends on the growth of the plant and system of planting. Adoption of low planting densities has been the major constraint in India, contributing towards high cost of production per tonn of pineapple. One of the ways to reduce cost of production is to increase yield per unit area by following high density planting.

Spacing followed for 63,758 plants per ha was 22.5 cm from plant to plant, 60 cm from row to row and 75 cm between beds. This planting density did not adversely affect fruit size, quality and canning ratio. The following is the spacing required for different plant populations per hectare.

Plant population/ha	Distance (cm)		
	Plant to plant with in row	Row to row	Trench to trench
43,500	30	60	90
53,300	25	60	90
63,700	22.5	60	75

Manures and fertilizers

The following fertilizer schedule should be followed for fruitful production:

Time	Type of fertilizer	Fertilizer rate/ha
Before planting	Lime	2.5 Tonnes
At time of planing	CIRP	200 Kg
3 months	NPK 12:12:17:2	200 Kg
6 months	NPK 12:6:22:3	500 Kg
9 months		

Weeding

The major factor, which contributed to the high cost of production of pineapple, is the manual weeding, which accounts for 40 per cent of the total cost of production. Six months after planting , weeding has to be done every 3 months. This can be done manually or by the use of weedicide like paraquat. Pre-emergence application of bromacil (4 kg/ha) and diuron (2 kg/ha) could effectively reduce both dicot and monocot weed population.

Irrigation

Pineapple is grown mostly as a rainfed crop in heavy rainfall areas. Optimum range of rain needed for pineapple is 1,000 to 1,500 mm. However, some of the pineapple growing areas come under high rain fall zone, where rainfall is to an extent of 3,000 and nearing 2,000 mm. Although pineapple is grown in India in rainfed areas, where sufficient rainfall is received, but it can also be grown successfully with a few irrigations during summer in the semi-arid tropics.

Regulation of flowering

In pineapple, flowering is erratic, and sometimes it is difficult to get good crop. For this, growers may use hormones and chemicals to make the plants flower and produce fruit faster than they would naturally. To induce uniform flowering, the following treatments are recommended.

1. At 40 leaf stage, 50 ml solution containing NAA at 10 ppm + 2% urea is poured into the crown.
2. 50 ml solution containing 2% urea + 0.04% sodium carbonate + 20 ppm ethrel is poured into the crown.

Sometimes flowering is erratic in pineapple. Hence, regulation of flowering is mandatory. It can be achieved by pouring NAA (10 ppm) or ethrel (20 ppm) in to crown during night.

Maturity, harvesting and yield

Pineapple flowers 10-12 months after planting and attains harvesting stage in about 15-18 months after planting, depending upon the variety, time of planting, type and size of planting material used and prevailing temperature during the fruit development. A pineapple plant bears one fruit for the first harvest and may bear two fruits for the second or third harvest. Most planters replant fields after every two or three harvests. In most countries, pineapples are harvested by hand. The pineapple pickers grab the fruit by the crown and twist it from the stalk. The average yield for the first year is between 40-65 tonnes per hectare, which depends on cultivar used.

Plant protection

Disease/pest	Control measures
Bacterial heart rot (*Erwinia chrysanthemi*)	Remove and destroy the affected plants. Refrain from planting in flood prone areas. Spray with the insecticide chlorpyrifos (Dursban) to prevent disease and control ants.
Deep eye (*Penicillium uniculosum*)	Chemical control has not been successful. Do not apply fertilizer while the plant is flowering and during the rainy period.
Fruit collapse (*Erwinia chrysanthemi*)	Destroy the affected plants and fruits. Spray with heptachlor just before flowering to control ants.
Mealy bug (*Dysmicoccus brevipes*)	Spray with the insecticide diazinon (0.05%) to control mealy bugs and ants.

ACTIVITIES/EXERCISES

- Plan a visit to some mango orchard. With the help of supervisor or gardener (*Mali*) make a list of important varieties grown in it. Also try to differentiate the varieties grown in the orchard. Also find some insect or disease infected plant parts. Observe the nature of damage and note down the symptoms of damage caused by an insect or disease.
- Go to some guava orchard. Note down the wilt affected plants and symptoms of disease. Also see if fruitfly attack is there. Cut such fruits into 2 halves and note down the extent of damage caused by the fly.

- Note the symptoms of guava wilt and panama wilt after visiting orchards of guava and banana, respectively.
- Plan a visit to pineapple plantations and observe the different plant parts and density of plantation.
- Attempt to give incisions to immature papaya fruits and collect latex and prepare papain from it after following all precautions.

CHECK YOUR PROGRESS

1) Name major varieties of mango. Name some hybrids developed by research institutes.
2) List major physiological disorders of mango.
3) List major insect-pests of mango and write their control measures.
4) Name major diseases of mango, banana and papaya. Write their control measures.
5) What is papain? Write procedure for making it.
6) Write briefly about regulation of flowering in guava and pineapple.

FILL IN THE BLANKS

1. ……is a serious disorder of Alphonso mango.
2. Dashehari is a famous variety of mango in ……India (North, South, West)
3. Epicotyl method of mango propagation is commercially followed in ……region.
4. Amrapali, a mango hybrid is a cross between …….. and ……..
5. Panama wilt is caused by……
6. ……..acts as vector for bunchy top of banana.
7. Pineapple is commercially propagated by……
8. Papain is obtained from immature ……. fruits
9. Pusa Delicious is a variety of……
10. Papaya is commercially propagated by …….

SUGGESTED FURTHER READINGS

- Bose, T.K., Mitra, S.K. and Sanyal, D. (2001). Fruits:Tropical and Subtropical (Vol. 1). Noya Udyog, Kolkata-6.
- Bal, J.S. (2007). Fruit growing Kalyani Publishers, Ludhiana, India.
- Chattopadhyay, T.K. (2008) A textbook on Pomology, Vol. 3 (Tropical fruits), Kalyani publishers, Ludhiana, India.
- Chadha, K.L. (2001). Handbook of Horticulture. ICAR, New Delhi.
- Sharma, R.R. (2006). Fruit production: Problems and solutions. Intl. Book Distributing Co., Lucknow, India.
- Singh, R, and Saxena, S.K. (2008). Fruits. Nationa Book Trust, New Delhi.

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CHAPTER

4

SUBTROPICAL FRUITS AND THEIR CULTIVATION

OBJECTIVES

After studying this chapter, you will be able to:

- Identify subtropical fruits, describe their importance and their main production sites
- Describe major cultural requirements of subtropical fruits
- Identify major problems of subtropical fruits and describe their management
- Enlist major insect-pests and diseases of subtropical fruits and their integrated management strategies
- Able to establish orchards of subtropical fruits
- Able to start a business of these fruits

INTRODUCTION

In the previous chapter, you have learnt about tropical fruits, their production problems and management. In this chapter, you will come to know about subtropical fruits i.e., the fruits, which are grown in areas, which experience both the extremes of temperature i.e., high temperature during summer and very low temperature in winter. This type of the climate prevails in most of the northern states of our country where there are extremely cool winters and very hot summers. The major subtropical fruits grown in India are citrus, grape, pomegranate, *aonla*, *ber* and litchi. Although, some subtropical fruits can grow in tropical climate and others in temperate climate. For instance, pomegranate grows well in warmer temperate climate. *Aonla* grows in tropical climate as well. Most of the subtropical fruits are rich source of carbohydrates, proteins, vitamins and minerals and thus protect our body from several ailments. For example, *aonla* is very rich source of Vitamin C. *Ber* grows well in arid climate and is commonly called as apple of tropics. In this chapter, we will learn the cultural requirements of these fruits, their major problems and solutions.

What are subtropical fruits?

The fruits, which are cultivated successfully in areas, which experience both the extremes of temperature i.e., very high temperature during summer and very low temperature in winter are called as subtropical fruits.

CITRUS

Citrus comprise a group of fruits belonging to family Rutaceae, with basic chromosome number, X = 8. The members of this group are well spread over the areas ranging from tropical and subtropical regions of the world lying within 40^0N and 40^0S latitude.

Citrus species are believed to be originated in South-Eastern Asia. Citron (*Citrus medica* L.) is believed to have originated in south China or northern eastern India. Lime (*C. aurantifolia* Swingle) originated in the east of Indian Archipelago. Lemon (*C. limon* Burmann) originated in north Africa or from Spain. Sweet orange (*C. sinensis* L.) Osbeck originated in southern China or Indonesia, *Citrus grandis* (Pummelo) originated in Malaysia, grapefruit (*C. paradisi* Macf.) in Barbados (West Indies), Mandarin (*C. reticulata* Blanco) probably in Indo-China and South China. The others related minor genera i.e. *Poncirus trifoliata* (L.) Raf. (trifoliate orange) and *Fortunella margarita* (Lowi) Swingle, are known to have originated from southern China and both are freeze hardy species.

Some principal countries growing citrus are the USA, Brazil, Mexico, Spain, Italy, Algeria, Morocco, Israel, Egypt, Pakistan, China, India, Australia and Japan. In India, Maharashtra, A.P., Punjab, NE states, Karnataka and Bihar are the major citrus producing states.

Juice present in the vesicles is the edible portion of the citrus fruit. The juice contains 12-14 per cent sugars, citric acid, and ascorbic acid (Vitamin C). The leaves, flowers and fruits contain essential oil, which has several flavanoids. 'Hesperidin' is the universal oil present in most of the citrus fruits. Other flavonoids identified are neohesperidin, naringin, aurantamarin, limonin, narirutin, mobiletin, tangeretin etc. The bitter principles present are 'naringin' of graperuit and 'limonin' of Navel orange.

Soil and climatic requirements

Commercial citrus cultivation in India is done on soils ranging from coarse sands to heavy clays. Although, citrus has been reported to be grown in soils with pH ranging from 4.0 to 8.5 but ideal pH ranges from 5.5 to 6.0.

The growth and development in citrus is optimum in temperature regimes ranging from 25 to 30^{0}C to minimum of l3^{0}C. High temperatures cause poor pigment development in fruits and also sunburn or sun-scalding is occasionally met. Low humidity favours proper fruit colour development, while high RH leads to development of juicy fruits with thin rind thickness. Annual rainfall of 800-900 mm, well distributed throughout the year, is optimum for citrus growth and production.

Commercial cultivars

Sweet oranges: Mosambi, Sathgudi, Valencia, Pineapple, Jaffa, Hamlin, Shamouti, Malta, Malta Blood Red, Ruby, Washington Navel, Frost, Washington, Navelina, Gillett, etc.

Mandarins: Major varieties are Owara, Mikado, Wase, Silver Hill, King, Willow Leaf, Nagpuri, Khasi, Coorg, Kinnow and Satsuma.

Lemon: Major acid lemon varieties are Eureka, Lisbon, Assam lemon, Elaichi nimbu, Pani Jamir, Meyer lemon, Karna Khatta, and *galgal* (hill lemon).

Lime: West Indian (Mexican, Key), Kagzi, Tahiti lime (Persian), Pond, etc.


Mandarin fruit

Grapefruit: Duncan, Foster, Marsh Seedless, Thompson Seedless and Red Blush are the major cultivars of grapefruit.

Pummelo: Nagpur (*chakotra*) and Common pummelo are usually grown in India.

1. **Inter-varietal crosss:** Kinnow (King x Willow Leaf mandarin), Kara (Satsuma x King mandarin) and Wilking (King x Willow Leaf mandarin).
2. **Interspecific:** Tangelo (*C. reticulata* x *C. paradisi*), Tangor (*C. reticulata* x *C. sinensis*), Lemonime (*C. limon* x *C. aurantifolia*), Lemonage (*C. limon* x *C. sinensis*), Lemondrin (*C. limon* x *C. reticulata*).
3. **Intergeneric :** Citrange *(Poncirus trifoliata* x *C. sinensis*), Citrumelo (*P. trifoliata* x *C. paradisi*), Limequat (*C. aurantifolia* x *Fortunella japonica*), Citrandarin (*P. trifoliata* x *C. reticulata*), Citrudias (*P. trifoliata* x *C. aurantium*), Citrumquat (*P. trifoliata* x *F. japonica*).


Kinnow mandarin

Besides, some bi-generic and tri-generic hybrids and complex hybrids with distinct rootstock

characteristics have also been developed viz., Citrangequat (Citrange x *Fortunella margarita*), Citrangedin (Citrange x *C. mitis*), Citrangor (Citrange x *C. sinensis*), Citrange (Citrange x *P. trifoliata*).

Plant propagation and rootstock

Citrus trees are propagated by both vegetative mean and sexually by seeds. Vegetative methods are preferred because they ensure uniformity in quality and bearing. Seeds of several citrus species are polyembryonic and produce nuclear seedlings, which produce true-to-type plants. Mandarins and acid limes are mostly propagated as seedlings. Lemons, citrons, sweet limes are easily propagated by stem cuttings. Air-layering is mostly practiced in pummelo, mandarin, acid lime and seedless lemons. Most of citrus cultivars are propagated by 'T' budding on a suitable rootstock.

Rootstock and polyembryony: An ideal rootstock should have high degree of polyembryony, graft compatibility, adaptability to wide range of soil conditions and tolerant to biotic and abiotic stresses. No single rootstock possess all the characters together, however, few rootstocks commonly employed for citrus propagation are rough lemon, sour orange (*C. aurantium* L.), Karna Khatta (*C. karna*), Rangpur lime (*C. limonia*), sweet orange (*C. sinensis L. Osbeck*), Citranges like Troyer, trifoliate orange (*Poncirus trifoliata* L. Raf.), and Cleopatra mandarin.

Planting, agro-techniques and orchard management

Cultivated citrus genotypes are commonly planted in a square or rectangular system. Planting density has tremendously increased with the use of dwarfing rootstocks (planting densities of more than 400 plants/ha). It is now possible to accommodate higher number plants. In square system, the planting density of 4 x 4 m, 5 x 5 m, 3 x 3 m can accommodate 625, 400, 1111 plants/ha. Similarly, in rectangular system, spacing of 3 x 5 m (667 plants/ha) and 4 x 6 m (417 plants/ha) are being adopted.

Pits of 50 x 50 x 50 cm size are dug in summer according to the layout plan. The exposed soil after 30-40 days is mixed with 15-20 kg well rotten FYM and 50 g chloropyrophos (to kill white ants) and filled tightly. The best planting time is beginning of rainy season. Care must be taken that bud or graft point should be at least 10 cm above the soil surface. The irrigation channels/sub-channels basins are also laid out at the planting stage.

Intercropping: This is not recommended in citrus unlike other fruit crops as intercropping is reported to cause harm to the main crop. However, in the initial years of establishment, i.e., up to 3-4 years, vegetable crops like onion, potato, chillies, pulses, gram, etc. can be grown.

Weed control: A broad range of weeds compete with citrus plants namely, *Cyperus rotundus*, *Cynodon dactylon*, *Sorghum helpense*, *Euphorbia khirta*, *E. microphylla*, *Convovulus arvensis*, *Amaranthus viridis*, *Paspalum spp*., *Imperata cylindrica, Ageratum* spp. etc. These weeds appear according to the season and occupy the open space and area underneath the plants. Weeds compete for water and nutrients and harbour pests and diseases. Light hoeing is essential to control the geminated weeds. Chemicals viz., atrazine, simazine (6 kg a.i./ha) are recommended right from germination to flowering stages. Glyphosate is also gaining popularity as a broad spectrum weedicide. However, care must be taken to check the problem of spray drift.

Integrated nutrient management

For sustainable production of fruits and for proper maintenance of plant and soil health, efficient nutrient management programme must be adopted. Citrus is a nutrient exhaustive crop as plants in the population density of 400 plants/ha can remove about 200 kg N, 50 kg P_2O_5 and 200 kg K_2O/ha. Citrus is grown on a wide range of soils and hence no generalized recommendations can be made for any type. Besides. the dose of nutrients increase with the increase in plant age. For 'Khasi mandarin' application 300 g N + 250 g P_2O_5 : 300 g K_2O has been found economical. Under Coorg conditions, 600 g N, 200 g P_2O_5, 450 g K_2O/plant has been recommended

Bearing tree of grapefruit

for mandarins. Similarly, for lemons, 500 g N, 250 g K_2O was found ideal.

Foliar spray of micronutrients has given beneficial effect on improving the yield and quality. One to 2% urea, alongwith $ZnSO_4$, $MnSO_4$, $MgSO_4$ (each 0.5%) and $CuSO_4$(0.25%) is beneficial for all citrus cultivars.

Physiological disorders

Granulation: This is the major disorder of sweet orange, mandarin wherein the juice sacs become tough, enlarged, colourless and tastelss. There is a marked increase in the pectic substances, gels etc. and marked decline in sugars, organic acids and carotenoids. These fruits are insipid and fetch poor price in the market. Some of the factors associated with it are: high soil humidity, high relative humidity and temperature during fruit growth. Hamlin and Mosambi orange are highly prone to granulation. This malady can be kept under control with the application of 16 ppm of 2,4-D on developing fruits. Similar, effect was also noted with the spray of $ZnSO_4$ + $CuSO_4$ + KCl each at 0.25% at monthly interval from August to October.

Fruit cracking/splitting is a serious problem in lemon. It can be reduced by regular irrigation and spraying borax and calcium chloride.

Fruit drop: High fruit drop in citrus is primarily due to auxin deficiency. Commonly, this drop is also referred to as 'May-June drop' in sub-tropical regions. The developing fruitlets compete for carbohydrate, water, hormones and other metabolites. Excessive high temperature (35-40^{0}C) during fruit development causes high fruit drop. Application of 2,4-D or 2,4,5-T (10-30 ppm) during fruit development check fruit drop.

Fruit cracking: This is common disorder of sweet orange, lemons and acid lime. The splitting starts at stylar end and progresses towards the pedicelar end. Splitting is basically caused due to factors like deficit soil moisture, atmospheric temperature and relative humidity. Borax (0.2%) spray can check splitting and timely application of irrigation water must be ensured.

Cracked lemons

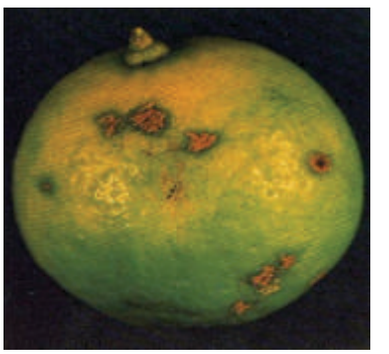
Plant protection

Maturity, harvesting and yield

Insect-pests	Damage	Control measures
Aphids (*Toxoptera citricidus, T. aurantii, Aphis pome, Myzus persicae)*	Suck sap from young leaves and twigs thereby causing severe curling of leaves, stunting of plant and facilitate sooty mould growth by excreting honey dew. These aphids act as vector for Tristeza virus.	Sprays of monocrotophos (0.025%), phosphomidon (0.03%) or parathion (0.03%) are useful for the control of aphids.
Citrus psylla (*Diaphorina citrii)*	Suck sap from young leaves and act as a vector for transmitting greening disease.	Spray systemic insecticides like phosphomidon (0.03%), monocrotophos (0.025%) or oxydemeton methyl (0.03%).
Leaf miner (*Phyllocnistis citrella*)	Yonug ones cause damage by mining the leaves.	Synthetic pyrethroids viz., fenvalerate (0.01%), permethrin (0.005%) or cypetnethrin (0.001%) are most effective. Oxydemeton methyl (0.03%) is also effective.
Lemon butterfly (*Papilio demoleus*)	Caterpillars may defoliate entire leaves.	Dusting and spraying with sevin (0.1%) has been found very effective.

Fruit sucking moth (*Ophideres* spp., *Achoea janata)*	Adult insects suck sap from mature fruits, thereby leading to fruit rot and drop.	Use light traps.
Nematodes like citrus nematode *(Tylenchulus semipenetrans)* and burrowing nematode (*Radopholus similis*)	Reduced plant growth and dysfunction of root system.	Soil application of aldicarb @ 6 kg a.i./ha is quite effective. Use oilcakes of *neem, karanj, mahua* or mustard.
Diseases	**Symptoms**	**Control measures**
Tristeza (Viral disease)	Symptoms like stem pitting, and yellowing of seedling yellows, etc. Infected plants show poor growth, die back, defoliations and ultimately death.	Use tolerant rootstock like Rangpur lime, Cleopatra mandarin, Trifoliate orange, use certified bud-wood, control aphids by insecticides.
Greening (Bacteria like organism)	The symptoms appear as chlorosis, resembling Zn deficiency, short twigs with upright yellow leaves, leaf drop, die back, formation of multiple buds and disfigured fruits.	Tree injection with tetracycline is found to be effective or employ cross protection technique. Control citrus psylla by suitable insecticides..
Phytophthora rot or gummosis *(P. citrophthora, P. parasitica* and *P. palmivora)*	Symptoms are noted as root rot, gummosis, blight of seedlings and fruit rot.	Use resistant rootstocks like *Poncirus trifoliata* or sour orange. Soil drenching with foltaf (0.2%) or avoiding water stagnation around tree trunk is widely adopted practices.
Bacterial canker (*Xanthomonas campestris* cv. *citri*)	Acid limes are most susceptible. Development of lesions with halo on leaves, twigs and fruits.	Spray 1% Bordeaux mixture or 500 ppm streptomycin sulphate and control of leaf miner (insect vector) by metasystox (0.1%). Prune infected portions.

Time of harvest in citrus varies with the region (tropical and subtropical) and the species. Marketable maturity is generally adjudged with the change in rind colour. Commercially, TSS: acid ratio is the most reliable method and it ranges from 10:1 to 16:1, depending upon citrus species and flush. 'Khasi mandarin in Northern-Eastern states is harvested during October-January, while 'Darjeeling' mandarin is harvested during November-December. 'Kinnow' in Punjab is harvested during January-February; 'Nagpur' mandarin is harvested during April-July, October-January in Coorg, January-February in Karnataka. Malta orange is harvested during January-February in Punjab. Mosambi is harvested in April-June (1st crop) in Maharashtra while pickings are also made during July and October-December. Sathgudi in Tamil Nadu is harvested during two seasons i.e. July (1st crop) and October-November (2nd crop). Hand picking is the most popular method to collect fruits while in some regions harvesting by shaking of main trunk is also done. Maximum productivity in citrus ranges from 700 to 1,000 fruits per tree, which depends on the age of plant, cultivar, rootstock and management practices. Kinnow plant can yield 300 to 800 fruits/plant, mandarin give 500 fruits, sweet orange 500-600 fruits/plant, Kagzi lime give 1,500 to 2,000 fruits/plant and



Citrus canker

lemon yields 600-800 fruits while rough lemon gives 1,000 to 1,500 fruits per plant.

GRAPE

Grape (*Vitis vinifera* L.) is one of the most delicious, refreshing and nourishing fruits. The fruit is utilized in many ways. About 80 per cent of the grapes are used for wine making and the remaining 20 per cent are used for raisin, juice and canning purpose. France, Italy and Spain are the leading producer of wine. In India, grapes are mainly consumed as fresh fruit.

The fruits are a rich source of sugars. The colour of grape berries is mainly due to four or five anthocyanins viz., cyanidin (red colour), delphinidin (blue colour), petunidin (purple colour) and malvidin (blue colour). Muscat Hamburg and Bhokri cultivars have Muscat flavour whereas Concord has foxy flavour. The foxy flavour and aroma in grape is due to the presence of methyl anthranilate.

The American grapes consisting of *Vitis labrusca* and other species of Euvitis and Muscadinia, are considered to have originated in the North American region. The original home of European grape (*Vitis vinifera* Linn.) is Caucasus region, which lies between black and Caspian sea.

Grape has been classified under the genus *Vitis* of the family Vitaceae. *Vitis* has two subgenera (i) Euvitis and (ii) Muscadinia. The distinguishing characters of the sub-genera are as follows:

Characteristics	Euvitis	Muscadinia
Somatic chromosome No. (2n)	38	40
Tendril	Forked	Unified
Bark	Loose	Tight
Lenticels	Absent	Present
Seed	Beaked and pyriform	Beak absent
Diaphragm at the node of shoot	Present	Absent

Soil and climatic requirements

The grape has a strong root system and can be grown on a wide range of soils but the best soil is sandy loam that is well-drained and fairly fertile having good amount of organic matter. Heavy clay, sand or slit are unsuitable for grape. Grape is relatively tolerant to soil salinity and alkalinity, and upper salt tolerance limit is 0.3 per cent.

Grape requires a long, dry and moderately hot season during cane maturity and ripening of berries followed by cool winter. Rains during growing season are useful, but continuous rains, make it difficult to control diseases. Rains at the time of berry ripening are harmful as even a single shower of rain during berry ripening can destroy the whole crop. Similarly, vines don't grow well in humid summer due to the attack of several diseases. Bright sunny days help in accumulation of sugars in berries.

Bearing plant of Pusa Urvashi

Commercial cultivars

Table grapes: Important table varieties of grapes are Thompson Seedless, Pusa Seedless, Perlette, Beauty Seedless,

Pusa Urvashi, Bhokri, Cardinal, Black Muskat, Tokay and Delaware.

Raisin grapes: Some notable examples are Black Corinth, Thompson Seedless, Muscat of Alexandria, Sundekhani, Pusa Seedless and Kismish Beli.

Juice grapes : Early Muscat, Black Champa, Concord, Bangalore Blue, White Riesling, Arka Hans, Arka Shyam and Pusa Navrang are suitable varieties for juice making.

Wine grapes : White Riesling, Pinot Noir, Cabemet Sauvignon, Black Cheaper, Rubired, Madeleine Angevine, Cheema Sahebi and Pusa Navrang produce wine of good quality.

Canning grapes: Thompson Seedless, Pusa Seedless and Perlette can be used for canning purpose.


A bunch of Perlette grape

Grape varieties can be seeded or seedless, as grouped hereunder:

(a) Seeded cultivars

Anab-e-Shahi, Bangalore Blue, Bhokri (Panchdraksha), Cardinal, Cheema Sahebi, Gold, Gulabi, Pearl of Casaba, Pinot Noir, Arka Kanchan, Arka Shyam, Arka Hans, Pusa Navrang are important seeded cultivars.

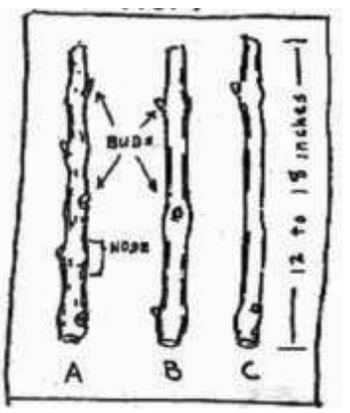
(b) Seedless cultivars

Beauty Seedless, Pusa Seedless, Perlette, Thompson Seedless, Delight, Himrod, Kishmish Charni, Arkavati, Pusa Urvashi are important seedless cultivars.

Some selections have been made by farmers. Tas-e-Ganesh, a selection from Thompson Seedless is popular in Maharashtra. It responds better than Thomson Seedless to gibberellic acid for berry elongation. Dilkush, Manik Chaman and Sonaka have been selected from Anab-e-Shahi in Hyderabad. In H.P., some local seedless types (Bargron, Shungron) having good berry quality are used for making a local wine called Angoori.

Plant propagation and rootstock

Grape is propagated by seeds for raising hybrid seedling or rootstocks whereas commercial varieties are propagated through hardwood cuttings. Cuttings are taken from mature canes of healthy, vigorous and disease-free vines. Depending on the length of internodes in a cultivar, the mature bud-wood from the annually pruned shoots should be cut into pieces (cuttings) of 25-30 cm so that each cutting has at least 4 buds. The cuttings should be of pencil thickness. The cut at the base of cutting should be perpendicular to the length of cutting, just below the bud, while the upper cut should be slanting and about 1.5 cm above the apical bud. These cuttings can either be planted in the field immediately after preparation or stored for sometime or buried in moist sand or saw dust in a cool place. The best time for preparation of cutting is north India is at the time of annual pruning in mid-January.



Hardwood cuttings of grape

Under certain specific conditions to impart protection from soil borne diseases and advance soil conditions (e.g, salinity), commercial varieties are budded or grafted on desired rootstocks (e.g., Dog Ridge, Salt Creek). 'T' and 'Chip' budding are successful methods for grape propagation.

Rootstock : For the control of Phylloxera in north American grapes, grafting on tolerant rootstocks like Riparia Gloire, St. George, 1202, or 99-R is done. Most of the *V. vinifera* cultivars are susceptible to nematodes. By grafting or budding the commercial varieties on Dogridge, Salt Creek, 1613, 1616 rootstocks, this problem can be avoided. Dog Ridge and Salt Creek rootstocks have also been found to be useful to impart resistance

against salinity in soil.

Cultivation

Layout and planting: Normally, a spacing of 2 m x 2 m is recommended for head system, 3 x 3 m for trellis and bower system, for low and medium varieties. Vigorous varieties are trained on bower system and hence a spacing of 3.6 x 3.6 m is usually followed. Square system is followed in most cases but under certain specific system of training, rectangular system of planting is followed. After deciding the spacing, planting spots should be marked, dug out to a dimension of 90 x 90 x 90 cm. The pits are allowed to remain open for 3 weeks. The pits should be re-filled with 1:1 mixture of top soil and FYM. One kg super phosphate, 500 g sulphate of potash and 30 g chloropyriphos may be mixed and added in each pit and irrigated immediately. The poles should be fixed at a specific distance, depending on the training system.

Planting : Usually, one-year-old rooted cuttings are planted. The planting is done during January-February in north India and during March-April and September-October in south India.

Training : Training is done to give proper shape and desired growth for good quantity and quality of fruiting. The different training systems are bower, head, kniffin, trellis, telephone, etc. The most commonly followed training system is bower system, which is also called as Arbour or Pergola system of training. It is best suited for vigorous cultivars like Thompson Seedless, Anab-e-Shahi, Cheema Sahebi and Bhokri. In this system, the vines are spread over a criss-cross network of wires, usually 2.1 to 2.4 m above ground, supported by pillars (concrete, stone or iron) and angle arms of iron. Vines are spaced 3 x 3 m or more and are allowed to grow straight, without any branch, upto the height of 2.4 m. When the wine reaches the wire, it is pinched off to induce initiation of side shoots. Two vigorous shoots, opposite in direction are selected as primary shoots. On each primary arm, 3 laterals are kept on each side as secondary arms. These arms are allowed to produce 8-10 tertiary branches, which act as fruiting canes. This system provides a very high cost benefit ratio (1:2.09) but cultural operations like spraying, pruning, etc. become difficult.

Pruning : Judicious removal of any plant part for increased productivity, facilitation of various cultural operation, regulation of crop and maintenance of vitality of vine is referred to as pruning. It is the most important and crucial operation in grape and should be done with great care keeping in view the growth pattern of the varieties under different climatic conditions. In north India, it is done during dormant season, from late-December to end- January, and in south, pruning for fruiting cycle is done during October-November and the foundation pruning for vegetative growth is done in April. After pruning, a single spray of blitox (0.2 per cent) should be done to avoid fungal attack on the cut portion of the vines. By staggered pruning, Bangalore Blue, Panch Drakshi and Anab-e-Shahi cultivars give two crops in a year.

Irrigation : In north India, the grape is irrigated at 7-10 days interval during growing season until beginning of sugar formation in berries and thereafter irrigation frequency is curtailed to allow proper ripening of grapes. Generally, 12-15 irrigations are given to grape in south India.

Manuring and fertilization

(a) Vines under the age of 3-5 years, should be given 40-50 kg well rotten FYM, and fertilizer combination of 500 g N + 300 g P_2O_5 + 700 g K_2O.

(b) Vines above 5 years of age, should be given 50-70 kg well rotten FYM and fertilizer combination of 500 g N + 700 g P_2O_5 + 1000 g K_2O per year.

The N and K fertilizers should be applied in two split doses. The first dose of 60 per cent N, full P and 50 per cent K and full FYM should be applied soon after pruning. The rest of N and K should be applied at fruit set during the first year, the fertilizers should be applied 30 cm away from the trunk in a circular ring. In the subsequent years, these should be applied in 15 cm deep furrows. The fertilizers should be mixed well in soil and the field should be irrigated immediately.

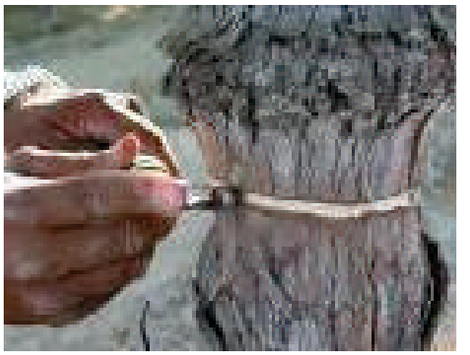
Weed control

In India, weeding in the vineyards is generally done manually. However, diuron @ 3 kg/ha and simazine @ 2 kg a.i./ha can control all weeds except *Cyprus rotundus*. Atrazine @ 2-3 kg/ha is another effective herbicide in the vineyard. Mulching also controls weed population and conserves moisture in a vineyard. Mulching with sarkanda (*Saccharum munja*) and black polyethylene has been found to be good mulch materials for vineyards.

Crop regulation and quality improvement

Some techniques can be used to regulate grape crop to obtain good yield and quality of grapes. These are described below:

(a) **Pruning and thinning:** A sizeable number of canes should be retained during pruning. In general, 60-70 clusters are considered optimum in Bower system at 3 x 3 m spacing. Similarly, 40-50 clusters in Telephone and Kniffin and 20-30 clusters on head system is optimum load. Berry thinning helps in proper development of berries, colour, ripening and quality.


Girdling in grapevine

(b) **Girdling:** It consists of removal of a complete ring (0.5 cm) of bark from the shoot, trunk or cane of a plant. The stage of girdling depends upon the cultivar and the grower's interest. For example, to improve berry set and yield, girdling is done one week before flowering, for increasing berry size, it is done at berry set or just after set and for advancing ripening, uniform colour and quality development, it is done at veraison (colour change) stage. Girdling wounds heal within a month. This technique is very effective if integrated with pruning, thinning or growth regulators sprays.

(c) **Growth regulators:** GA_3 has been found to be highly beneficial in loosening the bunches, increasing berry size and yield and in improving fruit quality in seedless varieties like Thompson Seedless, Beauty Seedless, Pusa Seedless, Perlette, Delight and Kishmish Charni. Sprays of 45 ppm GA_3 at full bloom in Pusa Seedless, 45 ppm at half bloom in Beauty Seedless, 30 ppm at half bloom in Perlette and 40 ppm in Thompson Seedless at full bloom stage have been recommended.

Plant protection

Insect-pests	Damage	Control measures
Chafer beetle (*Macrodactylus uniformis*)	It feeds on buds, young and old leaves, eating away whole lamina, leaving only the skeleton of veins.	Dust chloropyriphos on plants.
Thrips (*Phiphiphorothrips cruentalis*)	Thrips suck sap from the lower leaf surface, producing silvery blotches, affected parts turn brown, dry and brittle, which later drop off.	Spray malathion (0.5%) during March.
Nematodes *(Meloidegyne incognita* and *Rotylenchulus reniformis*)	Distortion of roots, stunted growth of plants	Aldicarb and carbofuran (6 kg a.i./ha) control the nematodes. Use nematode resistant rootstocks like Dog Ridge, Salt Creek and 1613.

Diseases	Symptoms	Control measures
Powdery mildew (*Uncinula necator*)	Virulent in south India. Powdery growth of fungus develops on the leaves and berries, which may drop. Berries do not ripen properly, become hard and crack.	Sulphur dusting or spraying wettable sulphur (0.2%) or karathane (0.1%) protect the vine from powdery mildew.
Downy mildew (*Plasmopara viticola*)	Initially, light-yellow translucent spots appear on the upper surface of leaf. Afterwards, white mould patches develop on the lower surface of the leaf. Severely affected leaves, flowers and young berries may dry and drop off.	Spraying Bordeaux mixture (1%) at a weekly interval or fytolan (0.25%) holds good for control of downy mildew.
Anthracnose (*Gloeosporium ampelophagum*)	Development of erupted brown to black spots on all green parts of the vine. The growth is completely checked, resulting in death of affected parts and splitting of bark.	Destroy affected plant parts. Spray 0.2 per cent copper oxychloride or blitox (0.3%) or fytolan (0.3%) or bavistin (0.2%) at fortnightly interval during rainy season.

Pink berry formation is a serious disorder in Thompson Seedless grapes. Its causes are unknown, yet high temperature and excessive use of ethrel enhances it.

Maturity, harvesting and yield

Grape is a non-climacteric fruit and does not ripen after harvest. Therefore, fully ripe fruits are harvested. Most commonly used maturity index is colour change, depending upon the cultivar. Harvesting of bunches is done by detaching them from the vine along with canes. Preferably, grapes should be harvested either in the morning or evening hours. The bunches after harvesting should be kept in shade. Immature, rotten, cracked, diseased or deformed berries are gently removed. Grading is done considering size, colour and variety. Packing is done in hard cardboard boxes with appropriate cushioning or packing material. Well-maintained vineyard of Perlette, Thompson Seedless may yield about 25-30 and 15-20 t/ha, respectively.

LITCHI

The litchi (*Litchi chinensis* Sonn.) is one of the most important sub-tropical evergreen fruit crops. Litchi fruit is famous for its excellent quality, pleasant flavour and attractive red colour. In India, litchi is mainly liked as a table fruit. In China, however, canned or dried litchi is preferred. Dried litchi is known as 'litchi nut'. In USA, frozen litchi is preferred. Litchi is mainly a source of sugar and acids.

Litchi is native to south China and China, Japan, Australia, South Africa, Thailand, Burma, USA, West Indies and New Zealand are major litchi producing countries. In India, it is cultivated in Muzaffarnagar, Saharanpur and Dehradun (UP), Darbhanga and Muzaffarpur (Bihar), Gurdaspur and Hoshiarpur (Punjab), Hoogly (West Bengal), Kangra valley and Sundarnagar (Himachal Pradesh), and Nilgiri hills of south India.

Litchi belongs to family Sapindaceae and genus *Litchi* with basic chromosome number, X= 7 and somatic

number, 2n= 28. Botanically, mature litchi fruit is called as 'one seeded nut' and its edible portion is 'aril'.

Soil and climatic requirements

The litchi can grow on a variety of soils but fairly deep, friable, welldrained soil with high organic matter and pH range between 5.5 and 7.5, are preferred. The water table should not be less than 1.5 to 2 m. Litchi requires mycorrhizal association for successful growth. Hence, it is suggested that new plants should be grown in soil taken from the vicinity of old trees for the introduction of mycorrhiza in the new site. The litchi is exacting in its climatic requirements. In general, litchi flourishes best in areas experiencing moist atmosphere, abundant of rainfall (125 cm or above) with freedom from frost. For proper vegetative growth, a temperature of 28-30^{0}C is best. However, for profuse flowering, a temperature below 7.2^{0}C (200 hrs) in autumn and winter is considered ideal. The dry hot winds in summer during fruit development are harmful and cause fruit cracking and subsequent damage to the fruit pulp.


A bunch of litchi fruits

Commercial cultivars

Shahi, Rose Scented, Purbi, Late Bedana, Rose Scented, Muzaffarpur, Calcuttia, Seedless Late, Dehradun, Desi, Bombai, Elaichi Late and China are popular varieties of litchi in India. Other cultivars like Early Bedana, Maclean, Longiya Kaisailiya are grown on a small scale.

Plant propagation

Litchi can be propagated by seed and several vegetative means. Propagation of litchi by seed is not common, as the plants raised through seeds take 8-10 years to come into bearing. Thus, the most common and easiest method adopted all over the world is 'air layering' or goottee. In this method, one to 1½ years old healthy and vigorous branches are selected. A ring of about 2-2½ cm wide bark is removed below the bud. This cut is covered with a mixture of mud or sphagnum moss and wrapped with polyethylene sheet. The roots start emerging from upper end of the cut within a month's time. However, the layers should be removed after two months when sufficient numbers of roots develop in them. The best time for layering in India is July-August when plants are in their active growth phase and there is high humidity in the environment. Use of IBA (2,000-5,000 ppm) to induce rooting in litchi layers has been suggested.

Agro-techniques

Planting: The pits of 1 x 1 x 1 m size, in a square or hexagonal system, at 8-10 m spacing should be dug about a month before planting time. These pits should be refilled with a mixture of farm yard manure, top soil and manures and fertilizers and then irrigated. Adding a basket of soil per pit from a litchi orchard containing mycorrhizal fungi helps in better establishment and growth of newly planted trees. The best time for litchi plantation is beginning of monsoon season. Immediately after planting, a light irrigation should be given. Litchi orchard needs to be protected from strong winds which cause complete flower or fruit drop. During summer, the hot winds ('loo') cause cracking and sunburn of fruits. Therefore, a suitable windbreak (e.g., seedling mango, *jamun*, or eucalyptus) should be raised around the orchard at a right angle to the direction of wind. A row of tall growing trees may be raised at least one year before the establishment of the orchard.

Irrigation: The critical period for irrigation is from end of January until the onset of monsoon as this is the time when vegetative growth and fruit development occur. The plants should not be irrigated during December-January as the floral initiation takes place during this time. During fruit development (March-May), irrigation is necessary at regular intervals to avoid severe fruit drop and cracking. Irrigation of young plants should be done by basin system and the fully grown plants can be irrigated by furrow or basin system, depending on the availability and source of water.

Inter-cropping: The litchi is slow growing plant and it takes about 5-6 years to come into bearing. Therefore, inter-cropping of young orchards will not only add to the income of farmer in the pre-bearing period

but will also protect the young litchi plants, enrich soil, improve physical conditions of the soil and keep the weeds under control. For intercropping, leguminous crops are usually preferred. Near big towns/cities, vegetable crops, pulses, quick growing fruits like papaya and banana can also be grown.

Weed control: Usual practice of weeding or hoeing is laborious and expensive. So, application of herbicides is recommended for controlling weeds. Diuron and atrazine both @ 2 kg/acre are quite effective for controlling weeds both in young and bearing litchi orchards. The systemic herbicides like glyphosate, is highly effective for controlling persistent weeds and paraquat for *Cyprus rotundus* and *Oxalis corniculata*. Mulching also controls weed population to a greater extent. Among various mulch materials, black polyethylene is most effective.

Manuring and fertilization

It advisable to get the nutrient status in soil and leaf tested to decide fertilizer doses. On the basis of foliar nutrient status, the following fertilizer schedule is recommended for litchi:

Fertilizer schedule for litchi based on leaf nutrient content

Age of plant (years)	Nutrients per plant per year (kg)			
	FYM	CAN	SSP	Muriate of potash
1-3	10-20	0.30-1.00	0.20-0.60	0.05-0.15
4-6	25-40	1.00-2.00	0.75-1.25	0.20-0.30
7-10	40-50	2.00-3.00	1.50-2.00	0.30-0.50
Above 10 years	60	3.50	2.25	0.60

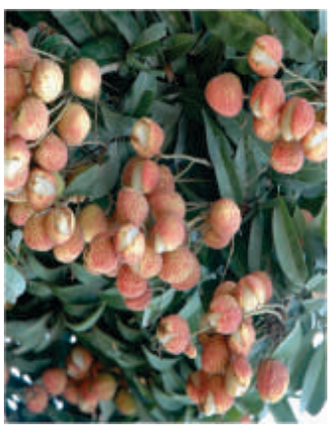
The fertilizers should be applied in 2-3 split doses i.e. during flowering, fruit growth and vegetative flush emergence. However, the fertilizer application should be withheld during the period of vegetative dormancy i.e. during autumn to winter. The fertilizers should be applied 30 cm away from the tree trunk, as litchi is sensitive to fertilizer burn. After mixing the fertilizers with soil, light irrigation should be given.

Flowering, and pollination

In India, the floral bud differentiation in litchi starts in December and ends by January. Subsequently, the flower emergence takes place in January and continues up to the end of February and fruiting takes place in April-May. The flowering duration ranges from 20-45 days, depending upon seasonal conditions. The flowers are self-sterile and insect pollinated. The chief pollinators are syrphid flies.

Fruit cracking and its control

Fruit cracking is a serious problem in litchi. Cracked fruits fetch very poor price in the market. High temperature, low humidity and low moisture conditions during fruit development, promote this disorder. A temperature higher than 38 ^{0}C and relative humidity below 60 per cent, are responsible for fruit cracking. Due to moisture stress during early period of fruit growth, the fruit skin becomes inelastic and cracks when internal pressure is increased due to rapid aril growth following irrigation or rain. Different cultivars have different intensity of fruit cracking, In general, varieties with relatively thin skin, few tubercles/unit area and round to flat in shape are less prone to cracking. Similarly, early cultivars are more susceptible than the late cultivars. Following remedial measures are suggested for checking fruit cracking:



Severely cracked litchi fruits

(i) Grow cultivars like China, Shahi and Calcuttia, which are comparatively less affected by sun burning and cracking.

(ii) Maintain optimum moisture level in soil by frequent irrigation during the critical period of fruit growth.

Fruit cracking is a serious problem in litchi. Sometimes 30-40% of crop is cracked. Its incidence can be reduced by growing resistant varieties (China, Shahi), maintaining optimum level of moisture during summer and spraying NAA (20 ppm) or GA_3 (40 ppm or borax (0.4%).

(iii) Growth regulators spray of NAA (20 ppm), 2,4-D (10ppm), 2,4,5-T (10 ppm) and GA_3 (40 ppm) also reduce the incidence of fruit cracking to a great extent.

(iv) Application of borax (0.4%) is effective in checking fruit cracking.

(v) Spraying zinc sulphate (1.5%) at weekly intervals, starting from pea stage to harvest is useful.

Plant protection

Insect-pests	Damage	Control measures
Eriophyid mite (*Aceria litchi*)	Both nymphs and adults cause damage by sucking sap from young leaves, buds, inflorescence and developing fruits. After laceration, there is development of velvety growth, gall formation, thickening and pitting of the affected leaves.	Both nymphs and adults cause damage by sucking sap from young leaves, buds, inflorescence and developing fruits. After laceration, there is development of velvety growth, gall formation, thickening and pitting of the affected leaves.
Bark eating caterpillar (*Indarbela quadrinotata*)	Caterpillars eat the bark and make holes in the trunk or main stem, resulting in complete girdling of plant.	Plug the holes either with mud or cotton, soaked in chloroform, formalin or petrol. Spray dichlorvos (0.03%) or endosulfan (0.05%).
Disease	**Symptoms**	**Control measures**
Red rust (caused by an algal parasite, *Cephaleuros mycoides)*	Initially, small lesions of velvety white growth on the lower surface of leaves occur, which later turn into velvety growth. Leaves show velvety growth and affected plants show decline in vigour and yield.	Six spray of lime sulphur (3 in spring and 3 in autumn) control red rust satisfactorily.

Maturity, harvesting and yield

Litchi is a non-climacteric fruits. Therefore, the fruits should be harvested at correct stage of maturity when these have typical taste and flavour of the variety. The various criteria recommended for judging fruit maturity are : (i) days after fruit set, (ii) development of colour on fruit, (iii) firmness of tubercles and smoothness of epicarp, and (iv) chemical changes in fruit. However, the development of colour on fruit is more dependable maturity index, though it varies from variety-to-variety. Shape of tubercles also indicates maturity of fruits, and when tubercles become somewhat flattened, fruits are ready for harvesting. TSS, acidity and specific gravity of fruit are also taken as maturity indices for proper harvesting of fruits. Litchi fruits are harvested in bunches along with a portion of a branch and a few leaves. Harvesting should be done on a bright sunny day in the morning and evening hours.

Litchi plants start bearing after 5-6 years of age. Commercial bearing, however, starts from 15th year. Yield depends on variety, age of plant, environmental conditions and management practices. At the initial stage, 100-150 fruits/plant are obtained. On an average, a full bearing plant bears about 80-150 kg fruit.

Development of velvety growth due to mite damage

BER

Ber (*Ziziphus mauritiana* Larnk.) belongs to family Rhamnaceae and genus *Ziziphus*. *Ziziphus jujuba* Mill. (Chinese jujube) produces large fruits but is not common in India. In India, *Ziziphus mauritiana* (Indian jujube) is grown commercially. Its fruits are rich in sugars, vitamin C, A and B complex. *Ber* is also cultivated in Africa and Australia. Chinese jujube is cultivated in China, Korea, Russia and in some south European countries. In India, the major *ber* growing states are Haryana, Punjab, Uttar Pradesh, Rajasthan, Gujarat, Madhya Pradesh, Bihar, Maharashtra, Andhra Pradesh and Tamil Nadu.

Soil and climatic requirements

Ber is not particular in its soil requirement and can grow on a wide variety of soils, including saline and alkali patches. Once established, *ber* can withstand even high salinity in soil. It grows in a variety of climates up to 1,000 m above mean sea level. It can withstand extremely hot conditions but young plants are susceptible to frost. The trees shed leaves and enter into dormancy during summer. Under moderate climate of south India, however, the trees continue to grow throughout the year.

Commercial cultivars

The commercially varieties of *ber* are Umran, Banarasi Kadaka, Mundia, Gola, Seb and Kaithali. Cultivars like Gola, Seb and Mundia are suitable for extremely dry areas, Banarasi Kadaka, Kaithali and Meharun for the dry regions and Sanaur 2, Meharun and Umran for comparatively humid regions. In northern India, Gola is earliest to ripen, Kaithali and Mundia are mid season and Umran and Seb are late cultivars.

Fruits of Umran ber

Plant propagation

The *ber* is usually propagated by budding. The most common methods are modified ring, patch and 'I' or 'T' (shield) budding. Rootstock seedlings are raised by sowing seed kernels extracted by breaking the stones which germinate in about one week. If the seed stones are sown as such, germination takes in nearly one month. Germination of seed stones can be improved by soaking them for 48 hours in water or by treatment with sulphuric acid. Seedlings raised by sowing seeds of *boradi* (*Z. mauritiana* var. *rotundifolia*) or Z. *nummularia* are good rootstocks for *ber.* The best time for budding is June-July.

Planting

Transplanting of budlings or rootstock seedlings is best done with the onset of monsoon. For this, pits of 60 x 60 x 60 cm are dug during summer at a spacing of 6 x 6 m in low rainfall areas and at 8 x 8 m in irrigated and higher rainfall regions. While filling the pits in sandy areas, a layer of bentonite clay can be placed at the bottom and sides of the pit to reduce moisture losses by infiltration. Each pit is refilled with top soil, mixed with 15-20 kg FYM along with 50 g of chloropyrophos dust to protect damage by termite. In rainfed areas, the inter-spaces between the tree rows can be shaped to provide 5 per cent slope towards the plant. This would help to accumulate runoff water during monsoon near the tree roots thereby resulting in higher establishment success. In irrigated areas, *ber* plants can be transplanted during January-March also.

Training and pruning

During the first 2-3 years after planting, *ber* trees are trained to develop a strong frame. After planting during July, the main shoot is headed back during March keeping 1-2 nodes above the bud union to induce vigorous new growth from which one upright vigorous shoot is retained to develop into the main trunk. This is kept clean of side shoots up to 30 cm height from ground level and thereafter 3-4 well spaced shoots are allowed to grow. The main trunk is then headed back. During the second year, the side shoots are cut back retaining the basal 1-2 nodes from which vigorous new shoots emerge and form the main branches. On these main branches also, 3-4 upward growing well spaced shoots are allowed to grow.

Fruit bearing in *ber* takes place on current season's growth and the fruit quality depends on the vigour of shoots. Therefore, annual pruning is done to induce maximum number of healthy new shoots. It is also essential to remove the undesirable, weak, intercrossing, diseased and broken branches. The best time for pruning is during the hot and dry season when the tree sheds leaves and enters into dormancy. The time of pruning differs in different parts of the country. In Tamil Nadu, pruning is done during January to April, in Maharashtra by the end of April and in north India, it is done during the last week of May. In general, light pruning, i.e. pruning of the past season's main shoot at 25 buds has been found to be the best.

Nutrient management

250 g N and 250 g P_2O_5 increased fruit yield besides, an yearly dose of 40-50 kg well rotten FYM per tree is also applied. Total quantity of FYM and phosphatic fertilizer and half the dose of nitrogen are applied immediately after pruning and the remaining dose of nitrogen is applied during October when fruit development is in progress. In sodic soils, gypsum and pond soil should be added.

Water management

For establishment of young plants, 10 irrigations are considered essential during the first year. Irrigations during the period from November to February at 3-4 weeks interval should be given to get higher fruit production from *ber* orchards. Irrigation during October has been found to induce flower shedding and that during March-April, to cause fruit spoilage and delay in the ripening process in Punjab.

Plant protection

Insect-pests	Damage	Control measures
Fruitfly (*Carpomyia vesuviana*)	Maggots bore into fruits and feed on internal contents.	Collect and destroy the fallen fruits. Dig the soil under the tree and destroy the pupae. Schedule consisting of first spray at pea stage with 0.03 per cent monocrotophos, followed by second and third sprays with 0.05 per cent fenthion and third with 0.1 per cent carbaryl at 15 days interval should be followed.
Chafer beetle *(Adoretus* sp.),	Cause extensive damage to leaves by eating and biting holes.	Spray 0.02 per cent carbaryl 50 WP and 0.05 per cent monocrotophos.

Diseases	Symptoms	Control measures
Powdery mildew (*Oidium erysiphoides*)	White powdery mass appears on the leaves, tender branches and young fruits causing fruit drop. The fruits become unattractive in appearance and size.	The disease can be controlled by application of 2-4 foliar sprays of dinocap (0.1%), carbendazim (0.1%) and sulphur dust (250 g/tree) at 15-20 days interval after the initiation of the disease symptoms. One prophylactic spray of karathana (0.02%) must be done when new growth emerges after annual pruning.
Black leaf spot (*Isariopsis indica*)	Development of black spots on the lower surface of leaves causing leaf fall.	2-3 sprays of captafol (0.2%), carbendazim (0.1%), mancozeb (0.2%) and copper oxychloride (0.2%) at 15 days interval starting from the initiation of the disease symptoms.

Maturity, harvesting and yield

In north India, flowering in *ber* takes place during August-September. Fruits take 150-175 days to mature after fruit set. *Ber* is a non-climacteric fruit and all the fruits on the tree do not ripen at one time. Therefore, these have to be individually picked by hand or by mild shaking of branches several times during the ripening season. Fruits do not ripen after picking and over-ripe fruits lose their eating quality and storage life. Therefore, fruits which are just mature (having the desired sugar/acid ratio and ascorbic acid content) and have shining yellow colour should be harvested. Picking should be done in the forenoon. Pre-harvest spray of 750 ppm 2-chloroethyl phosphonic acid (ethephon) at colour turning stage induces early and uniform ripening and reduces number of pickings. Time of harvesting depends on cultivar and agro-climatic conditions. In south India, the fruits are harvested during October-November, in Gujarat during December-March, in Rajasthan during January-March and in Haryana, Punjab and Uttar Pradesh during February-April. Early maturing cultivars ripen during middle of February, mid-season cultivars during March and the late cultivars ripen by the end of March to mid of April. The average yield in different varieties during the prime bearing period (10-20 years) ranges between 80-200 kg per tree. Under rainfed conditions, 50-80 kg fruit per tree can be obtained.

Ber leaf damaged by chafer beetle

Powdery mildew affected ber twigr

POMEGRANATE

Pomegranate (*Punica granatum* L.) belongs to the family *Punicaceae* and genus *Punica* with basic chromosome number, x = 12. Pomegranate is a juicy fruit which can be processed into different beverages with the addition of sugar and preservatives. Sundried grains from cultivars having high acidity, known as *'anardana'* are used for garnishing curries and for culinary purpose. It is a delicious table fruit, rich in B complex vitamins and minerals like calcium, phosphorus and iron. Botanically, pomegranate is a '*Blausta*' in which arils around the seeds (grains) constitute edible portion.

Pomegranate is a native to Mediteranean region. It is commercially cultivated in Iran, Afghanistan, Russia,

Israel, North and Latin American countries, Africa and India. In India, it is cultivated in Maharashtra, Karnataka, Gujarat, Rajasthan, Andhra Pradesh and Himachal Pradesh.


Mridula pomegrante

Soil and climatic requirements

Although, pomegranate is not specific to soil requirement but it is sensitive to fluctuations in soil moisture particularly during the fruit bearing stage. Loam soils with medium texture having good moisture holding capacity is preferred. It thrives well in semi-arid and arid regions having marginal agro-climate. Warm and cool nights help in the development of good colour and sweetness in the aril. High humidity coupled with high temperature makes it susceptible to diseases. Fluctuations in atmospheric humidity cause fruit cracking.

Commercial cultivars

The popular cultivars of pomegranate are Ganesh and Muskat in Maharashtra, Bassein Seedless in Karnataka, Dholka in Gujarat, Kabul Red and Vellodu in Tamil Nadu and Kandhari, Jalore Seedless and Jodhpur Red in Rajasthan. Some promising clonal selections like Arkata, Bhagwa, Sindhuri, or hybrids like Mridula, and Ruby are also becoming popular. For *anardana*, seedling selections having high acidity have been made.

Plant propagation

Pomegranate is commercially propagated through semi-hard and hardwood cuttings treated with 1,000 ppm IBA as basal dip. The cuttings are planted in polythene tubes filled with a mixture of soil, FYM and sand in equal proportion. Cuttings taken from the mature, 6-12 mm thick branches emerging from the base of main stem, give better rooting. February-March is the most suitable season for planting of cuttings in nursery. However, planting can also be done during rainy season.

Planting

Pomegranate is planted at 5 x 5 m spacing. Pits of 60 x 60 x 60 cm size are dug about one month before planting and filled with top soil, pond silt and FYM mixture in 1:1:1 proportion adding 50 g methyl parathion to protect them from termite. Rainy season is the best time of planting. In north India, planting can also be done towards the end of winter when the plants are in dormant condition. In south India, where plants remain evergreen, onset of monsoon is the best time for planting. Under arid and semi-arid regions of Rajasthan, planting is done during rainy season.

Water management

Although pomegranate is a drought hardy fruit plant but to obtain good yield and fruit quality, assured irrigation is essential. To achieve better survival of plants, light irrigation is necessary just after planting of new orchard. Water requirement of pomegranate largely depends upon the desired *bahar*. For *ambe bahar*, 13 irrigations are considered enough for good growth and yield. For *mrig bahar*, 9 irrigations are found to be sufficient. In *ambe bahar* crop of Ganesh, regular irrigations from March to July at 7-10 days interval increased the fruit yield. In arid region, due to scarce irrigation resources, *mrig bahar* crop is preferred to take advantage of the moisture available during monsoon. If long dry spell occurs, irrigations may be required even for *mrig bahar* crop.

Nutrient management

Doses of manures and fertilizers for application in pomegranate orchard depend on the fertility status of soil. In normal soils, yearly dose of 10 kg FYM alongwith 125 g nitrogen, 50 g phosphorus and 50 g potash should be applied per plant up to five years of age. In sandy loam soils of Maharashtra, yearly dose of 625 g nitrogen, 250 g phosphorus and 250 g potash should be applied to a 5-6 years old pomegranate plant besides the basal dose of 40-50 kg FYM. Upto non-bearing stage, fertilizers are applied in three split doses during January, June and September. After fruit bearing starts, time of fertilizer application should suit the *bahar* to be taken. Generally, nitrogenous fertilizers are applied in two split doses, one at the time of first irrigation after *bahar* treatment and

the second after three weeks of the first application. Full doses of phosphorus, potassic fertilizers and FYM are applied at one time after *bahar* treatment.

Training and pruning

Pomegranate is bushy in growth habit and thus produces considerable number of shoots from the base. Retaining all these would create crowding leading to infestation by shoot borers. Since single stem training of trees takes the fruiting area too high, of 3 to 4 well spaced stems are kept at the ground level. Pomegranate bears fruits on terminal and maxillary short spurs arising from the mature shoots and thus does not require regular annual pruning. However, water sprouts, diseased and pest affected or dried branches should be removed.

Crop regulation

Pomegranate has three main flowering and fruiting seasons or *bahars* such as *ambe bahar* (spring season flowering), *mrig bahar* (June-July flowering) and *hasth bahar* (September-October flowering). For commercial production, only one crop in a year is desirable. Therefore, by crop regulation, the tree is forced to rest by different ways and then it produces profuse blossoms and fruits during the required *bahar*. Selection of the *bahar* depends mainly on the availability of irrigation water, risk of damage by diseases and pests and market factors. In dry areas of north-western India, with limited irrigation resources, *mrig bahar* is preferred to utilize the water available during the monsoon period. In irrigated parts of Maharashtra and Gujarat, respectively *ambe bahar* and *hasth bahar* are preferred since the fruit yield, quality and profitability from other *bahars* are impaired by the incidence of insect -pests and diseases and market factors. The operation, thus, maximizes production from the available inputs and also avoids fruiting during the period when insect-pests and disease infestation are common. For this, operations like withholding irrigations, root exposure, root pruning and spray of chemicals (thiourea, NAA or potassium iodide) are practiced to induce leaf drop and cessation of growth during the period of the unwanted *bahar*. This is followed by application of normal irrigation, fertilizer and tillage operations one month prior to the desired *bahar* to induce new growth, flowering and fruiting. In order to increase proportion of good size grade fruits, number of fruits on a tree is regulated to retain 50-60 fruits on one bush by hand removal or by chemical floral thinning by spray of 2,000 ppm ethephon or 500-3000 ppm Alar.

In India, pomegranate flowers thrice a year in certain localities, called *bahars*. Fruits of all the bahars may not be commercially desirable. Hence, regulation of flowering is desirable to produce fruits in desirable bahar. It can be done by forcing the plants to rest by different ways in unwanted bahar. After rest, plants produce profuse flowers during the required bahar.

Plant protection

Insect-pests	Damage	Control measures
Pomegranate butterfly (*Virachola isocrates*.)	Caterpillars enter the developing fruits during July and feed on the seeds resulting in rotting and premature drop of fruits. The holes made by caterpillars can be seen on the fruit.	Bagging of fruits with butter paper. Two sprays, one each with 0.002% deltamethrin and 0.2% carbaryl at 21 days interval in rotation after fruit set.
Bark eating caterpillar	Eats bark and enters the stem by making holes.	Training of bushes and keep only 3 to 4 stems. Spray dichlorvos (0.08%), or fenvalerate (0.04%), or carbaryl (1 %) or quinalphos (0.08%).

Diseases	Symptoms	Control measures
Fungal leaf and fruit spot	Development of brown spots on leaves, which not only affects leaf vitality and number but also affects fruit growth and spoils their appearance and market value.	Four sprays of copper oxichloride (0.4%) or thiophenate methyl (0.1%) or mancozeb (0.2%) or zineb (0.2%) at an interval of 15-20 days starting from the initiation of disease have been highly effective.
Bacterial leaf and fruit spot *(Xanthomonas compestris* var. *punicae)*	Occurs in more humid areas. Affected fruits become unmarketable.	Three sprays with 500 ppm pausamycin + 0.2% copper oxychloride at 15 days interval starting from the initiation of the disease significantly reduce the incidence.

Fruit cracking and its control: Fruit cracking is a major problem in pomegranate, which can be reduced to some extent by maintaining optimum moisture level in soil by frequent irrigation, spraying PGRs like NAA (20 ppm), or 2,4-D (10 ppm) or GA_3 (40 ppm) or by the application of borax (0.4%).

Cracked pomegranates

Maturity, harvesting and yield

Pomegranate bears male, female and hermaphrodite flowers on spurs and intermediate shoots. Only the bisexual flowers produce fruit. Fruits generally ripen 6-8 months after fruit set. Being non-climacteric, tree ripen fruits are harvested. Change in rind colour from light-green to yellowish-pink or red with waxy shining surface and a cracking sound of grains on pressing the fruit indicate fruit maturity. Ripe fruits are individually picked. A full grown pomegranate bush normally produces 40-50 fruits. However, as high as 100 fruits per bush can be obtained under good management.

AONLA

Aonla or Indian gooseberry (*Emblica officinalis* Gaertn.) is an ancient, indigenous fruit of India. It belongs to the family *Euphorbiaceae*. All parts of the plant including the fruits of *aonla* are medicinally rich and are used in the preparation of various *Ayurvedic* medicines. Fruits are commercially used for preparation of *chayanprash and triphala*. Being a rich source of vitamin C, *aonla* is helpful in curing scurvy, problems of teeth, gums, eye and stomach. Fresh fruits are also used for the preparation of products such as preserve (*murabba*), pickle, *chutney*, shreds, etc. *Aonla* is cultivated in arid and semi-arid parts of India in the States of Rajasthan, UP, Haryana, Maharashtra, Gujarat and Tamil Nadu.

Aonla fruits

Soil and climatic requirements

Aonla can be grown on a wide range of soils but well-drained deep sandy loam soil having good water holding capacity is considered the best. In sandy soils, *aonla* plants can be successfully grown if irrigation facility is available. Calcareous soils are usually not suitable for its growth. However, if some amendments are used, *aonla* plantation can be raised on saline and sodic wastelands.

It can be successfully grown in hot arid climate. The trees shed their leaves and become dormant during winters. In young plantations, frost causes severe damage. The plants have to be protected by thatching and light irrigations in frost susceptible areas.

Commercial cultivars

Cultivars like Chakaiya, Banarasi and Francis have been grown in India. Shy bearing in Banarasi and predominance of internal necrosis in Francis are, however, serious demerits of these two cultivars. However, several other varieties have been developed. These are Krishna, Kanchan, NA-6, NA-7, Balwant, and Laxmi-52.

Fruits of Krishna variety

Plant propagation

Patch and modified ring budding on rootstocks of pencil thickness are the most successful methods for *aonla* propagation. July-August is the best time for budding in *aonla*. Budding period can be extended up to September-October in north India but in that case, bud union occurs but sprouting commences during February-March. *In situ* budding can also be done on the rootstocks raised in the field. Plants can also be propagated by softwood grafting and inarching. Old seedling trees can also be converted into improved cultivars by top-working.

Planting

Aonla is planted at 8 x 8 m spacing. Pits of 1 x 1 x 1 m size are dug during May-June and are filled after 15 days with FYM and top soil mixture in 1:1 ratio. To protect the plants from termites, 50 g methyl parathion dust (5%) is mixed in each pit. Plantation of *aonla* saplings is done during July-August. If assured irrigation and protection facilities are available, planting can be done during February and October. Since *aonla* has self-incompatibility, ten per cent population (15 plants/ha) should consist of pollinizer trees to ensure good fruiting. NA-7 is a good pollinizer for NA-6. In any case, planting of more than two cultivars in a block would take care of the pollinizer requirement. Plantation of seedling trees on the borders to serve as windbreak also provides seeds for raising rootstock plants.

Water management

Frequent irrigations at short intervals of 3-4 days are done for about one month after planting to ensure essential establishment of *aonla* plants in light soils of arid region. Afterwards, irrigation interval can be increased to 25-30 days. Flowering, fertilization and development of embryo in *aonla* takes place during the spring (March-April) and, therefore, light irrigations during March-July at 10-15 days interval are most beneficial. Drip irrigation on 20 per cent wetted area basis on alternate days has been found to improve growth and yield of *aonla*. In a normal monsoon year, irrigation during rainy season may not be required but in late maturing cultivars, irrigation is essential during September-October to avoid moisture stress. During winter, light irrigations are done particularly before the suspected time of frost occurrence to save the young plants from damage.

Nutrient management

Application of 10 kg FYM, 100 g N, 50 g P_2O_5 and 50 g K_2O per plant per year has been considered sufficient in arid region soils. The doses should be increased every year by the same quantity up to 10 years and then stabilized. The best time for manure and fertilizer application is January-February and June-July when the plants are in floriferous and fruit development stages, respectively. Full dose of FYM and phosphorus and half dose of nitrogen and potash are applied during spring season and the remaining half dose is applied during the rainy season. Deficiencies of micronutrients cause poor growth in *aonla*. Application of 250-500 g zinc sulphate/plant is found to be beneficial in sandy soils of arid region. Three foliar sprays with 0.06 per cent borax at 10-15 days interval have been found to reduce the malady of necrosis.

Plant protection

Insect-pests	Damage	Control measures
Bark eating caterpillar	Feeds on the stem and branches and makes holes in them causing girdling.	For its control, holes are cleaned, cotton swab soaked in kerosene / petrol / endosulphan (0.4%) is inserted and then these are plugged with moist clay.
Shoot capsule borer	Caterpillars make capsules on growing tips, which check growth of the shoots.	Removal and destruction of the affected portions followed by 2-3 sprays of 0.01% monocrotophos at 15 days interval provide effective control.
Disease	**Symptoms**	**Control measures**
Rust	Development of brown pustules on fruits	3-4 sprays of 0.2% chlorothalonil or blitox-50 or diathane M-45 at 15 days interval provide effective control.

Maturity, harvesting and yield

Vegetatively propagated trees start bearing 3-4 years after planting while the seedling trees take more than 8 years to start flowering and fruiting. In vegetatively propagated trees, commercial yield of 150-200 kg starts after 8-10 years. The fruits mature by November-December in different cultivars. In south India, however, flowering takes place during June-July. Maturity of fruit is indicated by the presence of shining green colour and reduction in acridity and increase in vitamin C content. Fruits are harvested by manual picking or by beating the branches with bamboo sticks. The fruits are collected and packed in gunny bags.

ACTIVITIES/EXERCISES

- Visit some *ber* orchard during summer, and observe how pruning is done in the orchard.
- Collect samples of insect damaged fruits from orchards of different fruits. Indentify the pest after looking its damage pattern and suggest measures for the control.

CHECK YOUR PROGRESS

1) Suggest measures to control fruit cracking in litchi
2) How can you regulate flowering in pomegranate?.
3) Enlist major production problems in litchi, *ber*, pomegranate, and *aonla*.
4) Enlist major varieties of sweet oranges and mandarins grown in India.
5) Enlist major insect-pests of citrus, which are found in India and suggest their control measures.
6) Enlist commercial seedless cultivars of grapes.
7) Enlist training systems of grape followed in India. Which systems gives best benefit cost ratio?

8) Describe briefly about citrus decline and granulation. Suggest measures to control these problems.

9) Describe one major disease of citrus, pomegranate, litchi, and *ber*. Write briefly about their management.

10) Describe briefly the damage caused by *anar* butter fly, fruit sucking moth, fruitfly and eriophite mite and write their management measures.

FILL IN THE BLANKS

1. Greening is a serious disease of ……
2. Leaf miner causes heavy losses to the nursery plants of …….
3. Red rust is a serious disease of ……..
4. Ber is commercially propagated by…….
5. Lemon plants can be commercially propagated by ……..
6. Fruit sucking moth causes damage to…… during night.
7. Krishna and Kanchan are varieties of …….
8. Kinnow is a ……. (mandarin, sweet orange)
9. Head system of training is commonly used in …….
10. The length of grape hardwood cutting should be …….
11. Best time for planting citrus plants is ……
12. Ber plants are pruned during…….
13. Budding in ber should be done during ……
14. ……..is used to control red rust of litchi.
15. Nagpuri is a variety of …….

SUGGESTED FURTHER READINGS

- Bose, T.K., Mitra, S.K. and Sanyal, D. (2001). Fruits:Tropical and Subtropical (Vol. 1). Noya Udyo Kolkata-6.
- Bose, T.K., Mitra, S.K. and Sanyal, D. (2002). Fruits:Tropical and Subtropical (Vol. II). Noya Udyog, Kolkata-6.
- Chadha, K.L.(1991). Advances in Horticulture. Malhotra Publishing House, New Delhi, India.
- Bal, J.S. (2007). Fruit growing Kalyani Publishers, Ludhiana, India.
- Chattopadhyay, T.K. (2008) A textbook on Pomology, Vol. 3 (Sub Tropical fruits), Kalyani publishers, Ludhiana, India.,
- Chadha, K.L. (2001). Handbook of Horticulture. ICAR, New Delhi

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CHAPTER

5

ROOTSTOCKS FOR FRUIT CROPS, THEIR PROPAGATION AND USES

OBJECTIVES

After reading this chapter, you will be able to know:

- About rootstock and its importance in fruit industry
- Characteristics of an ideal rootstock
- Favourable influences of rootstock on scion cultivar
- Different rootstocks being used commercially in fruit industry

INTRODUCTION

Points to remember

- Rootstocks are divided in to two groups: seedling and clonal.
- Seedling rootstocks in general provide better anchorage than clonal rootstocks, yet their use is limited as they are not genetically uniform.
- Clonal rootstocks are propagated through vegetative means and impart favourable influences on scion.

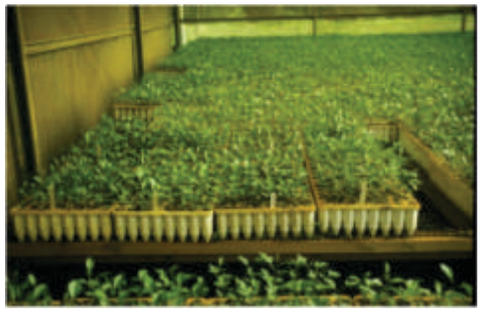
In class XIth and in previous chapters, you have read about propagation of horticultural crops. Most of the fruits are propagated by vegetative methods rather than seeds. Some fruits respond better to budding and grafting techniques of propagation rather than to cutting, or layering. For raising fruit plants through budding or grafting, we need another plant (rootstock) on which scion of desired variety is raised. Budded and grafted plants are called as 'composite plants', as they have two parts, one which grows in soil (rootstock) and another, which is a desirable variety or cultivar (scion), which later bears fruits. Thus, rootstock provides anchorage to the composite plant. You might have gone to a fruit plant nursery and might have seen some plants having joints. So the plant part below joint is rootstock and above the joint is scion. In this chapter, you will come to know about the importance of rootstock, characteristics of an ideal rootstock and favourable influences, which a rootstock can exert on scion cultivar.

Classification of rootstocks on basis of propagation

Rootstocks can be divided into two groups viz. seedling and clonal rootstocks on the basis of their method of propagation.

Seeding rootstocks

These rootstocks develop from the germinated seeds and have some advantages like, it is relatively simple and economical to raise them through seeds. Such rootstocks are usually well adapted to mass propagation. Moreover in some cases, the root system tends to grow deeper and to be more firmly anchored than the vegetatively propagated rootstocks as experienced in case of plum rootstocks. Most of the seedling plants do not retain viruses dwelling in parent plants although some exceptions are there like that of citrus.



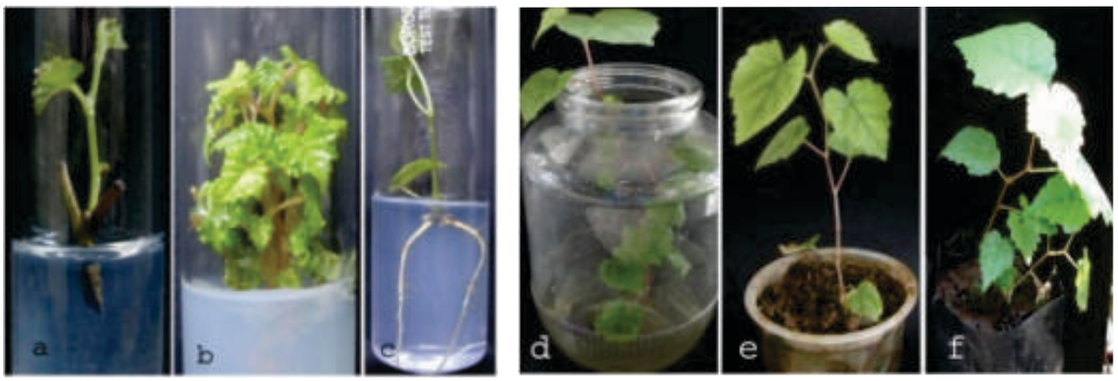
Raising citrus rootstocks

Seedling rootstocks have certain drawbacks, like genetic variation, which results in un-uniform growth and performance of scion cultivar (s) of the grafted or budded plants. Seedling rootstocks are commonly used in mango, *ber*, pecan nut, pistachio nut etc.

Clonal rootstocks

These rootstocks are those, which are multiplied through vegetative means either by stooling, layering, rooted cuttings or by aseptic tissue culture method. Individual rootstock plant so raised has the same genetic make-up, which in turn result in uniform growth and performance of scion of grafted plants. In polyembryonic species like citrus, seedlings of nucellar origin are clonal and to great extent uniform in growth. The clonal rootstocks are more popular in fruit crops, like apple, pear, plum, cherry, grape and citrus.

A view of raising guava rootstocks by stooling



Different stages of micropropagation of grape rootstock

History of the rootstock use

The use of rootstock in fruit production can be traced back to ancient times. There are evidences that the use of rootstocks was known to the Chinese as early as 1560 BC. Like wise, in Europe, during the days to Roman Empire, the use of olive rootstocks was very popular. The use of *Phytophthora* resistant rootstocks in citrus industry in Azones started in 1842. However, the development of Malling series of rootstock in apple brought revolution in the history rootstock uses. Since then, many rootstocks have been developed and used in fruit industry for various desirable effects on scion.

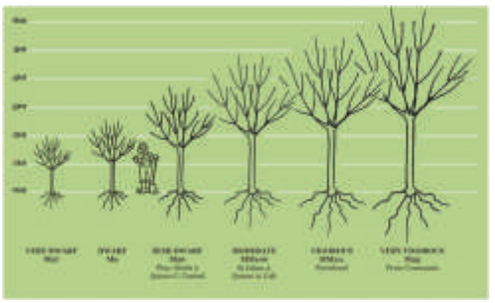
Points to remember

- Development of Malling series of rootstocks at East Malling Station, England revolutionized the apple industry in Europe.
- These rootstocks were susceptible to woolly apple aphid, and then MM series rootstocks were developed by closing M series with Northen Spy.
- M-series rootstocks were not successful in India due to poor fertility status of Indian soils, bad suckering habit and rainfed conditions. However, MM series rootstocks were successful and have been used for HDP of apple in India.
- M_{27} is the most dwarfing apple rootstock and Flying Dargon for citrus, used commercially for high density planting (HDP) throughout the world.

Characteristics of an ideal rootstock

An ideal rootstock should fulfill the following criteria:

- It should be easy to propagate either vegetatively or by seeds.
- It must have good root system, which will provide adequate anchorage to support the tree grafted on it without staking.
- It must produce a good, clean, upright stem, easy to budding or grafting.
- It should have wider soil and climatic adaptation.
- It should have better congeniality/compatibility with the scion cultivar (s) or interstock.
- It should impart favorable influences to the scion cultivar.



A view of size control in apple with different rootstocks

- It should have high degree of winter hardiness, tolerance to high salts, diseases and insect-pests etc.
- It should be easily available.
- It must induce dwarfing, precocity in bearing and heavy cropping effects to the scion cultivar.

Beneficial effects of rootstocks

The various effects of stock on the scion cultivar have been described briefly hereunder:

Tree vigour

Using rootstock, the vigour of scion cultivar can be controlled as per the grower's need. For example, on the basis of varying degree of effect on the vigour of scion cultivars, the apple rootstocks have been grouped in different categories like very dwarfing, dwarfing, semi-dwarfing vigourous and very vigourous.

Very dwarfing : M_{27} is the most dwarfing clonal sootstock. It was developed at East Malling Research Station, England in 1929 from a cross between $M_9$and M_{13}.

Dwarfing : It is the most widely used dwarfing rootstock for apple. It had originated as chance seedling.

Semi dwarfing : M_{29}, M_7, MM-106.

Vigourous : MM-104, MM-109, MM-111.

Very vigorous : M_{16}, and M_{25}.

In mango, rootstocks like Taimuria, Olour, Rumani, Nekkare and Kurukkan have been classified as dwarfing rootstocks, while Dashehari, Chausa, Moovandan, and Sukar China as vigourous rootstocks. Vellai Kolumbam, Totapuri Red Small and Creeping have also been classified as dwarfing rootstocks. In citrus, Flying Dragon is the most dwarfing rootstocks, primarily used in high density planting systems in most part of the world.

Anchorage

The primary and most important function of rootstock is to provide anchorage to tree by growing deep into the soil. Rootstocks with deeper root system avoid the need of staking and hence reduce the cost of cultivation. The dwarfing apple rootstocks like M_{27} and M_9, usually require staking particularly in early years due to brittle nature of their roots. Hence, these rootstocks could not prove to be beneficial to apple industry in Himachal Pradesh (India) because apple is grown in rainfed conditions whereas these rootstocks perform well under irrigated conditions. Similarly, seedling plants owing to their deep root system are preferred as rootstocks in windy area.

Precocity in bearing

Dwarfing rootstocks bring precocity in bearing in fruit crops. Most striking example of induction of precocity in bearing has been the use of dwarfing rootstock (M_9 and M_{27}) in apple. In citrus, Sathgudi orange shows precocity in bearing when budded on Gajanima and acid lime rootstocks. Similarly, Kinnow plants come into bearing at an early date if budded on Troyer citrange, as compared to *Karna Khatta* and *Soh Sarkar* rootstocks. Flying Dragon, a world known citrus rootstock also induces precocity in bearing in the different scion cultivars.

Flowering, fruiting and yield

It is a well-known fact that flowering, fruiting and yield are chiefly governed by rootstocks employed in different fruits crops. In general, the yield per tree basis is less on dwarfing rootstocks but yield in terms of per unit tree volume is always very high. Moreover, due to dwarfing effect of rootstocks, accomodation of plants is 2 to 3 times higher than on the conventional rootstocks, which further adds to yield. Dwarfing rootstocks usually

help the scion cultivar to flower early and profusely than the vigorous rootstocks (e.g. apple rootstocks).

Fruit size and quality

Rootstocks have significant influence on fruit size, yield and quality. Dwarfing rootstocks, although induce precocity in bearing but fruits size is somewhat reduced. Vigorous rootstocks produce fruits of larger size. For example, small sized fruits are produced by dwarfing apple rootstocks (M_9 and M_{27}) than the seedling rootstocks. Further, Kinnow fruits on Troyer citrange are smaller in size than on *Karna Khatta* and *Soh Sarkar* rootstocks. In guava, the fruits of Allahabad Safeda are smaller in size but with better quality on Pusa Srijan than on its own roots.

Overcoming incompatibility

The problem of graft incompatibility is often encountered in various fruit crops, such as, pear, *ber*, walnut, cherry, citrus etc., leading to short orchard life. But in citrus and *ber,* the graft incompatibility has been used as a tool to dwarf the plant. *Ber*, when grafted on *Zizyphus nummularia* develops the symptom of inverted bottle neck disorder due to graft incompatibility. This disorder has been utilized for induction of dwarfing in *ber* for high density planting.

Diseases

Rootstocks are classified as susceptible or resistant according to their response to pathogen attack. The different relations of rootstocks to the various pathogens may be grouped into the following types *viz*. susceptible, tolerant, resistant and immune. For example, among 16 rootstocks tested for sweet orange, Sohmyndog, Jambhiri Kodur, Jambhiri Bombay and Rangpur lime were tolerant to tristeza viral disease and greening mycoplasmal disease but were susceptible to *Phytophthora* root rot. Similarly, Cleopathra mandarin is almost resistant to all viral diseases.

Abiotic stresses

Abiotic stresses like salinity and alkalinity, frost etc. cause havoc to the fruit crops and thereby effect the production and productivity invariably. Some rootstocks have special feature to fight against these abiotic stresses. For example, Kurukkan is highly suitable mango rootstock in salt affected soils as it can tolerate high salts effectively. Salt Creek and Dog Ridge have been classified as salt tolerant rootstocks for grape. Rangpur lime rootstock of citrus has wider soil adaptability. Trifoliate orange citrus rootstock can exclude the winter injuries effectively. *Citrus unshiu* is regarded as freeze tolerant rootstock of citrus. *Jatti khatti* strain of Rough lemon citrus rootstocks is suitable for saline and alkalive soils.

Insect-pests

On the basis of rootstock's response to insect-pest attack, these have been classified as susceptible, tolerant, resistant and immune. For example almond rootstocks like Almen, Almen 88 and Almen 201 are resistant to nematodes. Grape rootstocks like Dog Ridge and 1613 are resistant to phyloxera root louse.

A brief information about different rootstocks and their chief characteristics used in fruit industry has been given in the following table.

- Visit a fruit plant nursery in your locality. Ask gardener (*mali*) for budded and grafted fruit plants. Make a

S.No.	Fruit crop	Fruit crop	Distinct influence on scion
1	Mango	Totapuri Red Small	Dwarfing
		Vellai Kollumban	Dwarfing
		Rumani, Olour	Dwarfing
		Kurukkan	Salt tolerance
		Creeping	Dwarfing

2	Grape	Dogridge	Resistance to *Phylloxera*, nematodes and salts.
		Salt Creek	Resistance to salt and nematodes
		St. George	Resistance to *Phylloxera* root louse
		Temple	Resistant against pierce's disease, anthracnose and downy mildew
3	*Ber*	*Ziziphus nummularia*	Dwarfing effect
4	Guava	Pusa Srijjan	Dwarfing effect on Allahabad Safeda scion cultivar
		Psidium pumilum	Dwarfing effect on Allahabad Safeda scion cultivar
5	Citrus	Flying Dragon	Most dwarfing, highly suitable for high density planting
		Trifoliate orange	Deciduous, cold hardy, dwarfing, resistant to nematodes, resistant to most viral diseases
		Cleopetra mandarin	Most salt tolerant citrus rootstock
		Rangpur lime	Resistant to tristeza, and exocortis
		Sweet orange	Hardy rootstock, adaptable to various soil conditions and salt tolerant
		Rough lemon	Relatively tolerant to saline and calcareous soils
		Sour orange	Cold hardy, resistant to phytophthora root rot but highly susceptible to tristeza
		Citrus unshiu	Freeze tolerant
6	Apple	M_9	Dwarfing effect and highly suitable for high density planting
		M_{27}	Ultra-dwarfing, suitable for high density planting
		Malus sikkimensis	Induces precocity in bearing
		M_{26}	Better anchorage to scion cultivar
		M_7	Semi-dwarfing, stronger and deeper root system
		Mm_{111} & MM_{106}	Suitable for light sandy soils
		Northen Spy	Wooly aphid resistant
		MM-series	Wooly aphid resistant
		EMLA series	Free from viruses

7	Peach	Nemaguard	Resistant to nematode and crown gall
		GF-557	Nematode resistant
		GF-677	Drought tolerant, and high pH tolerant
8	Pear	Quince C	Semi-vigorous rootstock
9	Plum	Pixie and St. Julien	Dwarfing rootstocks
		Mariana 2624	Semi-resistant to nematodes, crown gall, cold hardy and tolerant to high soil moisture
		Myrobalan B	Resistant to bacterial gummosis
10	Almond	GF-557 and GF-677	Tolerant to high soil pH
		Alnem 1	Resistant to nematode

ACTIVITIES/EXERCISES

list of fruit plants and rootstocks.

- Plan a visit to some ICAR institute related to fruit crops. Visit their orchards. Make observation on the effect of rootstocks on different fruit plants.

CHECK YOUR PROGRESS

1. What is rootstock? Describe the importance of rootstock in fruit industry.
2. What characteristics an ideal rootstock should have? Discuss in brief.
3. Discuss briefly the positive influences of rootstock on scion cultivar.

FILL IN THE BLANKS

1. Seedling rootstocks provide better ..... in the soil.
2. Clonal rootstocks are usually propagated through.....
3. .....is the most dwarfing rootstock of apple.
4. .....is the most dwarfing rootstock for citrus.
5. .....rootstock of grape is resistant to salts and nematodes.
6. Pusa Srijan is a rootstock of .....

SUGGESTED FURTHER READINGS

- Aldriance, G.W. and Brison, F.R. (2000). Propagation of horticultural plants. Mc Grow Hill Book Company. Inc, New York.
- Bose, T.K., Mitra, S.K., Sadhu, M.K .and Das, P. (1997). Propagation of Tropical and Sub tropical Horticultural Crops. IInd Edition, Naya Prakash, Calcutta.
- Sharma, R.R. (2002). Propagation of Horticultural crops: Principles and Practices. Kalyani Publishers, New Delhi.
- Sharma, R.R. and Srivastav, M. (2004). Plant propagation and nursery management. Intl Book Distributing Co., Lucknow
- Hartman, H.T, Kester, D.E. and Davies, F.T. (1993). Plant propagation: Principles and Practices. 5th Edition. Prentice Hall of India, New Delhi.

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CHAPTER

6

MANAGEMENT OF ROOTSTOCKS AND MOTHER STOCKS

OBJECTIVES

After studying this chapter, students will be able to:

- Shortcomings practiced in fruit nurseries
- Know about importance of mother stocks in fruit propagation
- Know about maintenance & management of mother stock
- Know about bud wood certification in fruit crops

INTRODUCTION

Mother block or progeny block

A separate block of generically pure, healthy and disease-free plants of a particular fruit variety.

Fruit crops are mostly composite plants and consists of scion and rootstock except in banana, papaya and strawberry. As reported in the previous chapter that rootstock exhibits a great influence on the performance of scion in terms of production efficiency, yields, quality, adaptability, vigour and resistance against biotic and abiotic stresses. The primary function of a rootstock is to provide anchorage or support to the scion by growing deep into the soil and also regulate the uptake of moisture and nutrients. The rootstock cannot be changed during life-time of a plant so it makes it inevitable to pay more focused attention on it because its functions are long term. Success of any orchard mainly depends upon the availability of right type of planting material. The initial planting material is the basic requirement on which the final crop depends both in terms of quality and quantity. In case, any mistake in done in the initial years, it cannot be rectified in the subsequent years and it will cause everlasting damage to productivity and income of the orchardists. In the recent past, the demand for quality planting material has increased manifold throughout the country due to increasing importance of fruit crops. However, the main bottleneck in the expansion of area under fruits is the non-availability of genuine and quality planting material in adequate quantity from reliable sources.

General shortcomings practiced in fruit nurseries

- Bud wood certification programme is not followed for the production of fruit plants, which are prone to attack of viruses.
- Provision for mother block for scion and rootstocks is not appropriate.
- Pedigree of the mother plants (scion source) is not known or not maintained adequately.
- Scion shoots are taken from such mother plants without knowing its characteristics.
- Scion shoot are collected from disease infected trees.
- Scion shoots are taken from juvenile tree, which can delay fruiting in most nurseries.
- Provision of source for rootstock is lacking.
- Seedling plants are mostly used as rootstocks, which result in variation in the performance of scion cultivars.

- Enough rotation is not practiced in the nursery and same bed is repeatedly used year-after-year.
- Least attention is paid towards phytosanitory conditions of the nursery.
- Transportation of plants along with earth ball is expensive, tedious and less efficient. Often, a number of diseases and pests are also carried along with earth ball.
- For the shake of making money, non-authentic saplings are sold to the growers in the name of quality one by private nurseries.

Classification of rootstocks

Rootstocks can be divided into two groups viz. seedling and clonal rootstocks on the basis of their method of propagation.

Seeding rootstocks

These rootstocks develop from the germinated seeds and have some advantages like, it is relatively simple and economical to raise them through seeds. Such rootstocks are usually well adapted to mass propagation. Moreover in some cases, the root system tends to grow deeper and to be more firmly anchored than the vegetatively propagated rootstocks. Most of the seedling plants do not retain viruses dwelling in parent plants although some exceptions are there like that of citrus. Seedling rootstocks have certain drawbacks, like genetic variation, which results in un-uniform growth and performance of scion cultivar(s) of the grafted plants.

Seedling rootstock: Rootstocks develop from the germinated seeds or stones

Clonal rootstock: Rootstocks, which are developed through vegetative means such as stooling, layering, rooted cuttings or by tissue culture

Seedling rootstocks of mango under shade net

Polyembryonic clonal mango rootstock

Clonal rootstocks

These rootstocks are those, which are multiplied through vegetative means either by stooling, layering, rooted cuttings or by aseptic tissue culture method. In polyembryonic species like citrus, seedlings of nucellar origin are clonal and to great extent uniform in growth.

Management of rootstocks

Rootstock is that part of the plant onto which a scion bud or bud stick is placed. It provides the root system to the grafted or budded plant. It is well known fact that rootstocks have strong influence on the growth, flowering, precocity and fruit quality of the scion variety. Rootstocks also impart resistance to abiotic and biotic stresses. The desired performance of the scion cultivar depends on the correct choice of the rootstocks. It is therefore imperative to pay attention for raising good quality rootstocks and their management in the nursery.

The seeds should be collected from the healthy, disease-free tree. The seeds are to be washed thoroughly and dried in shade prior to sowing. Some seeds need immediate sowing. The spacing and depth of sowing vary with the size of seed, viz. citrus seeds are sown 2 cm apart in rows at a depth of 1 cm whereas mango stones are placed

at a depth of 5 to 6 cm with a spacing of 15-20 cm between rows. The germination of seeds normally commences about three weeks after sowing. The young seedlings are susceptible to extremes of climate. They should be protected against frost in winter and hot desiccating winds during summer months. Light dressing with nitrogenous fertilizers after one month helps in rapid growth of seedling at initial stages. The bed should be kept free from weeds. Irrigation should be given at an interval of 7-10 days during summer months. Seedlings become ready for grafting or budding at the age of one year when they attain a size of pencil thickness at about 15 to 20 cm above the ground level.

Provision of mother block

Each nursery must have provision of mother block of scion and rootstock varieties. Invariably, separate space should be provided for establishment of Mother Block within the premises of the nursery. The pedigree of these plants should be known and any change in its characteristics should be taken care. For example, expression of mutation could result in significant variation in the performance of original one. Following are some issues require attention of nurseryman in the mother block management.

Selection of mother plants

Selection of mother plant as a source of scion wood is of utmost importance and should be done with the greatest care since the performance of progeny depends entirely upon characteristics of mother plant. The mother trees selected for scion wood should have attained full bearing age, since its characteristics will be known only after bearing age. Mother plants performing consistently better and giving higher yield, producing high quality fruits and are free from diseases and insect pests, should be used as scion wood source, i.e., as mother plants.

Procurement of source plants for mother block

Genetic purity and freedom from diseases and insect-pests of the mother plants is of utmost importance. Maximum efforts should be paid for getting plants of specific varieties from the organization which has released that one. If not possible, plants for mother block should be taken from State Agricultural Universities located in different states or ICAR institutes or state horticulture department. If again not possible then make sure to get the plants from a reliable government or private nursery. In case of citrus and apple where viral diseases are common, only indexed plants of specific variety should be taken for mother block purpose.

Establishment of mother blocks

In order to increase the availability of enough scion sticks, mother tree blocks need to be established on a suitable rootstock and planting at a spacing of 3 m x 2 m distance. These plants should be severely pruned to produce enough shoots for propagation purposes. The maintenance of these blocks is to be done rigorously so that these are healthy and free of diseases and insect pests. If there is any congestion and problem of light penetration, then alternate plants first within plant to plant then later on within rows can be eliminated depending upon the situation.

Mother block of Amrapali mango

Maintenance of mother plants

A permanent register indicating the layout of promising varieties of the region needs to be maintained. The maintenance of mother plants, right from the time of planting to the stage of bearing and subsequent years involves timely application of manures and fertilizers, irrigation, weeding and other inter-culture operations, training and pruning and plant-protection measures. These agro-techniques need to be undertaken judiciously, so that vigorous and healthy scion shoots are made available for multiplication. Till scion shoots form elite plants planted in mother blocks are not available, scion woods can be procured from the scion banks of ICAR institutes, SAU's and other district level government nurseries or promising trees in the area marked through a group of experts and scion shoots from these sources may be utilized for multiplication of planting materials.

Management of mother block

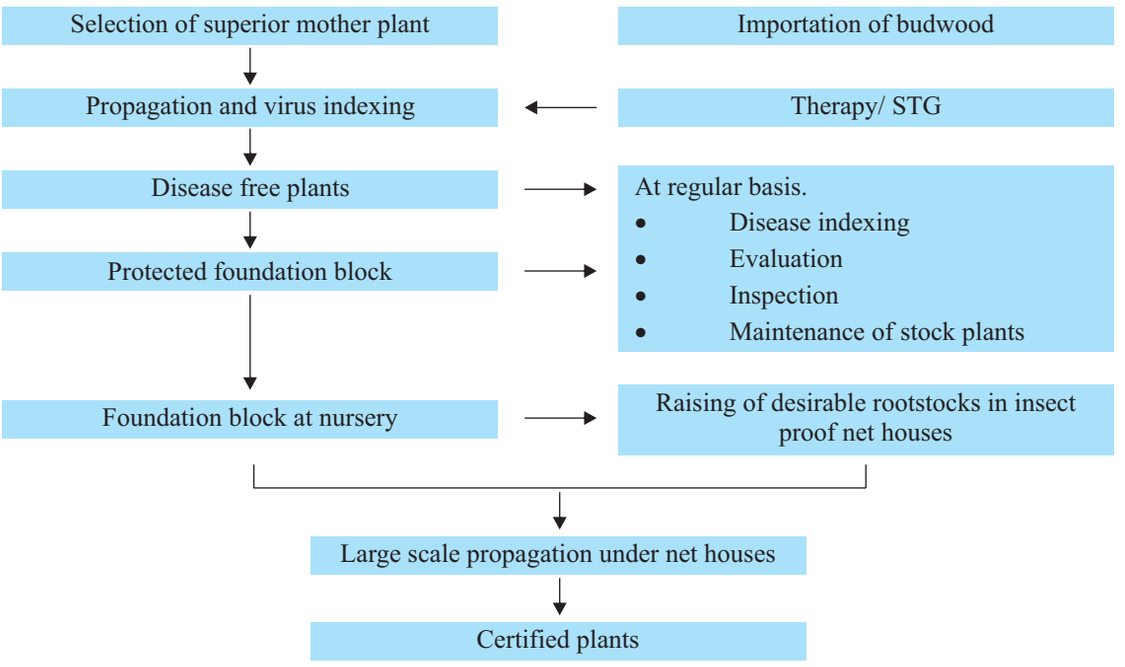
Training and pruning: For proper framework, it is advisable not to allow the growth of shoots from the base. Clean stem should be kept up to 20-30 cm from the ground and then branches are allowed to develop in different directions. After collection of shoots for multiplication, branches should be pruned back severely to induce new growth.

Pest and disease management: A number of pests and diseases attack during different stages of plants in mother block. In order to minimize the incidence, adopt preventive measures and keep proper sanitation as prevention is better than cure.

Protected structure for mother stocks: Poly shelter of plant height in frost and hailstorm prone areas be stretched all over. In fruits like citrus, insect proof net house is required to keep them free from viral contamination. After every two years, virus testing through indexing or other techniques should be got done.

Budwood certification in fruit crops

Most of the fruit crops are propagated vegetatively and may have high rate of infection by viruses, viroids and phytoplasma. To ensure disease-free panting material budwood certification is necessary. Budwood certification programmes have the objective of producing certified nursery plants that will guarantee that the sanitary status i.e., the pathogen free state of the parent material and desirable horticultural characters of candidate mother plant are maintained during commercial propagation. A certification programme is an essential step in producing high quality fruit plants and has to be established in every country, which desires to produce high quality and healthy nursery plants. The use of budwood from infected trees in the nursery for propagation is the primary cause for the distribution of the diseases. The mother plant serves as a source of primary inoculums as it is the source of budwood and secondary inoculums when vectors use the infected budwood to infect adjoining pathogen free trees. Due to this, virus and virus like diseases spread uncontrolled to most of the fruit growing areas of the country. A mandatory certification programme can prevent or eliminate destructive pathogens before they enter the mainstream of budwood supply. A successful certification programme needs careful planning and adequate facilities. An insect free propagation facility, testing laboratory, foundation block, an increase block, a regulatory agency and well trained, motivated proper scientific personnel are needed. The money invested in a certification scheme is bound to pay large dividends to the fruit industry.A schematic representation of methodology of a successful citrus certification progarmme is given below:



Disease indexing methods

The mother plants are monitored regularly for the presence of major viruses and virus-like agents such as citrus tristeza virus, ring spot virus, citrus greening and exocortis. This is done by biological indexing and serological indexing under insect proof controlled conditions.

Biological indexing or bio-diagnosis: Biological indexing is an old method for determining the presence of virus in plant tissue. The virus is detected in the plant tissue by budding or grafting of a scion from plant suspected of having virus onto other susceptible (Indicator) plants identified for specific virus.

Budding in citrus

Serological methods for indexing: The serological methods are indirect method of virus detection. This method is fast and efficient than bio-indexing. In general ELISA (Enzyme linked immune-sorbabent assay) and DIBA (Dot Blot immune binding assay) are performed.

Indicator citrus species	Viruses
Biological indexing	
Mexican lime	Tristeza, vein enation, leaf rugose, witches' broom
Pineapple sweet orange	Psorosis, ringspot, concave gum, cristacortis" impietratura, greening
Dweettangor	Psorosis, ringspot, impietratura, mosaic
Troyer citrange	Tatter leaf, kumquat disease
Etrog citron	Exocortisana other viroids, infectious variegation, tristeza, kumquat disease and satsuma dwarf
Parson's Special mandarin	Cachexia, ringspot
Serological indexing	
ELISA	Tristeza, stubborn, satsuma dwarf, infectious variegation
DIBA	Tristeza, stubborn, satsuma dwarf, infectious variegation

ACTIVITIES/EXERCISES

- Visit fruit nursery in your area, and try to find out if rootstocks or mother stocks are managed properly or not.
- Meet some nurseryman and enquire about the different cultural practices used for rootstocks and mother stocks.

CHECK YOUR PROGRESS

1) Enumerate the general shortcomings practiced in fruit nurseries.
2) Differentiate between clonal and seedling rootstocks.
3) What is biological indexing? Name some indicator plants for specific viruses in citrus.

FILL IN THE BLANKS

1. The primary function of a rootstock is to provide ……. to the scion by growing deep into the soil and also to regulate the uptake of ……..... ……..

2. ELISA stands for ..…….

3. DIBA stands for ..…….

4. Most of the fruit crops are propagated …… and may have high rate of infection by ……... To ensure disease free panting material, ……. is necessary.

5. On the basis of propagation method, rootstocks can be divided into two groups,1. ……..., and 2. ……. rootstocks.

SUGGESTED FURTHER READINGS

- Chadha, T.R. (2000). Textbook of temperate fruits. ICAR, New Delhi.
- Bose, T.K., Mitra, S.K. and Rathore, D.S (1991).Temperate fruits. Naya Prokash Publishers, Kolkata, India.
- Bal, J.S. (2007). Fruit growing. Kalyani Publishers, Ludhiana, India.
- Chadha, T.R. (2000). Textbook of temperate fruits. ICAR, New Delhi
- Chattopadhyay, T.K. (2004). A textbook on Pomology, Vol. 4 (Temperate fruits), Kalyani publishers, Ludhiana, India.,
- Sharma, R.R. (2006). Fruit production: Problems and solutions. Intl. Book Distributing Co., Lucknow, India.
- Sharma, R.R. (2009). *Adhunik Phalotpadan*.Kalyani Publishers, Ludhiana, India.

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CHAPTER

7

FERTIGATION IN FRUIT CROPS

OBJECTIVES

After studying this chapter, you will be able to:

- Understand fertigation, its uses and advantages

INTRODUCTION

In the recent years, there has been significant improvement in fruit production technologies. Of several such technologies, development of fertigation has forced us to think and talk about this technology as its use has tremendous effect on yield and quality production with significant reduction in water use. You might have heard about this technology, if not, we will discuss about its uses, and advantages in this chapter .

What is fertigation?

Fertigation is defined as the application of fertilizer or chemicals through the drip irrigation system. It is a controlled system to supply soluble plant nutrients at the root zone of the irrigated crops. Fertigation is done through tank, ventury or pump systems. The most practical method of applying of fertilizers through the irrigation system is by creating a 10% bypass flow of the main line flow, through an artificial fertilizer mixing tank.

Advantages of fertigation

Some of the advantages of fertigation are as under:

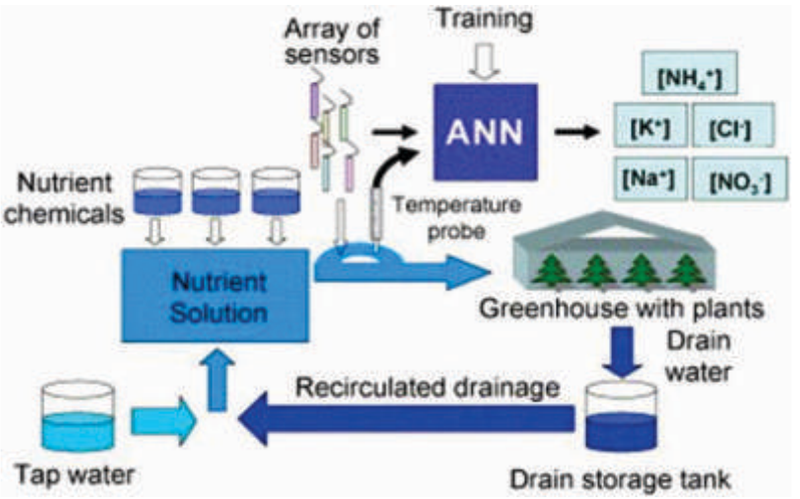
- Fertilizer use is optimum without fluctuation.
- Loss of fertilizer due to leaching is minimum.
- Nutrients can be applied any time during the growing season based on crop need.
- Mobile nutrients such as nitrogen can be carefully regulated in the soil profile by the amount of water applied so that they are available for rapid use by the crop.
- Fertilizer use efficiency is very high.
- There is saving of fertilizers by about 40-60%.
- Some tillage operations may be eliminated, especially if fertilization coincides with the application of herbicides or insecticides.
- There is significant increase in crop yields .
- There is no pollution of water source.
- Significant saving of energy and labour .
- Natural resources are efficiently utilized.

- Groundwater contamination is less likely with fertigation because less fertilizer is applied at any given time.
- Application of fertilizers through drip can correspond to maximum crop needs.

There are several advantages of fertigation but it has not picked up in all parts of the country. The major constraints coming in the way are:

- Liquid fertilizers are not available at reasonable rates.
- Initial cost of establishment is very high
- There is lack of research and development efforts in developing fertilizers suitable for fertigation.
- Policy environment for promoting the growth in the sector is inadequate.

Presently, water soluble fertilizers suitable for fertigation are not being manufactured in India. Hence, some of the available normal fertilizers are being used with some modifications. Besides, some formulations are being imported which are expensive. The solid fertilizers which supply nitrogen (N) are (a) Anhydrous ammonia, which increases pH leading to precipitation with calcium and magnesium and results in clogging of the drip system, (b) Calcium nitrate is relatively soluble and does not cause much pH shift.



Pictorial view of fertigation

Tanks of fertigation system containing nutrient solutions

In general, application of phosphorus fertilizers through the drip irrigation system is not recommended, because (1) basal application of phosphorus satisfies the plants requirement in most of the cases, (2) phosphorus is limited in its movement and has high rate of fixation in the soil (3) most of the applied phosphorus creates chemical and physical precipitation leading to clogging problems. Glycerophosphate and inorganic phosphorus are the other sources of phosphorus used in fertigation. Liquid fertilizers are solution containing one or more plant nutrients. These can also be supplemented with micronutrients. The raw materials used in liquid fertilizer production are mainly bulk fertilizers such as ammonium sulphate, ammonium nitrate, urea, ammonium phosphate, phosphoric acid, potassium nitrate, potassium chloride, potassium sulphate etc. The liquid fertilizers are pure and do not precipitate. Normally, the liquid fertilizers are acidic (pH 5.5-6.5) and help in correcting the soil pH to some extent and also help in preventing clogging of emitters. However, for acidic soils, liquid fertilizers with neutral pH or even higher pH could be used. These liquid fertilizers are available as chloride free

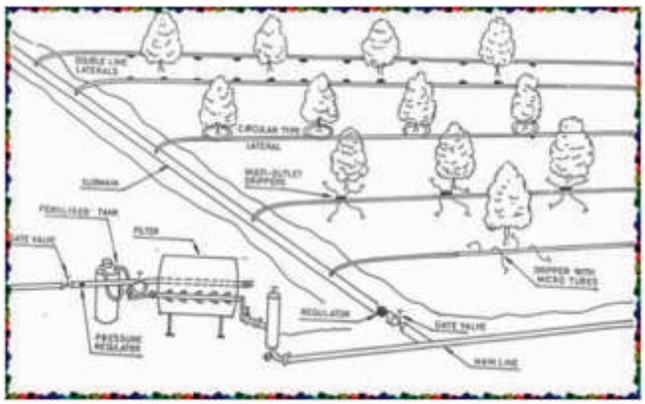
normal fertilizers. Certain fertilizers like aqueous ammonia, calcium nitrate, potassium sulphate, zinc nitrate and ferric sulphate are not suitable for fertigation.

Disadvantages of fertigation

Although, fertigation is highly advantageous. However, it is felt that it may have the following diasvantages as well:

- Initial establishment costs are very high, which is beyond the reach of common farmer.
- Salts, which are common in irrigation water precipitates and can form inside of irrigation pipelines and clog nozzles.
- Some fertilizers such as ammonia, various polyphosphates and iron carriers can react with soluble calcium, magnesium and sulfate salts to form precipitates.
- Many fertilizer solutions are corrosive.

A view of fertigation in banana



Pictorial view of drip irrigation

ACTIVITIES/EXERCISES

- Visit some fruit orchard in which drip and fertigation facility is installed. Note different components and their functions.

CHECK YOU PROGRESS

1) What is fertigation? Write its advantages.
2) Inspite of several benefits of fertigation, why fertigation technology could be become popular in India.
3) Why phosphatic fertilizers should not be applied through drip irrigation system?

WRITE TRUE (T) OF FALSE (F) FOR THE FOLLOWING STATEMENTS

I) Liquid fertilizers are used in fertigation.

ii) Liquid fertilizers are produced in plenty in India.

iii) Phosphorus is highly mobile in soil.

iv) Liquid nitrogen is frequently used in fertigation

v) Clogging of lateral in fertigation is quite common problem.

SUGGESTED FURTHER READINGS

- Bose, T.K., Mitra, S.K. and Sanyal, D. (2001). Fruits: Tropical and Subtropical (Vol. 1). Naya Udyog, Kolkata-6.
- Bal, J.S. (2007). Fruit growing. Kalyani Publishers, Ludhiana, India.
- Chattopadhyay, T.K. (2008) A textbook on Pomology, Vol. 3 (Tropical fruits), Kalyani publishers, Ludhiana, India.
- Sharma, R.R. (2006). Fruit Production: Problems and solutions. Intl. Book Distributing Co., Lucknow, India.

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CHAPTER 8

MATURITY STANDARDS, HARVESTING, GRADING AND RIPENING OF FRUITS

OBJECTIVES

After studying this chapter, you will be able to:

- Differentiate between maturity and ripening of fruits.
- Understand the importance of maturity indices and harvesting of fruits at appropriate maturity
- Differentiate between climacteric and non-climacteric fruits
- Know about ripening of fruits and methods of fruit ripening

INTRODUCTION

We consume several types of fruits. Fruits are usually eaten when fully ripe whereas most of the vegetables (except turnip, water melon and musk melon) are eaten when they are physiologically mature. Have you ever tried to know how they grow and attain ready-to-eat condition? Why few fruits can be ripened artificially while others can't? At what point of maturity, a particular fruit should be harvested and why? What will happen if a fruit is not harvested at appropriate maturity? How harvested fruits should be handled at the farm to keep them in fresh and eatable condition for longer time? You can face several questions of this category. For harvesting a fruit at right time of maturity, several maturity indices have been standardized. Harvested fruits need proper handling at field level to keep them in fresh form for longer time or be stored at appropriate place. In this chapter, attempts have been made to explain about the importance of maturity index in fruits, maturity indices standardized for different fruits and about grading and ripening of fruits.

Harvesting

Fruits harvested too early may lack flavour and may not ripen properly, while produce harvested too late may be fibrous or have very limited market life. Therefore, harvesting of fruits at proper stage of maturity is of paramount importance for attaining desirable quality. The level of maturity actually helps in selection of storage methods, estimation of shelf life, selection of processing operations for value addition etc. The maturity has been divided into two categories i.e. physiological maturity and horticultural maturity.

Physiological maturity: The stage at which a plant or a plant part continues ontogeny even if detached from its parent plant or the point of origin.

Horticultural maturity: It may be defined as the stage at which a plant or a plant part possesses all the pre-requisites for utilization by the ultimate consumer for a particular purpose. For example, horticultural maturity stage of tomato if harvested for long distance transportation would be the turning stage of peel 'from green to red' while the optimum stage of harvesting of the same crop for home use or local markets would be 'when the fruits have attained full red colour'.

Maturity indices

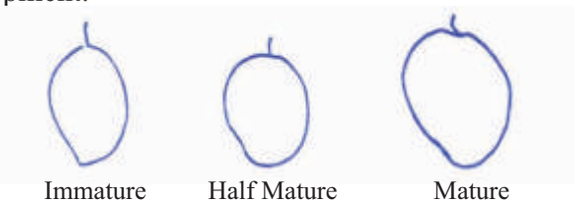
The indicators, which dictate at which stage of maturity a fruit should be harvested for fresh consumption, storage or marketing. If a fruit is harvested at an immature stage, it is likely that it may not develop attractive size, colour, and flavor and have poor eating quality and low storage life. As a result, it will fetch very low price in the market. Hence, a commodity should be harvested at an appropriate stage of maturity. In general, a single

maturity index is not considered to be reliable. In most of the crops, more than one or two indices should be made use of while determining the exact stage of optimum maturity. Experience of growing, harvesting and marketing of a particular crop along with critical observations would be the best for determination of the optimum maturity. A beginner should seek the help of a local experienced person in determination of maturity of a crop till he himself gains experience and confidence. Some typical maturity indices are described below:

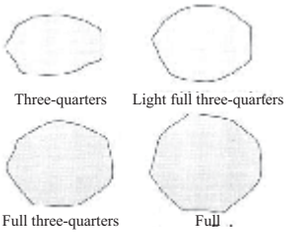
Maturity indices for horticultural crops

1. Visual

i) Size and shape: Maturity of fruits can be assessed by their final shape and size at the time of harvest. Fruit shape may be used in some instances to decide maturity. For example, the fullness of cheeks adjacent to pedicel may be used as a guide to maturity of mango and some stone fruits. Size is generally of limited value as a maturity index in fruit, though it is widely used for many vegetables, especially those marketed early in their development.



Judging mango harvest maturity by shape of shoulder



Cross-section of banana finger showing changes in angularity

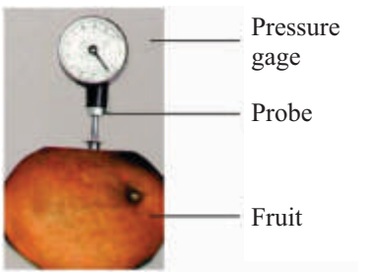
With these produce, size is often specified as a quality standard, with large size generally indicating commercial over-maturity and under-sized produce indicating an immature state. The assumption, however, is not always a reliable guide for all-purpose. The appearance of the product is the most critical factor in the initial purchase, while subsequent purchase may be more related to texture and flavour.

ii) Colour: The loss of green colour of many fruits is a valuable guide to maturity. There is initially a gradual loss in intensity of colour from deep green to lighter green and with many commodities, a complete loss of green colour with the development of yellow, red or purple pigments. Ground colour as measured by colour charts, is useful index of maturity for apple, pear and stone fruits, but is not entirely reliable as it is influenced by factors other than maturity. For some fruits, as they mature on the tree, development of blush colour, that is additional colour superimposed on the ground colour, can be a good indicator of maturity. Examples are red or red-streaked apple cultivars and red blush on some cultivars of peach.

2. Physical indices

i) Firmness: As fruit mature and ripen they soften by dissolution of the middle lamella of the cell walls. The degree of firmness can be estimated subjectively by finger or thumb pressure, but more precise objective measurement is possible with pressure tester or penetrometer. In many fruits such as apple, pear, peach, plum, guava, Kinnow etc. firmness can be used to determine harvest maturity. Penetrometer measures the pressure necessary to force a plunger of specified size into the pulp of the fruit. Such pressure is measured in pounds and kilograms force.

ii) Specific gravity: As fruit mature, their specific gravity increase. This parameter is rarely used inpractice to determine when to harvest a crop but it could be where it is possible to develop a suitable sampling technique. It is used, however, to grade crops into different maturities. To do this, the fruit or vegetable is placed in a tank of water; those that float will be less mature that those that sink. To give greater flexibility to the test and make it more precise, a salt or sugar solution can be used in place of water. This changes the density of the liquid, resulting in fruits or vegetables that would have sunk in water floating in the salt or sugar solution. Specific gravity is used a index for mango and apple.



Penetrometer

3. Chemical measurements


Refractometer

Measurement of chemical characteristics of produce is an obvious approach to the problem of maturity determination. The conversion of starch to sugars, called as starch iodine index (SII) (4.5/10) during maturation is a simple test for the maturity of some apple cultivars. It is based on the reaction between starch and iodine to produce a blue or purple colour. The intensity of the colour indicates the amount of starch remaining in the fruit. The total soluble solids of the fruit can be measured with refractometer, which indicate the harvest maturity of fruits. Acidity is readily determined on a sample of extracted juice by titration with 0.1 N NaOH. The sugar: acid or TSS: acid ratio is often better related to palatability of fruit than either sugar or acid level alone.

4. Calculated indices

i) **Calendar Date**: For perennial fruit crops grown in seasonal climate, which are more or less uniform from year-to-year, calendar date for harvest is a reliable guide to commercial maturity. However, it largely depends on grower's experience.

ii) **Heat Units:** It has been found that a characteristics number of heat units or degree-days required for maturing a crop under usually warm conditions, maturity will be advanced and under cooler conditions, maturity is delayed. The number of degree days required to maturity is determined over a period of several years by obtaining the algebric sum from the differences, plus or minus, between the daily mean temperatures and a fixed base temperature (commonly the minimum temperature at which growth occurs). It is commonly followed in grapes and date palm.

iii) **Days after full bloom:** This is the most important maturity index used for harvesting of temperate fruits (apple, pear, plum, peach). For example, some apple varieties mature in 88±4 days and some in 180±4 days after full bloom (DFFB). It has been reported that DFFB do not change in a variety grown under any climactic conditions.

5. Respiration and ethylene evolution rates

Now, maturity index of fruits can also be determined by measuring the rate of respiration or ethylene evolution. This method is primarily used under lab conditions only.

Maturity Indices for selected fruits and vegetables

Fruits	Maturity indices
Almonds	Splitting of hull, separation of hull from shell, development of abscission zone
Apple	DFFB, Calendar date, Starch Iodine Index (SII), Change in colour, fruit firmness
Asian Pears Pathar Nakh Baggugosha	Peel colour change from green to yellowish green 145 days after fruit set 135 days after fruit set
Banana	Disappearance of angularity in finger
Ber	Colour break stage (when light yellow colour appear)
Cherry	TSS = 14-15%, light red colour
Grapes (table)	Minimum SSC % of 14 to 17.5, depending on cultivars, SSC/TA of 20 or higher.
Guava	Colour break stage (when skin colour changes from dark green to light green)
Lemon	30% or more juice by volume

Lychee/litchi	TSS: total acid ratio of 70, bright red in colour
Kinnow	TSS/acid ratio 12:1 to 14:1
Kiwifruit	TSS – 6.2%, Firmness = 14 lbs
Mango	*Tapka* (natural falling of fruits), changes in shape (increase in fullness of cheeks or bulge of shoulder), flesh colour yellow to yellowish-orange, specific gravity
Papaya	Skin shows yellowing
Peaches	Ground colour change from green to yellow (varied for different cultivars), DFFB
Plum	Skin colour changes, DFFB
Pomegranate	Metallic sound on tapping, TSS:acid = 70
Strawberries	2/3 of berry surface showing pink or red colour

Methods of harvesting

A. Hand harvesting

Harvesting by hand is being practiced in all the horticultural crops since time immemorial. In India, hand harvesting is still the most common method used in horticultural commodities due to inadequate mechanization, small land holding and diversity of crops being grown by a small farmer. Some harvesting aids can be used for increasing the efficiency of labour.

B. Mechanical harvesting

Harvesting by use of machines is called mechanical harvesting. It is very useful for rapid harvesting of a particular crop and at low cost. Special harvesting machines are designed for specific crops. In developed countries, mechanical harvesting is common for most of the crops, but in India it is still very uncommon. For avoiding spoilage of fruits during harvesting, several institutes have developed harvesters for mango, guava, spaota etc. Similarly, clippers have been developed for harvesting strawberry and Kinnow in India.

Precautions to be taken during harvesting

- There should be minimum damage to the commodity
- Method of harvesting should be less expensive
- During harveshing, there should be less damage to the plant
- Harvesting should be done at optimum harvesting stage
- Some fruits like malta, lemon, orange etc., and temperate stone fruits (plum etc) are reported to have longer shelf life and lesser rotting during storage when harvested alongwith attached pedicel. So such fruits should carefully be harvested with attached pedicel.

Time of harvesting

Although, fruits and vegetables can be harvested at any time of the day but these should be harvested either in the morning or evening hours. If these are harvested at noon or warmer time of the day, they will loose their freshness because of faster rate of respiration and transpiration. In addition, such fruits will require much more precised handling than those harvested in the morning or evening hours.

Tools used for harvesting

Although, fruits and vegetables are usually harvested manually but now several tools and equipments have also been developed. For example, fruit harvesters have been developed for mango, sapota, Kinnow, strawberry etc. Similarly, for potato, digging machine has been developed. Some fruits need to be clipped or cut from the parent plant for which clippers or knives have been developed. Varieties of such instruments are available in the market, which allows the picker to harvest without a catching bag and without dropping fruits.

Grading of fruits

After sorting, the healthy produce should be graded according to size and colour. Different fruits are graded in to different grades but usually produce is graded as A, B or C as per size and colour. A grade produce is supplied to class A cities where you will find consumers of such class, and so on. Unclassified produce can be utilized for making value added products like jam, jelly or pickle etc. Grading can be done manually or by machine. In our country apple and Kinnow are primarily graded mechanically. Several units of apple and Kinnow graders have been established in H.P. and Punjab, respectively. According to size, apple is classified in to 7 different grades in H.P. The smallest sized fruits are called as '*pittoo*', which are usually made into juice by HPMC and sold at premier price at HPMC counters in different cities of India.

Ripening of fruits

Ripening is a dramatic event in the life of a fruit during which structure and composition of unripe fruit is so altered that it becomes acceptable to eat. Ripening marks the completion of development of a fruit and the commencement of senescence and it is normally an irrevesible event. On the basis of ripening behaviour, fruits have been classified as climacteric and non-climacteric fruits.

Climacteric fruits: In several fruits, ripening is associated with a rapid increase in respiration. This sudden upsurge is called as 'climacteric rise' in respiration and the fruits are conventionally called as 'climacteric fruits'. Apple, apricot, blueberry, fig, guava, jackfruit, kiwifruit, mango, muskmelon, nectarine, papaya, passion fruit, peach, pear, persimmon, plantain, plum, sapota, tomato, and watermelon are climacteric fruits

Points to remember

- Climacteric fruits are those in which the respiration rate is minimum at maturity and remains constant even after harvest which gradually increase at the beginning of ripening followed by sharp rise to a peak (climacteric peak) and then slowly decline (post climacteric stage).
- Non-climacteric fruits are those that show a gradual decline in respiration rate with ripening. These fruits ripen on the tree and therefore may be harvested when they become edible.

Non-climacteric fruits: Some fruits don't have distinct and well coordinated pattern of ripening as in climacteric fruits. Such fruits show neither rise in respiration nor an associated production of ethylene during ripening process. Thus, the fruits, which do not exhibit respiratory climacteric (pronounced increase in respiration coincident with ripening forming a peak) are known as non climacteric fruits. Coincident with ripening, the non-climacteric fruits produce much lesser amounts of ethylene than climacteric fruits. For example, *ber* (Jujube), blackberry, cashew apple, cherry, cucumber, eggplant, grape, grape fruit, lemon, lime, litchi, loquat, olive, orange, pepper, pineapple, pomegranate, Satsuma mandarin, strawberry, blueberry, cranberry, cacao, rose apple, tamarillo, summer squash, sweet orange, tangerine etc.

Differences between climacteric and non-climacteric fruits

S. No.	Climacteric fruits	Non-climacteric fruits
1.	Fruits exhibit respiratory climacteric (pronounced increase in respiration) coincident with ripening forming a peak	Fruits do not exhibit respiratory climacteric
2.	Coincident with ripening fruits produce much larger amounts of ethylene	No such relationship exists in these fruits

3.	Fruits may ripen on and off the trees	Fruits ripen on the tree only
4.	Important examples are apple, banana, sapota, plum, mango guava, papaya, tomato etc.	Important examples are citrus, pineapple, pomegranate, cashew apple, grape, litchi, loquat, cucumber etc.

1. Ripening facilities

a) Ripening room: Fruit are ripened in specially built rooms that must be gas tight, have systems for controlling humidity and concentrations of carbon dioxide and ethylene, and have equipment to control product temperature. Ripening rooms are usually insulated but they typically operate at temperature range of 15-21^{0}C. The ripening process is always done at relative humidity above 85%.

b) Temperature: Ripening is controlled on the basis of fruit pulp temperature. It should be measured during each cycle with a calibrated pulp thermometer. Simultaneously, room air temperature must also be regularly monitored with calibrated thermometer.

c) Relative humidity: The refrigeration system must be designed to contain 85-95% RH. Humidity below this range causes excessive product weight loss . Humidifiers are needed to add moisture to the air in rooms. Air humidity should be periodically monitored with a wet and dry bulb psychrometer.

d) Air flow: Air flow is needed to distribute ethylene gas to the product and to add or remove heat from the product during ripening cycle. Boxes must be stacked with space between them to allow good air flow around each box. Boxes or pallet bins should be ventilated to allow air flow. If packaging materials are placed in the boxes they should not block vents. Poor venting will cause high fruit temperatures and non-uniform ripening.

2. Ripening Techniques

i) Ripening with ethephon/Ethrel: Ethephon (2-choloroethyl-phosphonic acid) is commercially available and is registered for pre-harvest use on a variety of crops for controlling developmental processes or inducing ripening. This chemical is approved for post-harvest use on fruits crops for enhancing ripening. For post-harvest treatments, the known quantity of ethephon is diluted in water and fruits are dipped in the solution for a specified period. This substance ensures that there is uniform ripening of fruits. This technique provides a safe and effective method of ripening of fruits compared to the conventional technique of using calcium carbide.

Ethrel, a ripening agent

ii) Ripening with ethylene gas: In this technique, the fruits are exposed to low level of ethylene gas (10-100ppm) in an air-tight ripening chamber for 24 to 72 hours so as to induce ripening. The most important thing in this technique is temperature and relative humidity control inside the ripening chamber, which should range between 15-25ºC and 90-95% relative humidity, depending upon the fruit type. Several methods are used to provide proper ethylene concentration in the ripening room.

a) Gas cylinders: Ethylene is available in large steel cylinders where it is stored under pressure. As it is highly flammable, hence the use of pure gas is discouraged. Therefore, it is usually diluted with nitrogen or other inert gases. Typical mixtures are 95 per cent nitrogen and 5 per cent ethylene or 95.5 per cent nitrogen and 4.5 per cent ethylene. The measured quantities of ethylene are introduced in ripening room at regular intervals or continuously and the flow is regulated through metering devise or flow meter. Any piping leading into the ripening room should be grounded to prevent possible electrostatic ignition of ethylene gas.

b) Shot system: On small scale, commodities can be treated using shot method with ethylene liberated from ethephon. A calculated amount of ethephon in stainless steel bowl is placed around the room. The fruits are

stacked in the room and sodium hydroxide is added to ethephon and all ventilation to the room is then blocked. When sodium hydroxide reacts with ethephon, ethylene gas is released that ripens the fruits, Precaution should be taken while handling sodium hydroxide and ethephon as these are corrosive. Safety glasses and rubber gloves should be used while their handling.

c) Ethylene generator: This is a portable device, which is placed inside the ripening room. A liquid (ethyl alcohol) is filled into the tank fitted with ethylene generator and it is connected to an electric power source. The ethyl alcohol gets heated in a controlled manner in the presence of a catalyst that produces ethylene gas. Gas is maintained inside the ripening room until colour break occurs in the fruits.

Ethylene generator

iii) Calcium carbide: In India and many other developing countries, the banana and mango are ripened with the use of calcium carbide, which releases acetylene and ethylene gases on interaction with moisture coming from fruits. This chemical is harmful to human health and its use for ripening of fruits is banned in India.

Health hazard: Workers at a fruit market using calcium carbide to ripen raw mangoes

ACTIVITIES/EXERCISES

- Go to any fruit orchard, especially during harvesting season. Observe the harvesting practices followed by the workers. Observe the difference in fruits harvested by hand or by instruments (harvester).
- Harvest mature and immature fruits. Keep them in your school's laboratory and observe the differences in ables of both types.
- Harvest some fruits in the morning hours and some at noon. Keep them in your school's laboratory and observe the differences in fruits of both types.
- Plan a visit to a fruit market. Note down the sorting, grading and packing systems followed for them.

CHECK YOUR PROGRESS

1. Differentiate between horticultural maturity and physiological maturity. Discuss importance of maturity index in fruits and vegetables.
2. What is maturity index? Write maturity indices for mango, apple, sapota & pomegranate.
3. Differentiate between climacteric and non-climacteric fruits. Write different ripening systems followed in India

4. Classify the following fruits into climacteric and non-climacteric: mango, mandarin, sapota, apple, strawberry, banana, pineapple, grape, litchi etc.

WRITE TRUE (T) OR FALSE (F) FOR THE FOLLOWING STATEMENTS

1. In India, ethrel is commercially used for the ripening of mango and banana.
2. Mango is a climacteric fruit.
3. *Tapka* is related to apple.
4. Refractrometer is used to determine acidity in fruit sample.
5. Penetrometer is used to determine TSS of a fruit sample.
6. Fruit ripened by calcium carbide are harmful to us.
7. In climacteric fruits, there is sudden upsurge in respiration rate of fruits.

SUGGESTED FURTHER READINGS

- Chattopadhyay, S.K. (2007). Handling, transportation and storage of fruits and vegetables. Gene-Tech Books, New Delhi.
- Hui, Y.H. (2008). Handbook of fruit and vegetable processing. Wiley India Pvt. Ltd., New Delhi.
- Sharma, S.K. (2010). Postharvest management and processing of fruits and vegetables. New India Publishing Agency, New Delhi.
- Sharma, S.K. and Nautiyal, M.C. (2009). Postharvest technology of horticultural crops. New India
- Publishing Agency, New Delhi
- Srivastava, R.P. and Kumar, S. (2001). Fruit and vegetable preservation. Intl. Book Distributing Co., Lucknow, India.
- Verma, L.R. and Joshi, V.K. (2000). Postharvest technology of fruits and vegetables. Indus Publishing Co., New Delhi.
- Wills, R.B.H, McGlasson, W.S, Graham, D. and Joyce, D.C. (2009). Postharvest: An introduction to the physiology and handling of fruits, vegetables and ornamentals. CABI International, Cambridge, USA.

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CHAPTER

9

MECHANICAL HARVESTING OF FRUITS

OBJECTIVES

After studying this chapter, students will be able to:

- Understand about mechanical harvesting and its advantages in fruit cultivation
- Modes of mechanical harvesting and their uses
- Understand different modes of mechanical harvesting

INTRODUCTION

You might have sometime seen harvesting operation in some fruit orchards. In our country, fruits in general, are harvested manually by hands. For this, orchardists employ labourers for a specific period. For example, peak mango harvesting season in north India is May-June and for apple, it is August-September. During this period, you can see plenty of labourers in such orchards. Hand harvesting has certain disadvantages; hence for harvesting in a large holding or under high density plantings, it is done through machines in most of the developed countries. Even in our country, several machines/equipments have been developed for easy and safe harvesting of fruits. In this chapter, you will learn about mechanical harvesting of fruits, its advantages and different modes.

History of mechanical harvesting

The history of mechanical harvesting dates back to the 1950's and is associated with the cultivation of citrus in Florida. The idea of a mechanized harvesting system was developed from the struggle of the citrus industry, which was facing concerns about costs and availability of harvesting labour. Even today, fruit growers of large orchards, face two significant problems, which could determine the future of their business; (i) lack of adequate labour supply, and (ii) competitiveness in the global market.

Mechanical harvesting

Harvesting by use of machines is called 'mechanical harvesting'. It is very useful for rapid harvesting of a particular crop and at low cost. Special harvesting machines are designed for specific crops. In developed countries, mechanical harvesting is common for most of the crops, but in India, it is still very uncommon.

Advantages of mechanical harvesting

- Harvesting is rapid, thus there is lot of saving in time.
- Less dependency on labour. No risks of labour strikes and labour management related problems.
- Improved working conditions for workers.

Disadvantages of mechanical harvesting

- It requires skilled manpower for use of machine, therefore dependence on trained labour.
- Improper machine usage may result in huge economic losses.
- Machine requires regular maintenance.

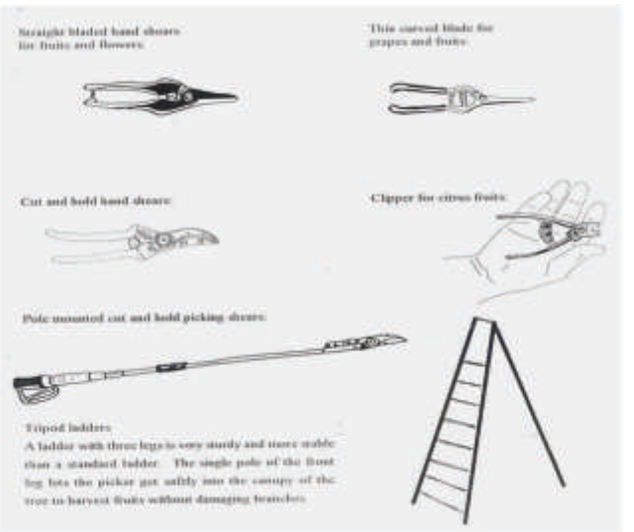
- Same machine cannot be used for harvesting in many other fruit crops.
- May cause damage to bark and branches of trees of perennial crops.
- Social impacts of low labour requirements and employment.

Modes of mechanical harvesting

There are basically three modes of harvesting by machines. These are labour-aids , labour saving machines and robotics & automation.

Labour aids

Labour-aids are aimed at reducing the drudgery of farm labour by reducing the effort and endurance required for the fruit-picking operation. The major examples are the power ladders, which are considered as the basic picking-aid. They eliminate the need for pickers to climb ladders and carry the fruit load on their shoulders. As the workload is eased and both hands are free when not maneuvering the platform, pickers can be more accurate and efficient. Usually fruit can be picked cleaner with less physical damage (bruising). Power ladders allow the picker to continually move to maintain fruit at the most comfortable position for picking. A safety frame surrounds the picker minimizing the chance of a fall and allowing the picker to concentrate on picking.



Some harvesting tools

Similarly, a self propelled hydraulically operated raised platform is also used for harvesting of fruits from large trees, sometimes, as in case of oil palm. Likewise, for efficient harvesting of mangoes a simple, low cost and portable mango harvesting device has been designed and developed at the Central Institute for Subtropical Horticulture, Lucknow; IARI, New Delhi and IIHR, Benguluru. Mango 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 fruit 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. Similarly, sapota harvester has also been developed in the country.

Labour-saving machines

The main characteristics of such machines are their ability to remove fruits in multiples i.e., mass harvesting. Few examples are machine operated mass-harvester for grapefruit in Israel and mass-harvesting system for olives in Italy. A Shake & Catch System for harvesting oranges, apricot & cling peaches are being used in U.S.A. at commercial orchards. The system consists of a long sloping padded

Clipper for harvesting of Kinnow and strawberry

platform mounted on a trailer. The platform catches the fruit and runs it into bins or boxes carried underneath. Typically there are two catching surfaces, one large and one small, forming a valley. The trailer is drawn up alongside the tree with its lower side (the smaller platform) close to the trunk. The operators stand on the larger platform and shake the branches individually with a hooked metal rod or tap them gently with rubber mallets to shake the ripe fruit on to the padded platforms. The fruit rolls down the slope into shallow trays held beneath the platforms.

Kinnow harvesting with clipper

Mango harvester

Likewise, grapes and soft fruits for processing, such as black currants, may be harvested by tractor-mounted machines which have combing fingers which are run up the stems pulling, off the fruit bunches. However, these mechanical harvesters cannot harvest selectively, leading to heavy losses of overripe and green fruits.

On the other hand, advances made in this area have enabled machines to help mitigate specific problems associated with particular crops. For instance, problems with raspberry harvesting is that fruit matures over a period of 20–40 days and requires 5–10 pickings or more if each fruit is to be picked in prime condition. To overcome this problem, a machine was developed in Scotland, which shake the canes at such a frequency that only the ripe fruit fall off. This is coupled with an effective catching device. Apple trees grown on a hedgerow system could be harvested with combing fingers giving 85% Grade-1 fruit.

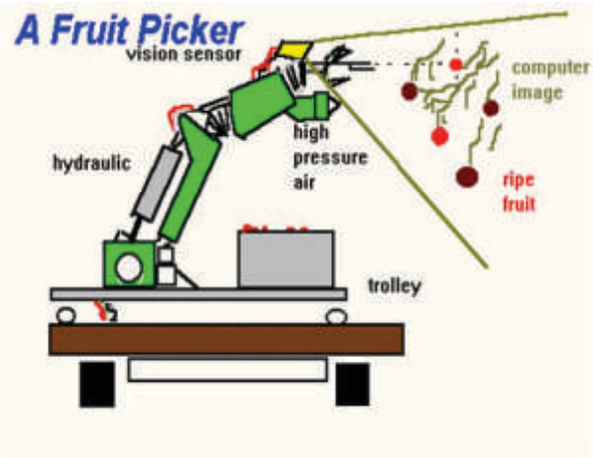
Mechanical harvesting of citrus

As stated earlier, the feasibility of employing such high-input machines is possible only under high-density planting system. In the meadow orchard system of growing apples, peaches and guavas, the whole of the tree is harvested just above the ground each year or every other year. The fruits are then separated from the stems by machines in the pack house. Using this method, trees are planted very close together with densities in the order of 10,000 trees per hectare compared with conventional densities of 87–125 trees per hectare.

Robotic fruit harvesting

A robotic fruit picker was first developed in France for harvesting apples. Robotic fruit harvesting aims to automate the fruit picking process by using a system that emulate the human picker for decision making and picking. Conceptually, it should provide the same or better quality, at a much faster rate. Unfortunately, although remarkable and encouraging results have been already obtained (with apple & citrus), robotic harvesting is yet not feasible and can't be considered as a competitive solution due to high investment incurred.

The major advantage of mechanical harvesting is reduced labour cost through reduction in the number of pickers required to be employed. Further, with fewer pickers, the quality of the fruit coming into the cutting shed can be more easily monitored and controlled.



A robotic harvester

ACTIVITIES/EXERCISES

- If you are living in an area where some orchards are there, visit those orchards in harvesting season. Observe the harvesting practices followed by the workers. Make a list of difference in fruits harvested by hand or by instruments (harvester).

CHECK YOUR PROGRESS

1. What is mechanical harvesting? What are its advantages and disadvantages over manual harvesting?
2. What are different modes of mechanical harvesting? Describe them briefly.

WRITE TRUE (T) OR FALSE (F) FOR THE FOLLOWING STATEMENTS

i) Robotic harvesting is commonly followed for harvesting apples.

ii) Mango harvester has been developed at CISH, Lucknow.

iii) Mechanical harvesting saves lot of labour.

iv) Hand harvesting is done by skilled manpower.

v) Labour-aids are aimed at reducing the drudgery of farm labour

SUGGESTED FURTHER READINGS

- Hui, Y.H. (2008). Handbook of fruit and vegetable processing. Wiley India Pvt. Ltd., New Delhi.
- Sharma, S.K. (2010). Postharvest management and processing of fruits and vegetables. New India Publishing Agency, New Delhi.
- Sharma, S.K. and Nautiyal, M.C. (2009). Postharvest technology of horticultural crops. New India Publishing Agency, New Delhi
- Wills, R.B.H, McGlasson, W.S, Graham, D. and Joyce, D.C. (2009). Postharvest: An introduction to the physiology and handling of fruits, vegetables and ornamentals. CABI International, Cambridge, USA.

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CHAPTER

10

ROLE OF BIOTECHNOLOGY AND MICROPROPAGATION IN FRUITS

OBJECTIVES

After reading this chapter, you will be able to:

- Understand the various applications of biotechnologicals tools in improving fruit production.
- Explain different methods of micropropagation
- Know the status of microparopagtion of fruit crops in India

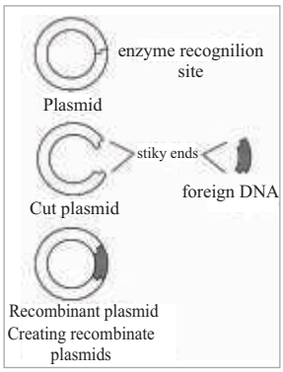
INTRODUCTION

The term biotechnology has become so important that everybody starts talking about it, although we may not know completely about it. This branch of science is of considerable importance to meet challenges in agricultural production. As you know that with the increase in ever-burgeoning population, the demand for fruits is increasing proportionally. Although, conventional plant breeding techniques have made considerable progress in the development of improved high-yielding varieties, they have not been able to keep pace with the increasing demand for fruits in the country. Therefore, an immediate need is felt to integrate biotechnology to speed up the crop improvement programmes.

Applications of biotechnology

Modern biotechnology holds considerable promise to meet challenges in agricultural production. The aim of agricultural and plant biotechnologies are (i) rapid multiplication of useful microorganisms for various uses, (ii) micropropagation of plants, (iii) production of diagnostic tools for the identification of plant diseases and detection of contaminants, and (iv) genetically engineered plants – i.e., alter their basic structure, which has now new characteristic to improve the efficiency of crop production. The goal of aforementioned aim is to produce more and better crops at lower cost.

In class XI, you have learnt about some of the important applications of biotechnology in fruit production. In this class, you will know about some more advanced application of this vital branch of science. The important ones are being discussed below;



Creating recombinant plasmids

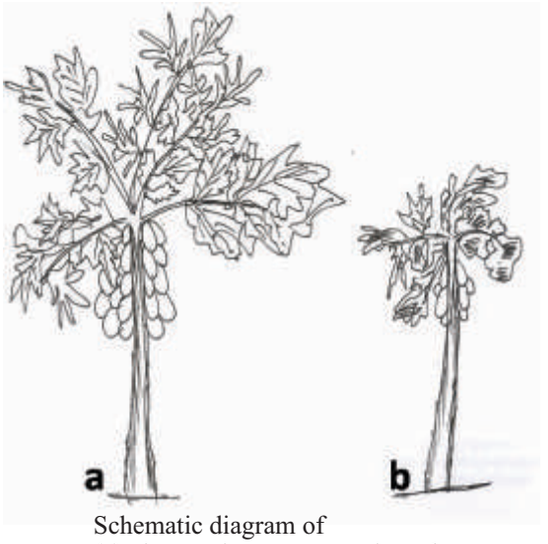
(i) Recombinant DNA manipulation: Recombinant DNA manipulation technology is the construction of a stretch of DNA sequence consisting of components derived from different sources. They are used as diagnostic test probes in horticulture to detect specific diseases. It is now possible to detect the plant diseases

even before onset of symptoms by using DNA probes. Probes are nucleic acid sequences of pathogen causing organisms labeled with certain markers. For instance, viral diseases of fruit crops are confirmed by this recombinant DNA based technology.

(ii) Gene transfer technology: Gene transfer technology is the ability to identify a particular gene – one that encodes a desired trait in an organism. The gene transfer technology involves identification and isolation of suitable genes for transfer followed by a delivery system to insert desired gene into recipient cells and finally expression of new genetic information in recipient cells. The plants developed through this technology are referred as transgenics. Genes for the following traits have been introduced to the crop plants:

a. Herbicide tolerance: Transgenic plants are developed that are resistant to herbicides allowing farmers to spray crops so as to kill only weeds but not their crops. Transgenic plants using *bxn* gene from microbes like *Klebsiella* and bar gene from *Strepotomyces* have been obtained in potato and sugarbeet and are found to have herbicide resistance. These transgenic plants reduce the use of labour involved in weeding and hence production cost and increased yield.

b. Engineering pathogen resistance: Viruses are the major pests of crop plants, which cause considerable yield losses. Viruses are submicroscopic pockets of nucleic acid (DNA or RNA) enclosed in a protein coat and can multiply within a host cell. Many strategies have been applied to control virus infection using coat protein and satellite RNA. Transgenic resistant papaya cultivar 'Sun Up' has also been developed against papaya ring spot virus.



Schematic diagram of
(a) virus-resistant transgenic and
(b) susceptible papaya cultivar

c. Stress resistance: A number of genes responsible for providing resistance against stresses such as to water stress heat, cold, salt, heavy metals and phytohormones have been identified. Using a bacterial gene capable of synthesizing mannitols, an alcohol-sugar, it is possible to raise the level of mannitol very high and thereby making plants resistant to drought.

d. Fruit Quality: Tomatoes which ripen slowly are helpful in transportation process. Tomatoes exhibiting delayed ripening have been produced either by using antisense RNA against enzymes involved in ethylene production. This increases the shelf life of tomatoes. These tomatoes can also stay on the plant long giving more time for accumulation of sugars and acids for improving flavour. Such tomatoes are produced at commercial level in European and American countries.

e. Pest resistance: The insecticidal ß endotoxin gene (*bt* gene) has been isolated from a bacterium *Bacillus thuringiensis,* the commonly occurring soil bacteria and transferred to a number of plants like cotton, tobacco, tomato, soybean, potato, etc., to make them resistant to attack by insects. These genes produce insecticidal crystal proteins which affect a range of insects. These crystals upon ingestion by the insect larva are solubilised in the highly alkaline midgut into individual protoxins; thereby, killing insects. *Bt* resistant plants are already in the market.

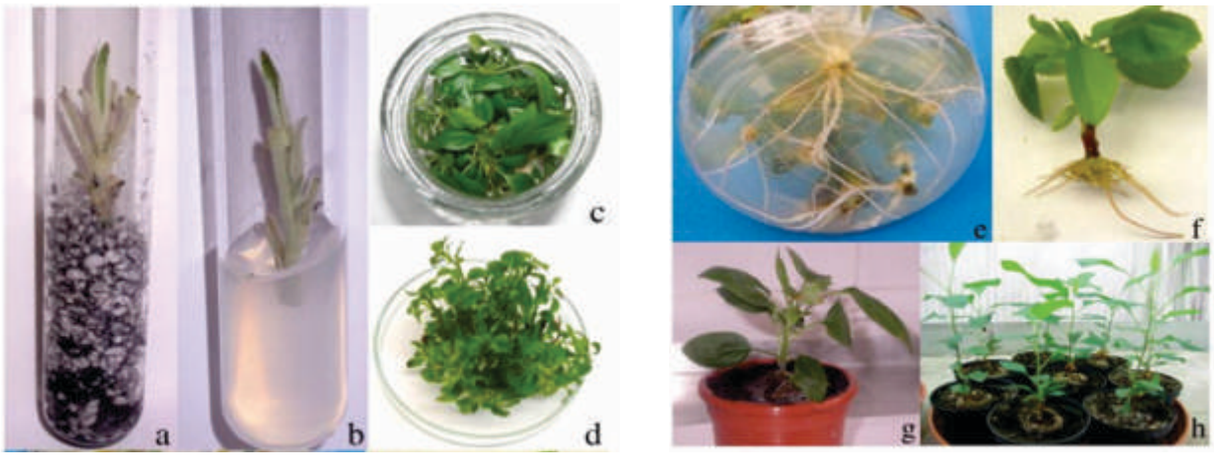
(iii) Molecular markers: A molecular marker (identified as genetic marker) is a fragment of DNA that is associated with a certain location within the genome. Molecular markers are used in biotechnology to identify a particular sequence of DNA in a pool of unknown DNA. It has its applications in horticulture for (i) Species identification; (ii) Ascertaining genetic variation; (iii) Screening of the plants for different traits or disease resistance at the seedling stage itself. The use of RFLP (Restriction Fragment Length Polymorphism), RAPD (Random Amplified Polymorphic DNA), AFLP (Amplified Fragment Length Polymorphism) and isozyme markers in breeding of horticultural crops are numerous. Recently, microsatellile or simple sequence repeats (SSRS) markers have also become the choice for a wide range of applications in horticulture.

(iv) Micropropagation: In order to meet the ever increasing demand for quality planting material, micropropagation is the only answer. In the XIth class, you have read about advantages and disadvantages of micropropagation, its principles, different stages of micropropagation etc. In this class, you will come know about several micropropagation systems used for the propagation of horticultural crops and about micropropagation of different fruit crops.

Major Micropropagation Systems for Fruit Crops

Based on the type of explant, the different *in vitro* techniques have been employed in micropropagation of different plant species. A few of them are briefly discussed hereunder:

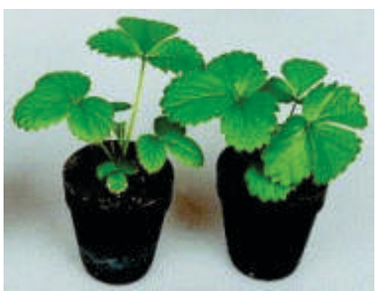
Meristem tip culture: This technique is widely used in horticultural plants like potato, dahlia, carnation and orchids. In this method, the meristem tip consisting of one or two pairs of leaf primordia are cultured in a medium. After a few weeks, the plantlets are re-generated and after hardening of the plantlets, these are transplanted in the soil under natural environmental conditions. Meristem tip cultured plants give rise to polyploid plants instead of diploid plants. Moreover, meristem tip culture is very useful for the elimination of viruses from infected plant material. Rapid multiplication of the plants, which are otherwise not easily propagated by vegetative means, is also possible through meristem culture. Plants produced are free from pathogens and can be stored for longer period and in smaller space.



Different stages of micropropagation of apple

Embryo culture: Aseptic culture of embryo has been standardized in many plant species. The embryo is rescued while it is immature and before the degeneration is initiated. The excised embryo is cultured on the semi- solid or solid culture medium as the case may be. However, in embryo culture, the addition of some plant extracts like coconut milk or yeast extract in the culture medium enhances growth and development of the embryos. Embryo techniques are primarily useful in case of making distant crosses in hybrid production. It is also useful technique to overcome seed dormancy. Many embryological problems can be studied through embryo culture. In grape, embryo rescue technique has been used worldwide to produce seedless varieties by excising immature embryo in crosses between Seedless x Seedless varieties, which is otherwise not feasible through conventional propagation or breeding techniques.

Callus culture: A callus is an unorganized mass of parenchymatous cells. Callus culture has been induced artificially in a wide range of plant species using some explants. Callus formation is basically a natural phenomenon and is essential in the healing of wounds, graft and bud union and rooting of cuttings. In callus culture, the stimulation of cell division and multiplication is required and thus culture medium is accordingly supplemented with necessary growth regulators. So, for callus culture, auxins are required frequently followed by cytokinins. In callus culture, organogenesis occurs in two stages. In first stage, formation of meristems takes place and in the second stage, active growth of



Micropropagated strawberry plants

stem buds and roots takes place. As the nutritional requirement of these two stages is different, transferring of first stage to the second stage with culture medium having different supplementations (especially hormones) is a must.

Anther culture: Anther culture is used to produce haploid plants. Haploid plants are very useful in genetical and biochemical studies and for producing homozygous lines (within six months) of F_1 hybrids, which, otherwise may take six generations or more with conventional methods of breeding. Guha and Maheshawari reported the first anther culture in Datura in 1959. In this technique, anthers are excised and cultured on to required and standardized cul ture medium. The stage, at which the anther is excised, depends on different species. However, in most cases, it is excised at or near microscopic mitosis, when the pollen grains passes from uninucleate to the binucleate condition. As a result of cell division, multicellular masses are developed, which may develop in to embroids or callus. Plantlets are developed from callus by organogenesis. Haploid plants are treated with colchicine for chromosome doubling and for producing the true breeding diploid plants.

Cell culture: Cell suspension cultures are obtained by homogenizing a piece of callus into liquid medium and shaking with shaker until medium becomes cloudy with suspended cells. Due to recent advances in plant biotechnology, it is now possible to derive full plant from a single cell. This technique is primarily useful to plant breeders because now it is possible to induce desirable variability in individual cell, which can be regenerated into a full plant.

Exudation of phenols in culture medium

Micropropagation of banana

Protoplast culture: In protoplast culture, the rigid cell walls are first removed either mechanically or enzymatically so as to expose the protoplast. The exposed protoplast is then cultured onto a suitable culture medium. Individual protoplast of the plants has been regenerated into full plant as in Nicotiana, Brassica and Aparagus etc. In plant breeding systems, protoplast culture has many advantages i). A large homogenous population (10^6 to 10^7) of plants can be obtained from a small sample (1 g leaf), ii) Fusion of two protoplasts of two different plant species is possible, which may bring a greater variability in plants.

Ovule culture: In this method, unfertilized ovules are excised and cultured into a medium. This technique has potential application to produce hybrid seeds in wide genetic crosses, which is rather difficult through conventional means. It is also efficient method to obtain plants in self-incompatible species. The technique of growing ovules in sterile culture is not a difficult job. However, one should have sound knowledge of the flowering and fertilization timing for isolation of the ovule at proper time.

Status of Micropropagation Industry in India

At present, an estimated 80 millions tissue cultured plants, from 130 tissue culture companies, are produced every year in the country. The major share of produced plants is occupied by banana (41%) followed by sugarcane (31%), ornamental plants (14%), spices (6%) and medicinal plants (4%). To bridge the gap between research and field testing, and to check the clonal fidelity in such planting material, the Department of Technology, Government of India, has set up pilot-scale facilities including Micropropagation technology Parks (MTPs) at the The Tata Energy and Research Institute, New Delhi; National Chemical Laboratory, Pune,

and National Facility for Virus Diagnostics and Quality Control of Tissue Culture Raised Plants (NFVDQCTP) at IARI, New Delhi, with 5 satellite centers NCL, Pune; TERI, New Delhi; IHBT, Palampur; IIHR, Bangalore and SPIC, Chennai. Commercial status in micropropagation has been achieved in over 500 species and genotypes including herbaceous species foliage plants and fruit crops like banana, strawberry, papaya etc. and vegetables like potato, asparagus, etc. In fruit crops different woody species, such as rootstocks of temperate fruit crops like apple, pear, peach and plum is also under multiplication in some western countries. In India there are over 130 commercial tissue laboratories, which mostly multiply fruit crops like banana, papaya, strawberry etc. At present, India produces about 80 millions plants per year; however, the installed capacity of such laboratories is 300 million plants per annum, which accounts to about twenty-five to thirty percent of the installed capacity. About seventy-five percent share is from the private sectors and joint ventures.

Micropropagation techniques have been successfully adopted in several agricultural and horticultural crops. Among fruit crops, strawberry was the first fruit crop to be propagated commercially through micropropagation. Micropropagation techniques have been standardized for many temperate, tropical and sub-tropical fruit crops (see table below). In India, tissue culture technique has also been perfected in banana, grape and papaya. In banana, shoot tip excised from rhizomes of sword suckers are suitable explants and MS medium suppleme nted with sucrose (3 per cent), gelite (0.25 per cent), is the best. Shoot tips and two nodal micro cuttings are highly suitable explants for faster and disease free production of grape plants through tissue culture. Salt tolerant rootstock of grape (Salt Creek and St. George) has great demand and *in vitro* propagation has been successfully used. Shoot tip culture technique has been demonstrated in papaya to produce female and male plants in the desired ratio. Similarly, pineapple is now being commercially propagated through micropropagation. In hard-to-root fruit species like, date palm and coconut, *in vitro* techniques have been perfected only recently. Scientists in India and different parts of the world have been trying hard for the micropropagation of mango and perennial forestry plants through tissue culture but the success has been limited due to recalcitrance and browning of explants.

Micropropagation technology developed for some fruit crops in India

S. No.	Fruit crop	Institution responsible for the development of technology
1.	Almond	Punjab University, Chandigarh
2.	Annona	IIHR, Bangalore; BARC, Mumbai; NCL, Pune
3.	Apple	UHF, Solan
4.	Banana	IIHR, Bangalore; TNAU, Coimbatore; NCL, Pune
5.	Ber	Pune University, Pune
6.	Citrus	NBRI, Lucknow; NRC, Citrus, Nagpur; University of Jodhpur, Jodhpur
7.	Grape	IARI, New Delhi
8.	Guava	GBPUAT, Pantnagar
9.	Papaya	IARI, New Delhi
10.	Pear	Punjab University, Chandigarh
11.	Pineapple	BARC, Mumbai
12.	Pomegranate	NCL, Pune
13.	Strawberry	Strawberry
14.	Date palm	CAZRI, Jodhpur

ACTIVITIES/EXERCISES

- Plan a visit to some tissue culture laboratory. Perform some activities in tissue culture laboratory like explants preparation, preparation of culture medium and culture establishment.

CHECK YOUR PROGRESS

1. What are major applications of biotechnology, write in brief.
2. Describe briefly the micro propagation techniques for fruit crops.

WRITE TRUE (T) OR FALSE (F) FOR THE FOLLOWING STATEMENTS)

1. Strawberry was the first fruit to be micropropagated.
2. Woody perennials can be easily propagated by tissue culture system.
3. All micropropgation protocols work on the principle of totipotency.
4. In India, about 100 million plants are produced through tissue culture.
5. Mango is easily propagated by micropropagation.
6. Anther culture in the world was first attempted in India.
7. Plants produced by meristem-tip culture are free from diseases.
8. 'Sun Up' is a transgenic mango variety.
9. A molecular marker is a fragment of DNA that is associated with a certain location within the genome.
10. Recombinant DNA manipulation technology is used as diagnostic test probes in horticulture to detect specific diseases.

SUGGESTED FURTHER READINGS

- Aldriance, G.W. and Brison, F.R. (2000). Propagation of horticultural plants. Mc Grow Hill Book Company. Inc, New York.
- Bose, T.K., Mitra, S.K., Sadhu, M.K .and Das, P. (1997). Propagation of tropical and sub tropical horticultural Crops. IInd Edition, Naya Prakash, Calcutta.
- Hartman, H.T, Kester, D.E. and Davies, F.T. (1993). Plant propagation: principles and practices. 5th Edition. Prentice Hall of India, New Delhi.
- Sharma, R.R. (2002). Propagation of horticultural crops: principles and practices. Kalyani Publishers, New Delhi.
- Sharma, R.R. and Srivastav, M. (2004). Plant propagation and nursery management. Intl Book Distributing Co., Lucknow
- Sharma, R.R. and Krishna, H. (2013). A textbook on plant propagation and nursery management. Intl Book Distributing Co., Lucknow.

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CHAPTER

11

PESTICIDE RESIDUE AND SAFETY

OBJECTIVES

After studying this chapter, students will be able to:

- Understand the concern of Codex Alimentarious Commission and Bureau of Indian Standards for human health
- Maximum residue limits of pesticides
- Points for safety of operators and consumers

INTRODUCTION

In the previous chapters, you have read about production technology of different fruits crops. In fruit production, role of pesticides (weedicides, fungicides, insecticides) can't be ignored. However, you might have read in newspapers or heard on television or radio about tremendous rise in serious diseases like cancer, diabetes and cardio-vascular arrests in our country, and also about the role of pesticides in these diseases. It is now proven that sudden rise in such serious diseases in India is due to high use of pesticides in crop production. The residues of these pesticides enter into our body and become one of the reasons for the cause of risk diseases. As a result, people in India have become health cautious. Due to this concern only, Codex Alimentarious Commission of World Health Organization (WHO) and Bureau of Indian Standards (BIS) are emphasizing on adoption of Good Agricultural Practices (GAP) for fruit production. These practices emphasize least use of pesticides, as a result, the residues of pesticides will be less, and consumers will also be safe or will take less amount of pesticide into their bodies, which will save them from risky diseases. In this chapter, you will come to know about GAP, maximum residue limits for pesticides and points for safety from pesticides.

Codex Alimentarius Commission and Bureau of Indian Standards (BIS) and their role

Points to remember

Several countries of the world have developed Good Agricultural Practices (GAP) for growing fruit crops. In this context, 'IndiaGAP' has been developed in our country, which aims at introducing a certifiable system for recognizing farmers who have implemented good agricultural practices as per design.

The consumption of fresh fruits has increased substantially over the last decades. However, there are instances of food borne illness associated with fresh fruits, which have raised concerns from public health agencies and consumers about the safety of these products. In order to assure the consumer that the food consumed is safe and nutritious, it is important to develop a comprehensive and effective food system, which ensures both safety and nutrition. This has led to development of various guidelines for cultivating fruits and also commodity standards by Codex Alimentarious Commission. The Codex Alimentarius Commission, established by Food and Agricultural Organization (FAO) and World Health Organization (WHO) in 1963 develops harmonised international food standards, guidelines and codes of practice to protect the health of the consumers and ensure fair practices in the food trade. Codex Alimentarius Commission has given guidelines about Good Agricultural Practices (GAPs), which help control microbial, chemical and physical hazards associated with all the stages of the production of fresh fruits from primary production to packing. Good Agricultural Practices (GAP) have been defined as practices, which address environmental, economic and social sustainability for on-farm processes, and result in safe and quality food and non-food agricultural products by the Food and Agriculture Organization.

In India, the Bureau of Indian Standards (BIS) adopted the 'Requirements for Good Agricultural Practices' in

2010. It recommends practices for every stage of farming from land preparation to post harvest supply chain such as quality of water for irrigation, washing, contamination from unsterlized manures, biosolids, pesticide residues, safety of agricultural workers, personnel hygiene and sanitary facilities, cleanliness and sanitation of post-handling equipment, machinery, etc. so as to produce safe food for human consumption. Safe food is one which has minimum pesticide residues, metals and other contaminants and is practically safe in the hands of consumer without any harmful effects.

On the other hand, pesticides are the chemical products used for plant protection. They include insecticides, fungicides, herbicides and plant growth regulators. Residues of pesticides may remain in treated products and get into human food chain. These residues should not exceed a limit above which they may pose risks to human health. The concepts of Maximum Residue Limits (MRLs) for pesticides have been devised to keep a check on the pesticides' residues in food chain and keep them within safe limits. MRLs are the maximum residues of pesticides, which may be expected in a product treated with them, considering that Good Agricultural Practices have been followed.

Status of Maximum Residue Limits in India

Food Safety and Standard Authority of India (FSSAI) is responsible for setting MRLs for the pesticides, which have been registered by Central Insecticides Board and Registration Committee (CIBRC), an organization responsible for registering pesticides recommending them for various crops in India. The exceptions for which MRLs are not required include neem based products, biopesticides and few chemical pesticides like sulphur. A total of 234 pesticides have been registered by CIBRC (including endosulfan, the use of which was banned in India in May 2011). The 20 pesticides namely, phorate, mMancozeb, methyl parathion, cypermethrin, carbendazim, monocrotophos, malathion, quinalphos, acephate, triazophos, dichlorvos, fenvalerate, dimethoate, captan, zineb, paraquat dichloride, chlorpyrifos, phosalone and carbofuran have been considered as some of the most used and widely recommended pesticides in India.

Classification of pesticides	Medium lethal dose by the oral route (LD_{50}: mg/kg of the body weight of test animal)	Colour of the identification band on the level
Extremely toxic	1 – 50	Bright red
Highly toxic	51 – 500	Bright yellow
Moderately toxic	501 – 5000	Bright blue
Slightly toxic	More than 500	Bright green

Points for safety of operators and consumers

Despite these recommended pesticides considered safe, the direct contact with them may cause poisoning. In order to prevent pesticide from getting in to contact with human body, following points should be kept in mind;

- Levels and instructions enclosed with the container should be carefully read; e.g., colour indicators of the pesticide toxicity.
- Operators should bear appropriate clothes. For this, overcoat, gloves and boots are used to protect the skin. When working with dusty substances, one must use overall of a dust proof fabric with a smooth surface such as moleskin, while for spraying or working with liquid pesticides one must use clothing made from acid proof fabr ics. Similarly, canvas footgear is used for protection when working with dusty toxicant and rubber boots when spraying. Rubber gloves are use to protect the hands when working with liquid forms of pesticide

Pesticide spraying with all precautions

and cotton gloves with film coating and acid proof impregnation when working with dusty toxicants. Likewise, to protect the eyes from pesticides, one must use the dust proof goggles. Antidust or antigas respirators and gas masks can also be used to protect the respiratory organs.

- Application equipments should be checked for leaks or any other defects and they should be kept in proper working condition.
- Clogged nozzles or hoses must not be blown out with mouth for cleaning.
- The working solutions are poured into the tanks of the machines through filters to prevent clogging.
- Spraying and dusting should be performed in the morning and evening and in dull weather in the daytime too. Treatment must never be performed before or during a rainfall. Do not spray in high wind and high temperature. Avoid drift by selecting proper direction of spraying and also holding nozzle and boom at a proper height. And to achieve this, start spraying near the downwind edge of the field and proceed upwind so that operator moves into unsprayed area.
- Pesticide should not be left unattended in the field.
- Plenty of clean water and soap should be made available, as well as clean clothing for change.
- Upon the completion of work, all the apparatus must be cleaned, washed with the soda solution and water, dried and then placed properly in store. After use, crush and bury the pesticide containers preferably in a land filled dump.
- Warning signs, such as red arrows are setup on the treated areas to protect poisoning incidence, of children and livestock.
- Children, pets and farm workers must not enter the prayed field for the specific period mention by the manufacturer of the pesticide sprayed. Even with safe period pesticide, at least spray deposit should be allowed to dry up before entering the field.
- Always keep recommended antidote or drug recommended for the safety of a particular pesticide.

A safe insecticide, malathion

ACTIVITIES/EXERCISES

- Go to some shop dealing with pesticides. Make a list of pesticides and note down the precautions written on them for safe use.
- Go to some fruit orchard. Ask the grower about the safety measures they adopt for spraying pesticides in the orchard.

CHECK YOUR PROGRESS

1. Define roles of Codex Alimentarius Commission and BIS.

2. What do you mean by maximum residue limit? Write LD50 for extremely toxic, highly toxic or least toxic pesticides.
3. What points will you keep in mind while using pesticides**?**

WRITE YES (Y) OR NO (N) FOR THE FOLLOWING STATEMENTS

1. Pesticides should be sprayed during morning or evening hours.
2. Good Agricultural Practices are mandatory for organic fruit culture.
3. Among insecticides, malathion is considered as most dangerous one.
4. Food Safety and Standard Authority of India (FSSAI) is responsible for recommending the use of pesticides on fruit crops.
5. The Bureau of Indian Standards (BIS) adopted the requirements for good agricultural practices in 2012.

SUGGESTED FURTHER READINGS

1. http://www.fssai.gov.in/AboutFSSAI/introduction.aspx
2. http://www.fao.org/prods/gap/
3. Requirements for Good Agricultural Practices – IndiaGAP. Bureau of Indian Standards, 2010.
4. ec.europa.eu/food/plant/protection/resources/intro_en.pdf
5. Chandra Bhushan, Avimuktesh Bhardwaj and Savvy Soumya Misra 2013, State of Pesticide Regulations in India, Centre for Science and Environment, New Delhi

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CHAPTER
12

ORCHARD REJUVENATION AND HIGH DENSITY PLANTING

OBJECTIVES

After reading this chapter, students will be able to:

- Understand the necessity for rejuvenation of orchards
- Know the technology of rejuvenation of orchards
- Understand the importance of high density planting and its advantages
- Tell the basic approached adopted for high density planting in different fruit crops

INTRODUCTION

While going on a long drive through a village, you & might have seen acreage and acreage of fruit plantation. Some of them must be in good conditions while others might be declining. Some must be very old while other may be in initial years of bearing. Similarly, some plantations must be little dense (closely planted) while others may be at normal planting distance. You might have observed that most of fruit plant orchards start declining after bearing certain fruitful life. Such old orchards bear low yield of poor quality. However, such orchards can be made fruitful by rejuvenating them scientifically. Similarly, due to non-availability of good land for fruit cultivation, trend has shifted to grow fruit in high density planting system. For this system, several techniques are used. In this chapter, you will come to know about the importance of rejuvenation in fruits, methods of rejuvenation, concept of high density in fruits and different approaches used for high density planting in India and abroad.

Rejuvenation of old orchards

Points to remember

- Most of fruit orchards in India are very old, and declining and produce low yield of poor quality. Such orchards can be made productive by 'rejuvenation'.
- Rejuvenation technology involves heading back of branches of declining tree and grafting or budding of selected branches with a desirable variety.

Despite the country being the second largest producer of fruits in world, the per capita consumption of fruits is one of the lowest in the world. The existing orchards are not able to meet the present requirements of the country. In fruit crops, the majority of the older plantations are of seedling origin embodying non-descript material and poor genetic potentiality, which become senile. In several areas, plantations of varieties having good genetic potentiality have either gone unproductive or showing marked decline in productivity. This is the outcome of over-crowded and intermingling of large branches and meager foliage, allowing poor light availability to growing shoots within the canopy. This renders them uneconomical. Such exhausted fruit trees can be rejuvenated by heading back of old declining mango orchards branches in winter for the production of new shoots, which can bear good crops in the years to come. The term 'rejuvenation' means renewal or making new or young again. As applied to the orchard tree, it would mean restoring the productive capacity of the fruit trees.

There are two approaches to rejuvenate an old orchard:

Canopy management: It is applicable in plantation of commercial varieties, where the canopy has become over crowded resulting in reduction in yield.

Top working: It is followed in older plantations of seedling origin, which have become senile. It is achieved

by top working by grafting (budding) with scion of superior varieties to upgrade seedling plantation with superior commercial varieties.

Old declining mango orchard

Heading back of branches

Technology for rejuvenating senile orchards

In several old fruit orchasds, there is a tendency of over lapping of canopy between 10 and 12 years of age depending on the nature of variety unless the canopy is maintained by trimming overlapping branches that lead to decline in yield in later years. Such plantation can be rejuvenated through canopy redevelopment. The redevelopment of canopy is necessary in older plantations, when the canopies are overcrowded, resulting in reduction in yield. This is possible by hedging of branches followed by shoot management to modify the tree structure and maintain canopy size.

Emergence of new growth in beheaded branches

The rejuvenation technology involves heading back (topping) of branches during December-January at a height of 2.5 to 3.0 m from the ground level in crops like mango and *aonla*. Before rejuvenation pruning, branches are marked with white chalk by making a ring around the branches. The cut portion of the branches is then pasted with copper oxychloride to avoid infection of fungal pathogens. Immediately after heading back, the pruned wood needs to be removed from the orchard so as to prevent the damage by trunk borers.

Manipulation of vegetative growth

The new shoots arise from pruned branches after heading back. Of which, 4 to 6 shoots are retained at proper spacing and allowed to grow towards periphery of trees. Successive removal of unwanted shoots, considering the vigour and growing direction is important.

During May-June, selected shoots are subjected to further pruning to about 50 per cent of their total length for emergence of multiple shoots below the pruning points. This is mainly done to modify the tree structure and maintain canopy size. Fruiting starts on third year after rejuvenation. Yield levels during initial year are slightly low, while the yield from third year onward has been found to be better than the unpruned trees.

Rejuvenation by top working

Top working can be easily adopted in old trees to improve the productivity of the old and senile plantations of seedling progeny with superior commercial cultivars. Top working involves two steps (i) beheading of the tree to be top worked, and (ii) budding with a elite material on the new flushes emerging out on the stumps of the beheaded tree. The plants are headed back in December-January to the extent of 2.5 to 3.0 m above the ground level. Four- to-six shoots from the outer directions on main limbs are allowed to develop.

During June-July, scion of desired variety is grafted/ budded on these shoots. After bud sprouting, the top

portion of the shoot is removed. Numerous side shoots, which emerge on the pruned branches after the budding operation should be removed regularly as and when they emerge, so as to encourage the growth of desired scion variety. The pruned trees must be irrigated at an interval of 15-20 days starting from March till the onset of monsoon. Adequate care should be taken to manage the insect-pest problems as these plants are prone to insect and sometimes to wind damage. Trees develop healthy and productive canopy after two years and bearing starts. Additional income from pruned wood and intercropping with short duration vegetables and ornamental crops are the other advantages of rejuvenated orchard.

High density planting system

High density planting (HDP) can be defined as accommodation of the maximum possible number of the plants per unit area to get the maximum possible profit per unit of tree volume without impairing the soil fertility status. This technique was first established in apple in Europe during sixties and now majority of the apple orchards in Europe, America, Australia and New Zealand are grown under this system. In this system, four planting densities are recognized for apples viz., low HDP (< 250 trees/ha), moderate HDP (250-500 tree/ha), high HDP (500 to 1250 trees/ha) and ultra high HDP (>1250 trees/ha). Recently, super high density planting system has been also established in apple orchards with a plant population of 20,000 trees per ha. In some orchards, still closer, planting of apple trees is followed (say 70,000 trees/ha), which is often referred as 'meadow orchards'.

Points to remember

- Accommodation of the maximum possible number of the plants per unit area to get the maximum possible profit per unit of tree volume without impairing the soil fertility status is called HDP.
- This technique was first established in apple in Europe during sixties and now majority of the apple orchards in Europeare are under HDP.
- In India, HDP has been standardized in mango, banana, pineapple, papaya and apple, but it is followed commercially in banana and pineapple.

Advantages of HDP

- Early cropping and higher yields for a long time.
- Best utilization of interspaces.
- Best utilization of natural resources (sun light).
- Better water and fertilization use efficiency.
- Reduced labour costs.
- Reduction in disorders like sun scald.
- Improved fruit quality.
- Adoption of mechanization is possible.
- Easy management due to smaller tree size.

Characteristics of trees for HDP

a. The trees of HDP should have maximum number of fruiting branches and minimum number of structural branches.

b. The trees are generally trained with a central leader surrounded by nearly horizontal fruiting branches.

c. These branches should be so arranged and pruned that each branch casts a minimum amount of shade on other branches.

d. The height should be one and half its diameter at the base. A key to successful HDP depends upon the control of tree size.

Approaches for high density planting

Use of dwarf cultivars/ spur type scions: Genetically dwarf varieties suitable for HDP are available in many fruit crops like Pusa Nanha & Pusa Dwarf in papaya, Amrapali in mango, Van & Stella in cherry, Dwarf Cavendish & Dwarf Naine in banana etc. In temperate fruit crops like apple, the cultivars are classified into a spur type or non-spur type. The spur types which have restricted annual growth are suitable for HDP.

Use of size controlling rootstocks: In apple, dwarfing rootstocks such as M_{27} and intermediate stocks like MM 106, MM 109, and MM 111 are used to control the size of the plant. In citrus, Flying Dragon is used commercially as a dwarfing rootstock. In pears, Quince A, Adam and Quince-C are commonly used as dwarfing root stocks. Similarly, in mango cv. Anupam has been recommended for its use as dwarfing interstock.

Training and pruning: Proper tree forms, branch angle and limb spacing among themselves aid in growth control of any plant. Once the tree is mature, excessive growth can be regularly removed by pruning to provide a short term or immediate benefit. This is achieved by heading back and thinning out. Heading back involves the removal of terminal apex and a portion of dominant shoots, while thinning involves removal of complete shoots or limb at the point of origin. Even a dwarf tree under after few years of commercial production show decline due to overcrowding and intermingling of canopies. Therefore, pruning has been recommended after twelfth year of planting in mango cv. Amrapali. Similarly, mango cv. Dashehari when accommodated under HDP system are severely pruned (dehorned) to 50% of their branches in 11th year and another 25% in the 12th year. Likewise, under Indian conditions, apple trees trained under spindle bush, dwarf pyramid, cordon systems are found to contain the growth of the trees appreciably for HDP systems.

Mechanical device and use of chemicals: Growth regulators such as paclobutrazol, daminozide, ethephon and chlormaquat are extensively used to reduce shoot growth. This results in increased flowering in the subsequent years and may be useful in encouraging earlier commercial fruit production in strongly vegetative fruitful young trees. Besides chemical manipulation, mechanical devices employing the use of spreaders and tying down the branches to make them grow from near horizontal to an angle of 45° from the main stem are also some of the standard practices to control tree size.

A view of HDP in pineapple

Planting system for high density planting

The success of HDP depends upon the appropriate choice of planting system. Generally, rectangular planting with single, double and three row plantings are followed. In single row planting, the distance within the row is close, whereas the distance between the row is wide (4x2m). In double row planting, a wider spacing is given after every two rows (4+2x2m) whereas in three row planting, a wider spacing is given after every three rows (4+2x2x2m). In meadow orchard system, a bed of 10 to 15 rows is closely planted (nay 30x45cm) and separated by alleys of 2.5m width between beds. This system is also called bed system.

High density orchard of Amrapali mango

HDP by hedgerow system in guava

Examples of successful HDP in fruit crops

There are quite a good number of success stories of HDP in fruit crops under Indian conditions as given in talbe below.

Performance of fruit crops under high density planting

S. No.	Crop	Variety	Density (Plants/ha)	Spacing (m)	Yield (t/ha)
1.	Banana	Basarai	4,444	1.5x1.5	78.0
2.	Papaya	Pusa Nanha	6,400	1.25x1.25	103.6
3.	Pineapple	Kew	63,758	0.22x0.6x0.75	118.8
4.	Guava	Lalit	5,000	1x2	55
5.	Mango	Amrapali	1,600	2.5x2.5	22
6.	Kinnow	Kinnow on Troyer citrange	2,990	1.83x1.83	Higher and precocious fruiting
7.	Litchi	Shahi	3,333	2.0x1.5	5.82

ACTIVITIES/EXERCISES

- Go to some old or declining fruit orchard. Ask gardener to demonstrate different steps involved in its rejuvenation.
- Go to some ICAR institute or Agricultural University in your area. Visit the fruit orchard. Note down the planting density and the approaches adopted for high density orchard, if they have any.

CHECK YOUR PROGRESS

1) Define rejuvenation. Write different steps involved in rejuvenation of a mango orchard.
2) What is high density planting? Write its advantages over traditional system of planting.
3) Write basic approaches employed for adopting HDP in fruit crops.
4) Write briefly about achievements made in HDP of fruits in India.

FILL IN THE BLANKS

i) Old orchards produce low yields of ……..quality.

ii) …… variety of mango has been recommend for HDP in mango.

iii) ……. variety is most suitable for HDP in papaya.

iv) For reducing growth of plant, …… growth regulator can be used.

v) In citrus, ……is used as the most dwarfing rootstock in the world.

SUGGESTED FURTHER READINGS

- Bal, J.S. (2007). Fruit growing Kalyani Publishers, Ludhiana, India.
- Chattopadhyay, T.K. A textbook on Pomology, Vol. 2 (Tropical fruits). Kalyani publishers, Ludhiana, India.
- Goswami A.M., Saxena S.K., Kurien, S. (1993). High density planting in citrus. (Chadha K.L., Pareek O.P. (Eds). Advances in Horticulture (Fruit crops) Vol. II., Malhotra Publishing House, New Delhi, India, pp. 645-648.
- Sharma R.R., Goswami A.M., Saxena S.K. (199). High density orcharding in fruit crops, Agro India 3:20-24.
- Sharma, R.R. (2006). Fruit production: problems and solutions. Intl. Book Distributing Co., Lucknow, India.

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CHAPTER

13

PACKING, STORAGE AND VALUE ADDITION OF FRUITS

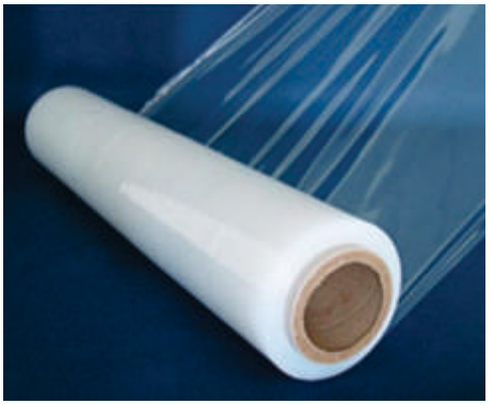
OBJECTIVES

After reading this chapter, students will be able to:

- Understand the importance of packaging of fruits
- Know the characteristics of a modern package
- Explain different storage structures used for the storage of fruits
- Know the importance of value addition of fruits
- Know about the processed products which can be prepared from fruits

INTRODUCTION

In your previous class, you have read about handling of fruits. After harvesting, different operations are necessary before the product is packed. Packing of fruits is an important aspect of postharvest operation, after which fruits are transported for marketing or stored for some time. Similarly, when there is very high production of fruits or when markets rates are very down, fruits can be processed in to several value added products to fetch good price in future. In this chapter, you will learn about packaging, transportation, storage and value addition of fruits.



Heat shrinkable film

Apples packed in CFB boxes

Packing of fruits

After grading, the produce is packed, for which different containers like polyethylene bags, plastic field boxes, wooden field boxes, CFB boxes, muslin cloth bags, bamboo baskets, nylon nets etc. Nowadays, CFB boxes are mainly used for bulk packing. However, different attractive consumer packs have been developed and are commercially used in India as well. Shrink wrapping is becoming quite popular in India as well. Modern packaging must comply with the following requirements:

- The package must have sufficient mechanical strength to protect the contents during handling, transport, and stacking.
- The packaging material must be free of chemical substances that could transfer to the produce and

become toxic to man.

- The package must meet handling and marketing requirements in terms of weight, size and shape.
- The package should allow rapid cooling of the contents.
- The permeability of plastic films to respiratory gases should be ideal for the commodity to be packed.
- It should be easily printable.
- Its mechanical strength should be largely unaffected by moisture content (when wet) or high humidity conditions.
- The package must either exclude light or be transparent.
- The package should be appropriate for retail presentations.
- The package should be designed for ease of disposal, re-use, or recycling.
- The cost of the package should be as low as possible.

Transportation of fruits

After packing, the produce has to be sent to market for sale. This is the most neglected area in our country because very less attention is paid for transporting of fruits from the production sites. In our country, fruits are transported by loading in the rickshaws, carts, rails, trucks, ship or by air. As a result, bulk of produce is lost during transportation. However, now producers are paying attention on this aspect and even refrigerated vans are used for transporting fresh horticultural produce.

Apples loaded on a truck

Storage of fruits

The marketable life of most fresh fruits can be extended by prompt storage in an environment that maintains product quality. The desired environment can be obtained in facilities where temperature, air circulation, relative humidity, and sometimes atmosphere composition can be controlled. Storage rooms can be grouped accordingly as those requiring refrigeration and those that do not. Storage rooms and methods not requiring refrigeration include: *in situ*, sand, coir, pits, clamps, cellars, barns, and evaporative cooling units. The following methods are commonly used for storage of fruits in India.

***In situ*:** This method of storing fruits and vegetables involves delaying the harvest until the crop is required. It can be used in some cases with root crops, such as cassava, but means that the land on which the crop was grown will remain occupied and a new crop cannot be planted. In colder climates, the crop may be exposed to freezing and chilling injury.

Sand or coir: This storage technique is used in countries like India to store potatoes for longer periods of time, which involves covering the commodity underground, with sand. Pits or trenches are dug at the edges of the field where the crop has been grown. Usually pits are placed at the highest point in the field, especially in regions of high rainfall. The pit or trench is lined with straw or other organic material and filled with the crop being stored, then covered with a layer of organic material followed by a layer of soil. Holes are created with straw at the top to allow for air ventilation, as lack of ventilation may cause problems with rotting of the crop.

Clamps: This has been a traditional method for storing potatoes in some parts of the world, such as Great Britain. A common design uses an area of land at the side of the field. The width of the clamp is about 1 to 2.5 m. The dimensions are marked out and the potatoes piled on the ground in an elongated conical heap. Sometimes

straw is laid on the soil before the potatoes. The central height of the heap depends on its angle of repose, which is about one third the width of the clump. At the top, straw is bent over the ridge so that rain will tend to run off the structure. Straw thickness should be from 15-25 cm when compressed. After two weeks, the clamp is covered with soil to a depth of 15-20 cm, but this may vary depending on the climate.

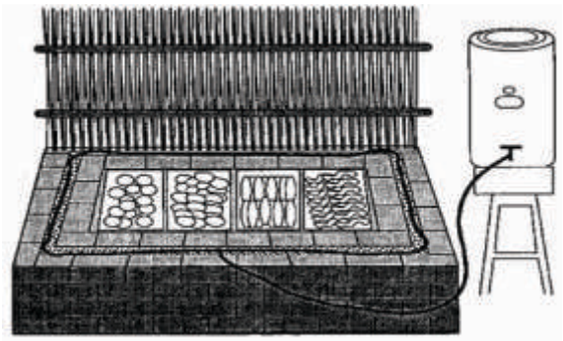
Points to remember

- Pusa Zero Energy Cool Chamber (PZECC) was developed at IARI, New Delhi.
- It works on the principle of evaporative cooling.
- It is highly useful for on-farm storage of fruits, vegetables and flowers.
- It can be made from locally available material.
- It can be used for pre-cooling of produce.
- It works well in areas having high temperature and low humidity.

Cellars: These underground or partly underground rooms are often beneath a house. This location has good insulation, providing cooling in warm ambient conditions and protection from excessively low temperatures in cold climates. Cellars have traditionally been used at domestic scale in Britain to store apples, cabbages, onions, and potatoes during winter.

Barns: A barn is a farm building for sheltering, processing, and storing agricultural products. Although there is no precise scale or measure for the type or size of the building, the term barn is usually reserved for the largest or most important structure on any particular farm. Smaller or minor agricultural buildings are often labeled sheds or outbuildings and are normally used to house smaller implements or activities.

Cold storage: Fruits are also stored in cold stores maintained at specific temperature. Temperature for cold storage of fruits has been standardized. For some fruits (e.g., apple, pear, peach, plum, apricot etc.) lower temperature (nearly 0 or 1ºC) is suitable, whereas some fruits are stored safely at higher temperature because such fruits (e.g., mango, avocado, pineapple, banana etc.) develop chilling injury at lower temperature. Hence, every care must be taken while storing the fruits in cold storage.



A design of Pusa Zero Energy Cool Chamber

Evaporative cooling: When water evaporates from the liquid phase into the vapour phase energy is required. This principle can be used to cool stores by first passing the air introduced into the storage room through a pad of water. The degree of cooling depends on the original humidity of the air and the efficiency of the evaporating surface. If the ambient air has low humidity and is humidified to around 100% RH, then a large reduction in temperature will be achieved. This can provide moist conditions during storage.

Controlled atmospheric storage: This is modern technique of storage of fruits. Controlled atmospheres are made of gastight chambers with insulated walls, ceiling, and floor. They are increasingly common for fruit storage at larger scale. Depending on the species and variety, various blends of O_2, CO_2, and N_2 are required. Low content O_2 atmospheres (0.8 to 1.5%), called ULO (Ultra Low Oxygen) atmospheres, are used for fruits with long storage lives (e.g., apples). Now several such structures have been developed in India as well for storage of high value fruit crops like apple.

CA Store for apples

Value addition in fruits

India is the 2nd largest producer of fruits and vegetables in the world. However, about 30-40% of this produce is lost during improper postharvet handling. Moreover, several fruits are seasonal in nature, which results in price fluctuations, thereby growers get low price of their produce. Therefore, to prevent losses, and avoid glut of fruits, the processing of fruits in to stable value added and processed products is required.

Benefits of value addition in fruits

Conversion of perishable fruits in to various value added products, apart from reducing the post-harvest losses considerably, avoids losses to grower by avoiding distress sale and minimizing the effect of glut during the seasons. It also ensures optimum utilization of perishables and also helps in better and full use of countries resources. Apart from all these benefits, setting up of processing unit generates employment both in rural or production areas. It also helps in improving the foreign exchange earnings of the country through exports.

Different value added products from fruits

Fruit beverages

Fruit juices

Fruit juices are rich sources of vitamins, particularly vitamin-C and minerals. These are easily digestible, highly refreshing and invigorating, thirst quenchers and far superior to most aerated drinks, which have practically no food value. They are beneficial against a number of ailments and tonics for heart and brain and serve as cold drinks in hot summer. Fruit juices are preserved in different forms such as pure juices, squashes, cordials, and fermented juices etc. These are broadly classified as under:

Pure fruit juice: This is the natural, unfermented juice processed out of the fruit and remains practically unaltered in its composition during preparation and preservation. Fruit juices can be prepared from almost types of fruits.

Fruit Squashes

Ready-to-serve (RTS) : This prepared from fruit juice. It contains minimum of 10% fruit and 10% sugars. It not diluted before serving.

Fruit juice beverage: This is a fruit juice, which is considerably altered in composition before consumption. It may be diluted before it is served as a drink.

Fermented fruit beverage: This is a fruit juice, which has undergone alcoholic fermentation by yeast. The product contains varying amounts of alcohol. Grape wine, apple ciders, berry wines etc., are typical examples for this kind of beverages.

Fruit juice squash: This consists essentially of strained juice containing moderate quantity of fruit pulp to which sugar is added for sweetening. Fruit squash can be prepared from mango, lemon, orange etc.

Fruit juice cordial: Sparkling, clear, sweetened fruit juice from which all the pulp and other suspended materials have been completely eliminated (e.g. lime juice cordial, guava).

Sherbet or Syrup: Clear sugar syrup, which has been artificially flavoured.

Fruit juice concentrate: Fruit juice, which has been concentrated by the removal of water either by heat or freezing. Carbonated beverages and other products can be made from this.

Fruit juice powder: Fruit juice which has been converted into a free-flowing, highly hygroscopic powder to which natural fruit flavour in powder form is incorporated to compensate for any loss of flavour in concentration, dehydration etc. Freeze dried fruit juice powders makes the best quality products. The powders are reconstituted to yield readily full strength, full fruit, fruit juice drinks..

Preparation: Fruit juices have their best taste, aroma and colour when they are freshly extracted and used for product making. The important steps in beverage making are selection and preparation of fruits, extraction of juice, de-aeration, straining, filtration, clarification and preservation.

Marmalade

Apricot butter

Jams, jellies and marmalades

Jam : Jam is a concentrated fruit pulp, posses sing a fairly heavy body and rich in natural fruit flavour. Pectin in the fruit gives it a good set and high amount of sugars (more than 68.5 %) facilities its preservation. It is prepared by boiling the fruit pulp and juice with sufficient quantity of sugar to get thick consistency. A good jam must have bright colour, rich typical fruit flavour, stiff but should not be sticky or crystallization of sugar.

Jelly: It is a semi-solid product prepared by concentrating essentially a clear fruit extract with sugar. In jelly making, pectin is the most essential constituent. Good jelly should be transparent, attractive in colour, give strong flavour of the fruit and firm enough to retain a sharp edge when cut. Pectin from cell wall of fruits sugar, acid and water combine together when corked to form jelly. Guava jelly is very popular in all parts of the world.

Marmalade: It is usually made from citrus fruits and consists of jellies or jam of the concerned fruit containing shreds of peels suspended in them. Usually citrus peel is used for making shreds in marmalade.

Fruit butter, cheese and toffees

Fruit butter: It is a thick product but soft enough to spread easily. The butters can be prepared from any fruit but, most commonly used fruits are apple, pear, plum, peaches, apricot and grapes.

Fruit cheese: This product is commonly prepared from fruits like guava, apple and pear.

Fruit toffee: It is prepared by using fruit pulp, sugar, glucose, skimmed milk powder, butter and essence.

Fruit cheese

Preserves (*murrabbas*) and candies

Preserves (*Murrabbas*) : It is a matured whole or in large pieces of fruit in which sugar is impregnated till it becomes tender and transparent. It retains the shape of the fruit and does not break or pulped. The preserve should have enough sugar (more than 68% TSS). Murabba can be prepared from amla, apple, mango, petha, grapes, muskmelon, and watermelon.

Candied fruit: A fruit impregnated with sugar, drained and dried is named as candied fruit. They are not sticky and are plump, tender and exceedingly sweet with high flavour.

Murabbah of *Aonla*

Glazed fruit: A candied fruit dipped for a moment in boiling syrup to impart a glossy finish to it, drained and dried- is called glazed fruit.

Crystallized fruit: Candied fruit drained, dried and rolled in crystal sugar is called a crystallized fruit.

Glazed fruit candy

Canning and bottling of fruits

Canning is a process of preserving the fruits by application of heat high enough to destroy essentially all microorganisms present together with sealing the food in air-tight sterilized cans to prevent recontamination and to preserve the food in the condition in which it is ready to eat or cook. When glass jars are used as containers in place of cans, the process is called bottling. Tin cans are most commonly used because they are unbreakable, easy to handle, strong to withstand heat processing, light in weight, permit quicker heat penetration and can be cooled quickly. Cans require can sealer or seamer for hermetic sealing.

Fermented products

Wine: Wine is made by fermenting grape juice with the help of yeasts. Wine can also be prepared by fermentation of other fruit juices such as mango, pineapple, guava, plum, kiwi, apple etc., which will be referred to as wine of that specific fruits (mango wine, pineapple wine etc.). Wine represents a non-toxic healthful beverage, which provides calories, vitamins, minerals and other nutrients.

Wine

Cider

Vinegar

Vinegar: The product made from carbohydrates obtained from different fruits by acetic fermentation is called vinegar. It can be manufactured as a byproduct from the pomace after extracting the juice from fruits. Fruit vinegars will have a unique flavour of the fruits used. Vinegar can be made from apple, grape or other fruits.

Pickles and chutneys

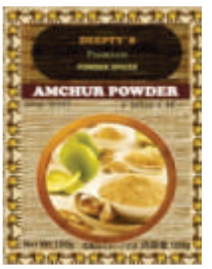
Pickles: The preservation of food in common salt or vinegar is called pickling. Spices and oil may also be added in pickles. Pickles are good appetizer aid to digestion and add to the palatability of the meal. In oil pickles, oil provides protection against outside infection. In other pickles, 15 to 20 % common salt is added to prevent spoilage caused by microbes. Moulds and even lactic acid forming bacteria do not grow at this high salt concentration, as a results pickle remains safe for several months.

World famous Pachranga pickle

Chutneys: In general, hot and sweet chutneys are relished by all. Mostly acidic fruits are employed for preparing chutneys. A good chutney is smooth and has a mallow flavour and is spicy. Chutney is mostly prepared from mango.

Dried products of fruits

It is an oldest and cheapest form of preservation of fruits. Drying can be carried out either in sun or by artificial heat (dehydration). Sun drying is practiced in tropical and sub-tropical regions where there is plenty of sunshine. However, nowadays, drying is done by mechanical dryers because of faster rate of drying and hygiene. Several fruit are used in dry form.



Amchur

Anardana

Anardana: It is a form of dried sour pomegranate arils used as a souring agent in food preparations. Anardan is prepared from a special wild form of pomegranate, which are highly acidic.

Amchur: It is a product obtained by powdering dry unripe mango pieces of sour nature. It is used as souring agents in food preparations.

Fruit bar: Fruit bar can be prepared from the pulp extracted from fully ripe fruits. Fruit pulp dried with suitable quantity of sugar and citric acid along with specified level of chemical preservatives. This product is called as intermediate fruit product but commonly called as leather/papad in our country.

Apple leather

ACTIVITIES/EXERCISES

- Visit some unit in which all packing-houses operations are done mechanically.
- Keep some fruits of tropical origin (e.g., mango, sapota, banana etc.) in your refrigerator. Observe the changes in skin colour, symptoms of chilling and quality after a week.
- Go to a bakery shop. Make a list of products, which are made from fruits. Try to differentiate between jam, jelly and marmalade.

CHECK YOUR PROGRESS

1. Why packing of fruits is important? Write characteristics of of a modern packing material.
2. Why storage of fruits is required? Write briefly different storage systems adopted for fruits.
3. What is value addition? Write different dried products which you have seen in the market.
4. Describe briefly different fermented products which can be prepared from fruits.
5. Differentiate between candied, glazed and crystallized fruit.
6. Differentiate between jam and jelly

FILL IN THE BLANKS

i) *Anardana* is a dried product prepared from pomegranate.

ii) For jelly making, fruit should be rich in vitamin C.

iii) For preparation of marmalade, shreds of citrus are used.

iv) RTS is diluted before serving.

v) Fruit bar is also called as intermediate moisture product.

vi) Vinegar is a fermented product.

vii) Cider is prepared from plums.

viii) Jam and jelly are preserved by citric acid.

ix) Petha is prepared from *aonla*.

x) Zero Energy Cool Chamber works on the principle of evaporative cooling.

SUGGESTED FURTHER READINGS

- Sharma, S.K. (2010). Postharvest management and processing of fruits and vegetables. NIPA, New Delhi.
- Siddappa, G. and Tandon, D.K. (1998). Presrvation of fruits and vegetables. ICAR, New Delhi
- Srivastava, R.P. and Kumar, S. (2001). Fruit and vegetable preservation: Principles and practices. International Book Distributing Co., Lucknow, India.

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Student Handbook

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