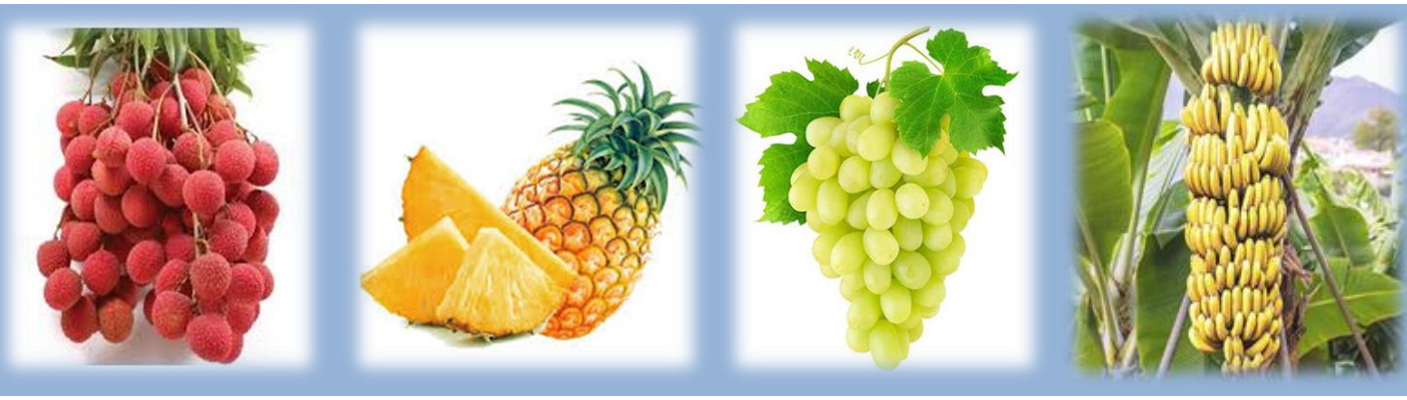
PRACTICAL MANUAL

TROPICAL AND SUBTROPICAL FRUIT CROPS

FSC-211



YAMUNA PANDEY

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Prof. Anupam Mishra
Vice chancellor
CAU, Imphal, Manipur

Prepared by:

Dr. Yamuna Pandey, Asst. Prof. (Hort.)
Prof. A.K. Pandey, Dean College of Horticulture (Bermiok)

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Prof. Anupam Mishra
Vice Chancellor

केंद्रीय कृषि विश्वविद्यालय
CENTRAL AGRICULTURAL UNIVERSITY
इंफाल-795004, मणिपुर
Imphal-795004, Manipur

Phone: 0385-2415933(O)
Email: vc@cau.ac.in
vcofficecau@yahoo.in

FOREWORD

Nature has blessed the country with unique diversity claiming one of the 12 mega biodiversity centers with 2 biodiversity hotspots embedded with rich reservoirs of plant genetic resources. India stands at 7th place in the global agricultural biodiversity status. Among fruit and nut crops, there are about 117 cultivated species with 175 wild relatives of which only 25 species have been domesticated. This unique fabric of plant diversity comprising traditionally cultivated landraces, primitive cultivars and wild relatives of cultivated plants are the basic raw materials that not only sustain the present day crop improvement programmes but is also required to meet the needs of future generations who may require altogether new sources of genes while facing unprecedented challenges of more virulent pathogens and pests, hostile climatic factors and abiotic stresses like salinity, drought and unfavorable temperatures. The fifth Deans' committee constituted for framing the course curricula of undergraduate Horticulture (Hons.) deserve for appreciation listing the country's rich wealth of tropical and subtropical fruits spread across different agroclimatic zones and setting priorities not only theoretical learning, but emphasizing much on practical exercises.

I am well confident that practical manual encircled covering various aspects of different tropical and sub –tropical fruit plants will enrich the students in their practical understanding.

(Anupam Mishra)

PREFACE

It is estimated that there are about 500 species of tropical fruit trees under 30 families and 59 genera in Asia Pacific Oceana region. In Southeast Asia, there are 120 major fruit species and 275 minor fruit species have been reported in different regions. Further, India is a land of rich diversity of an array of fruit crops falling in different group viz., tropical, subtropical and temperate fruit crops. Each and every fruit plant differs from others in respect of their growing practices, production and protection protocols, reproductive behaviours and consumers' preference. Accordingly the syllabus of UG Horticulture, subject of Tropical and Subtropical Fruit Crops has been designed by the Fifth Deans' Committee giving a very holistic approach to develop perfect understanding of theoretical as well as practical aspects of different fruits. While drafting the Practical Manual of Tropical and Subtropical Fruit crops, concerted efforts have been made to elaborate the concerned exercise so that student can attempt the practical problems with full of understanding and confidence.

Authors of this practical manual have firm belief that this text will be very useful for students, gardeners and all those who are engaged in teaching, research or extension activities pertaining to tropical and subtropical fruit crops of the country.

(Authors)

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Exercise No: 1 Date:

Description and Identification of Varieties Based on Flower and Fruit Morphology in Tropical Crops.

1.1 Description and Identification of Mango Varieties/ Hybrids

1. Banganapalli: It is early season variety available during the months of April to June. It is originally from Andra Pradesh town of Banganapalle. Fruit colour is bright yellow and oval –shaped. Slightly sour in taste, skin is edible mostly used to make preservatives**.**

2. Pairi: It is just like Banganapalli marks the early beginning of the mango season. **Season:** April to June, **Colour:** Yellow with Reddish Tinge on skin, **Shape:** Oval-shaped, **Taste:** Sweet with a noticeable sour taste, m as soon as you can after purchasing them. **Fruit** Weighs 250 to 450 grams.

3. Kesar: It has a distinctive fragrance to it that can liven up your house. It is grown and cultivated in the Girnar mountains of Gujarat, Ahmadabad and is named after the spice 'saffron'. **Season:** June to July, **Colour:** Skin is dull yellow with a green tinge and inside pulp is saffron-colour. **Shape:** Roundish shape with a curved tip, **Taste:** Sweet but Milder in taste than Alphonso's, **Other Characteristics:** Mostly used to make *aamras,* Size is small to medium A bit expensive than other types of mangoes.

4. Dashehari: This variety derives its name from the village Dashehari near Lucknow. It is a leading commercial variety of north India and one of the best varieties of our country. The fruit size is small to medium, shape is oblong oblique and fruit colour is yellow. Fruit quality is excellent and keeping quality is good. It is a mid season variety and is mainly used for table purpose.

5. Bombay Green : It is commonly grown in north India due to its early fruiting quality. It is also called Malda in northern India. Fruit size is medium, shape ovate oblong and fruit colour is spinach green. Fruit quality is good and keeping quality is medium. It is a very early season variety.

6. Alphonso: It is unlike any other type of mango and is the king of all mangoes. It is a native to Maharashtra but is also grown in some parts of Gujarat, Karnataka and Madhya Pradesh. It is the most expensive variety of mango due to its distinct taste, colour, and shape. **Season:** May to June, **Colour:** Bright golden yellow with a tinge of red.**Shape:** Voluptuous Oval-shaped (ovate oblique), **Taste:** Sweet with Rich flavor& creamy texture, **Other Characteristics:**Non- fibrous and juicy pulp, Popular all around the world, Medium-sized (4-6 inches long).

7. Totapuri: The Totapuri mango is the easiest type of mango to identify due to its parrot beak-like shape at the tip, hence symbolizing its name. It is from Andhra Pradesh, Karnataka, Telangana and Tamil Nadu. **Season:** June to July, **Colour:** Golden Yellow, **Shape:** Oblong with beak like pointed end, **Taste:** Not Sweet, **Other Characteristics:** Great for salads, pickles and mango juices. Large in size, Skin is very thick.

8. Chausa : It is the popular variety of Bihar and eastern Uttar Pradesh. It is seen at the end of the mango season. **Season:** July to August, **Colour:** Bright yellow, **Shape:** ovate (egg-like) to oval oblique, **Taste:** Extremely sweet and aromatic, **Other Characteristics:** Mostly found in North India, Fibrous flesh & juicy pulp, Medium keeping quality and exported.

9. Langra: This variety of mango was first grown by a farmer in Varanasi (Banaras) who was unfortunately disabled (limp) hence the name Langra came into being. It is very popular in West Bengal, Haryana, Bihar and Uttar Pradesh.**Season:** Mid July to August **Other Characteristics:** High level of natural sugar, Poor keeping quality, Very thin skin, Once ripened, it releases a very strong aroma.

10. Himsagar: Amongst all the varieties of mangoes, this variety has the shortest season span of them all. Himsagar originates in Northeast regions of India such as West Bengal. **Season:** May or June, **Colour:** Green skin and bright yellow pulp, **Shape:** Ovate (egg like) shape, **Taste:** Extremely sweet, **Other Characteristics:**Thin skin & known for its aroma, Good keeping quality, Medium-sized, Fibreless and fleshy.

11. Neelum: It is an ideal variety for transporting to distant places owing to its high keeping quality. Fruit is medium in size, ovate oblique in shape and saffron yellow to red tinge colour. Available during May- July. Fruit quality is good and keeping quality is very good. Sweet and sour in taste. It is a late season variety.

13. Mulgoa: This is a commercial variety of south India. It is quite popular among the lovers of mango owing to high quality of its fruit. Fruit is large in size, roundish oblique in shape and yellow in colour. Fruit quality and keeping quality are good. It is a late season variety.

HYBRIDS OF MANGO

1. Amrapali : This hybrid is from a cross of Dashehari and Neelum. It is dwarf, regular bearing and late maturing variety. The variety is suitable for high density planting as about 1600 plants may be planted in a hectare. It yields on an average of 16 tonnes/hectare.

2. Mallika: It is from a cross of Neelum and Dashehari. Its fruit is large in size, oblong elliptical in shape and cadmium yellow in colour. Fruit and keeping quality are good. It is a mid season variety.

3. Arka Udaya: Developed at ICAR- IIHR, Bagalore**,** Hybrid between Amrapali and Arka Anmol, it has semi-vigorous growth, Bunch bearing with medium sized fruits, firm pulp with deep yellow colour, fruit weight varies from 230 -250g, pulp recovery is 68-70 % and has excellent shelf life of 12-15 days

4. Arka Suprabhath: Hybrid between Amrapali and Arka Anmol Medium vigorous growth, Bunch bearing of medium sized fruits, Firm pulp with deep orange colour, Fruit weight 250 – 300g, Pulp recovery is 70 %, Shelf life is 8-10 days, Developed at ICAR- IIHR, Bagalore

5. Arka Neelkiran: It is a hybrid between Alphonso and Neelum. It is regular bearing late season variety with medium sized fruits having attractive red blush and free from spongy tissue.

6. Sindhu: It is from a cross of Ratna and Alphonso. It is regular bearer, fruits medium sized, free from spongy tissue with high pulp to stone ratio and very thin and small stone and called as seedless mango.

7. Arka Aruna: It is a hybrid between Banganapalli and Alphonso. It is dwarf, regular bearing and precocious. Fruits are large having attractive skin colour with red blush and free from spongy tissue. Suitable for homesteads as well as high density planting.

8. Ambika: This hybrid is a cross between Amrapali and Janardhan Pasand. It is a regular and prolific bearer. Fruits are medium sized having attractive skin colour with red blush, and late in ripening.

1.2 Description and Identification of Guava Varieties/ Hybrids

Arka Mridula: Selection from open pollinated seedlings of Allahabad Safeda.

Plants semi-vigorous and spreading.

Fruits round in shape weighing about 180 g.

Pulp white in colour; TSS 12° Brix.

Fruits good for jelly making;

Keeping quality is good.

Seeds soft.

Guava hybrid Arka Poorn

Progeny selection of the cross Purple local X Allahabad Safeda
Semi vigorous and prolific bearing
Fruits round in shape and big (200-230 g)
Pulp white in colour; TSS is 10-12° Brix.
Suitable for both table and processing purpose

Guava hybrid Arka Kiran:

Hybrid between Kamsari and Purple Local
Semi vigorous in growth habit,
Fruits round in shape and medium size (230 g)
Pulp dark red in colour: TSS 12° Brix with high,
lycopene (5 to 7 mg/100g)
Seeds medium soft (7kg/cm2)

Guava hybrid Arka Rashmi:

Hybrid between Kamsari and Purple Local
Fruit weight : 200 - 220g; TSS 12.0°Brix
Rich in ascorbic acid (235mg/100g) and lycopene (4 mg/100g);
Seeds medium soft (8kg/cm2)
Pulp deep pink in colour

L-49 (Lucknow-49): It is a prolific bearer, greenish yellow with milky white sweet pulp and rough surface. Shell is fairly thick, contains fairly soft few seeds in inner portion of pulp. Since the number of seeds is less, keeping quality is medium it is very popular in Maharashtra and Andhra Pradesh. It is suitable for table purpose and yields about 25t/ha.

Allahabad Safeda : This is the most famous variety grown in Uttar Pradesh for table purpose. Tree is medium in height (5.8-6.5m) with vigorous branching and dense foliage. Fruits are medium in size (180g), round in shape with few seeds. Fruit is white fleshed with good keeping quality.

1.3 Description and Identification of Papaya Varieties/ hybrid

1. Arka Surya: Developed at ICAR- IIHR, Bangalore. Gynodioecious hybrid from the cross Sun Rise Solo X Pink Flesh Sweet

Fruit weight 600 to 800g

Pulp pink in colour;

TSS 13-14°B

Yield 40-50 t / acre

2. Taiwan-786: It serves for both processing and table purposes. This gynodioecious variety produces ovate fruits, each of which is around 1-3 kg in weight with oval shape, sweet pulp, and lesser seeds. The fruits of this variety have a good taste and long shelf life.

3. Arka Prabhath: Developed at ICAR- IIHR, Bangalore. Gynodioecious hybrid from the cross (Arka Surya X Tainung-1) X Local Dwarf

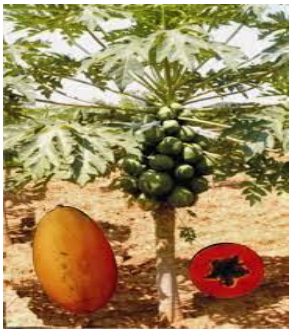
Fruit weight 1200 to 1500g;

Good shelf life,

Pulp pink in colour;

TSS 13-14°B,

Yield 80-90 t / acre



4. Washington: It is another table purpose variety with the fruits that may range from medium to large. These fruits are round or oblong. It has separate male and female plants and requires both for the production of fruits. These fruits take a bright yellow color when they are fully mature, and the average weight of each fruit is around 1.5-2 kg.

5. Solo: The fruits of this variety are best for kitchen garden. The fruits have thick pink pulp and amazingly sweet flavor.

6. Co-I: This popular variety is a selection from Ranchi cultivar of papaya. It produces medium-sized fruits, round in shape with smooth skin and yellow-green patches over it. These fruits come with good keeping quality due to its firm yet soft yellow flesh. One interesting fact about this variety is the absence of the typical papain odor.

7. Ranchi: One of the best types of papaya in India also comes from the states of Bihar and Jharkhand. The type is also a popular cultivar in some south Indian states. The fruits come with a yellow colour pulp that tastes sweet. A single tree can also bear many fruits in one season.

8. Mahabindu: Also popular as *Coorg Honey Dew*, it can serve in both processing and table purposes. The fruits are yellow-green with thick flesh and ovate or oblong shape. Besides being long, the fruits are also rich in flavour and taste. This variety sells for high market prices because of the fantastic quality of fruit.

9. Pusa Delicious: Another gynodioecious kind of papaya cultivar that produces plants with an average height. These plants produce good quality fruits and start yielding in around eight months from the date of transplanting. The fruits serve as a table purpose variety. The fruits are of medium size and weigh about 1-2 kg. They have orange-colored, deep flesh, which has a fantastic flavour and tastes delicious, making them one of the best varieties of papaya in India.

Pusa Majesty: variety produces medium-size fruits; each of the fruits weighs around 1- 1.5 kg fruits. These fruits are round in shape and have good taste and quality. It is a gynodioecious line, which means that it produces fruits from the coexistence of both female and hermaphrodite populations of plants in the same place. These plants can start fruiting in 145-150 days from the date of transplantation.

1.4 Description of Banana varieties

Udhayam

Similar to Karpuravalli banana.

Suitable for cultivation in banana growing states viz., Tamil Nadu, Andhra Pradesh, Bihar, West Bengal, North Eastern regions in place of local Karpuravalli banana.

The average yield is 37 kg., Dwarf in stature with duration of 15-16 months.

Cylindrical bunch with 13-15 hands and 15 - 20 fruits per hand.

Fruits are elongated with 14 -16 cm in length and 10-13 cm in circumference.

Field tolerant to nematode and leaf spot diseases.

Highly suitable for processing industry.

Kaveri Sugantham

This is a selection from **somaclonal variant of tissue cultured Manoranjitham.**

Pseudostem is dark green, dull with black blotches. There were larger black brown blotches appears on the sides of the petiole base.

Height 4.9-5.2 m with a pseudostem girth of 110 cm.

Bunch is compact and slightly angular in position.

Mature fruits are dark green and turn green yellow upon ripening.

Average bunch weight is 18-22 kgs with 12-14 hands and 17-20 fingers/hand as against 13-15 kg in local Manoranjitham.

Resistant to Fusarium wilt

Crop duration is 13-14 months.

Pulp is cream in color and Juicy sweet with intense aroma.

Kaveri Saba

An exotic introduction of ABB genomic group and Bontha subgroup.

Tolerant to drought and salinity.

Medium statured plant with 3- 3.5m height.

Leaves, dark green and shiny, Bunch slightly angular

9- 10 hands in a bunch and loosely packed. Weight 26- 29 kg, duration 360 – 380 days.

Fruits dark green, flattened, blunt tip, pulp starchy.

It is grows well both in plains and higher altitudes.

Saba is more suitable for marginal cultivation and saline sodic soils with pH 8.8 to 9.0.

Suitable both for culinary and dessert purposes

Kaveri Kalki

Plant dwarf 2-2.4m height with 90 cm circumference.

Plant stature is robust and sturdy with short leaves.

Green pseudostem with pink streaks.

Leaves are almost erect, suitable for high density planting. Can grow up to 1050 plants/ acre with the spacing of 1.85m x 1.85m.

Shortest duration of 12 months, suitable for annual cropping system.

Average bunch weighs 17-20 kg with 13- 15 hands and 16-18 fruits per hand. having a potential to yield up to 25 kg.

Marketable quality with sugary taste with 31oBrix.

Suitable for preparing value added products

Student's activity

1. Write down the characteristics of different mango varieties and hybrids.
2. Write down the identification features of guava varieties.
3. Write down the morphological characteristics of papaya varieties.
4. Write down the varietal characteristics of banana.
5. Write down the important varieties with features of other tropical fruits viz. jackfruit, pineapple, custard apple etc.

Exercise No. 2

Description and Identification of Varieties Based on Flower and Fruit Morphology in Sub-Tropical Fruit Crops.

2.1 Description and Identification of sweet orange (*Citrus sinensis*) Varieties.

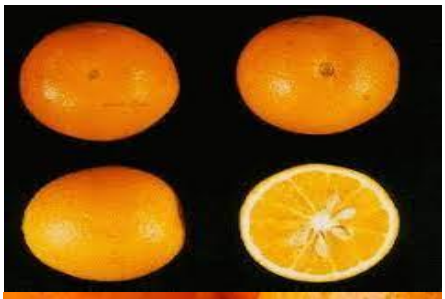
1. Mosambi: This variety of sweet orange is grown in Maharashtra and Andhra Pradesh .
Fruit light yellowish orange in colour, surface rough with prominent streaks on the rind, oblate to spherical, apex broad, rind thick, well-defined segments numbering 9 to 12, peeling difficult, pulp light yellow; juice sweet.

2. Malta (Common) : It is commonly grown in Punjab and Haryana, Fruit orange-yellow, surface smooth; shape spherical; medium to large in size; thickness of the rind medium, segments 10, well-defined; pulp orange, abundant juice, good flavor.

3. Malta (Blood Red): It is a popular variety of Punjab: Skin yellow with scarlet blush. Rind is relatively thin, tight and glossy. Pulp corn coloured and red strea ked, early ripening; pulp sweet, abundant juice, red coloured, pleasant flavour

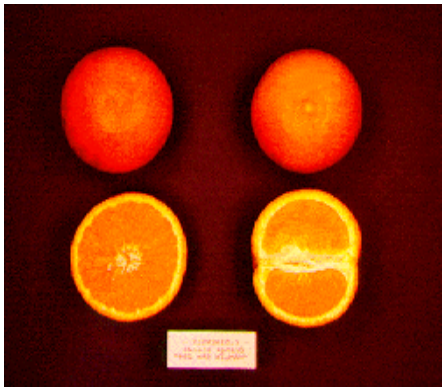
4. Sathgudi: It is a popular variety of Andhra Pradesh, Fruits are smooth and have attractive orange colour, shape spherical, size variable, rind medium thick, segments 10 to 12, pulp orange coloured abundant juice, good flavor

5. Pineapple: Trees are medium in size having spreading habit. Medium-size and Juicy Fruits. 10-20 Seeds are present per fruit. Fruit Ripens in the months of December-January. The average fruit yield is 38 kg per plant.



***6.* Jaffa:** This cultivar was discovered during the first half of the 19th century in an orchard near Jaffa, in Palestine and is probably a bud mutation of the local Beledi variety. The plant has thick foliage with an upright gr owth habit, average vigour, and high although not always consistent productivity.The oval or elliptical fruit are very large with slightly flattened ends and short radial furrows. The thick rind is evenly orange, with a medium-smooth surface, and peels easily. The tender, pale orange flesh is firm and aromatic with excellent sweet flavour. It is both eaten fresh and used for juice production.The fruit ripens from December through until the end of April and holds fairly well on the tree.

***7.* Hamlin:** Hamlin was found as a spontaneous seedling in the garden of A.G. Hamlin near Glenwood, Florida. It proved to be a new variety and was named after its finder. Hamlin has survived severe weather and several nights of frost, which has made it a popular variety in the northernmost regions of the citrus belt.
Hamlin is an early variety; the first fruit reach maturity in October and are seedless. Hamlin is juicy and very productive. It is one of the most important varieties for the Florida orange juice industry. Hamlin is also known as Norris.



Valencia is the world's most important orange variety. It originated in either Spain or Portugal, no one knows which. It was introduced to Florid a in 1870. It is a major variety in Florida, California, South Africa and Australia. Over 50% of the production is pressed for juice. Valencia grows well, is easy to cultivate and very productive. The fruit is of a high quality and commercially seedless (0-6 seeds). The peel is thin and the pulp is tender and very juicy. Valencia is a late variety and keeps well on the tree. It can be picked until late spring, or even early summer, which prolongs the season and increases productivity.
Valencia is one of the oranges that also thrives in the tropics. The fruit are of high quality

but in the heat and without cool nights the colour break does not occur and the fruit remain greenish in the tropics even when fully ripe. Producers treat the fruit with a gas to make the colour more attractive to the consumer.

Washington Navel is either identical with the Brazilian 'Bahia' navel or a close mutant of it. It was imported from Brazil to Washington in 1870 an d developed for release in Riverside, California. Washington Navel is the second most important orange variety in the world after Valencia. It is the leading variety in Brazil, California, Paraguay, South Africa, Australia and Japan.

The large exceptionally delicious round seedless fruits are rich in flavour and have a slightly pebbled orange rind that is easily peeled. The Washington navel is early in maturity, at its best in the late autumn to winter months, but will hold on the tree for several months beyond maturity and stores well. The original source of budwood for this variety, the Parent Washington from 1873 is still alive in Riverside and produces fruit. It was 134 years old in 2007.

Student's activities:

1. Write down the varieties of sweet orange with their special characteristics.
2. Evaluate the sweet orange varieties based on morphological characteristics.
3. Evaluate the sweet orange varieties based of physic-chemical characteristics.

Exercise No-3

Training and Pruning of Grapes, Mango, Guava and Citrus

A primary objective of training and pruning is to develop a strong tree framework that will support fruit production. Improperly trained fruit trees generally have very upright branch angles, which result in serious limb breakage under a heavy fruit load. This significantly reduces the productivity of the tree and may greatly reduce tree life. Another goal of annual training and pruning is to remove dead, diseased, or broken limbs. Proper tree training also opens up the tree canopy to maximize light penetration. For most deciduous tree fruit, flower buds for the current season's crop are formed the previous summer. Light penetration is essential for flower bud development and optimal fruit set, flavor, and quality. Although a mature tree may be growing in full sun, a very dense canopy may not allow enough light to reach 12 to 18 inches inside the canopy. Opening the tree canopy also permits adequate air movement through the tree, which promotes rapid drying to minimize disease infection and allows thorough pesticide penetration.

Pruning vs. Training

Pruning is the removal of a portion of a tree to correct or maintain tree structure. Training is a relatively new practice in which tree growth is directed into a desired shape and form. Training young fruit trees is essential for proper tree development. It is better to direct tree growth with training than to correct it with pruning.

Time of Pruning

Trees respond very differently to dormant and summer pruning. Dormant pruning is an invigorating process. During the fall, energy is stored primarily in the trunk and root system to support the top portion of the tree. If a large portion of the tree is removed during the winter, while the tree is dormant, the tree's energy reserve is unchanged. In the spring, the tree responds by producing many new vigorous, upright shoots, called water sprouts, which shade the tree and inhibit proper development. Heavy dormant pruning also promotes excessive vegetative vigor, which uses much of the tree's energy, leaving little for fruit growth and development.

Timing of dormant pruning is critical.

Pruning for crop regulation

Pruning in fruit trees play important role in crop regulation also. Recently it has been found very effective in managing the canopy of guava as wel as regulating the fruiting time also. In a humid and high rainfall area like Arunachal Pradesh, crop regulation of guava by using chemicals and growth regulators such as Urea, NAA, etc. are not much effective because the plant do not go into dormancy due to abundant rainfall received in this area which starts from the month of March. Therefore, pruning could prove to be the most effective method for eliminating rainy season crop and production of winter season guava.

If the guava tree is left unpruned, they tend to prolong the vegetative growth, reduce the bearing area, thus leading to decrease in fruit size, yield and quality. Hence, to get a good balance between the vegetative and reproductive growth, pruning becomes essential (Hau Ngaih Lian *et al*., 2019).

Pruning in Mango

Pruning in perennial fruit crops like mango, pruning is unavoidable necessity to control the canopy size and to produce high quality marketable fruits by facilitating better ventilation, high penetration of sunlight, easy application of plant protection chemicals and ease in harvesting (Burondkar et al.,1997; Gross, 1996). Pruning in mango has two important goals like encouraging the branching of young trees particularly in cultivars which do not branch readily on their own, stimulating the development of new shoots and maintaining the tree size (Oosthuyse, 1994). Juvenile trees do not flower due to short intervals between vegetative flushes. Normally mango tree takes three to four years to reduce the flushing frequency and sufficient stem maturity there by allowing flowering and to produce a commercially viable crop. Tip pruning forces a synchronized flush from pruned stems, which results in synchronized flowering in Keitt mango (Davenport, 2006). At harvesting, if the fruits are plucked along with the panicle, light pruning is affected automatically and the tree could send forth, from the distal lateral buds. The age of the last flush is the dominant factor regulating flowering of mango. Stems must be generally about 4 to 5 months to be able to induce for flowering in the next year (Davenport, 2003). Pruning is effective for early and higher accumulation of reserves by enhancing uniform post-harvest flushing and reduces flowering variation (Oosthuyse, 1994). Dashehari mango produced the maximum number of panicles in July pruned trees (Swaroop *et al*., 2001). Moderate pruning and spraying with GA3 at 100ppm, is promising for mango since it increased length of new flushes, panicle length and improved yield of Zebda mango trees in the off-year season (Shaban, 2009).

Training

Physical techniques that control the shape, size and direction of plant growth are known as training.

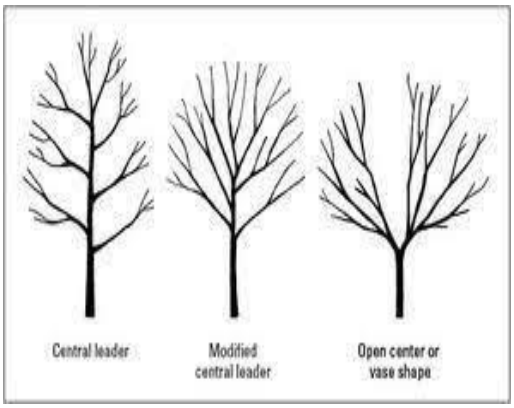
Objectives:

- To improve appearance and usefulness of plant/tree through providing different shapes and securing balanced distribution.
- To ease cultural practices including inter cultivation, plant protection and harvesting.
- To improve performance like planting at an angle of 45° and horizontal orientation of branches make them fruiting better.
- To admit more sunlight and air to the centre of the tree and to expose maximum leaf surface to the sunlight.
- To direct the growth of the tree so that various cultural operations, such as spraying and harvesting are performed at the lowest cost.
- To protect the tree from sunburn and wind damage.

- To secure a balanced distribution of fruit- bearing parts on the main limbs of the plant.

Training Systems

- ✓ Central Leader
- ✓ Open- Centre
- ✓ Modified Leader



Central Leader System

- ✓ Main trunk extends from the soil surface to the total height of the tree
- ✓ Several side branches grow at different heights in various directions.

Advantages:

- Such trees are structurally best suited to bear crop load and to resist the damage from strong winds.

Disadvantages: – Trees under this system grow too tall and are less spreading.

- Tree management (spraying, pruning, thinning and harvesting) is difficult.
- Shading effect on interior canopy (the lower branches of such trees may be so much in shade that the fruit may not be able to develop proper colour).

Open Centre System

- Main trunk is allowed to grow upto 1.0 m by cutting within a year of planting.
- 3-5 lateral branches are allowed to develop from short main stem.
- Good for mechanical harvesting.

Advantages:

- The trees so trained allow maximum sunshine to reach their branches.
- Better clouration of fruits on the interior side of the tree.
- Trees are more fruitful and low spreading tree greatly facilitate operations like spraying, pruning, thinning and harvesting.

Disadvantages:

- Such trees are structurally weak, and their limbs are more likely to break with crop load and strong winds.
- This system does not only need severe pruning to start with but also constant effort to maintain its form through drastic pruning treatment.

Modified Leader System

- This system combines the best qualities of the central leader and open centre systems.
- A leader develops on the young tree until it reaches the height of 2-3 m and then the growth is restricted.
- Laterals are selected to ascent in a spiral fashion up the central trunk and are cut until the proper number and distribution of branches have been obtained.

Advantages:

- The branches are well distributed, allowing plenty of sunshine to reach the interior of the tree.
- The trees are structurally strong and not prone to limb breakage. –
- Owing to limited height of trees, spraying, pruning and harvesting may be done easily.

Bower System

This system is also called overhead, arbour or pergola.Owing to vigorous of the vine and pronounced apical dominance in the tropics, this system is found most suitable for many of the commercial grape cultivars. Though it is very expensive, it was found most appropriate one and associated with highest yield. Bower system of training provides a desirable microclimate in the vine canopy and reduces the adverse effects of arid and hot weather on vine metabolism and life.

Kniffin system

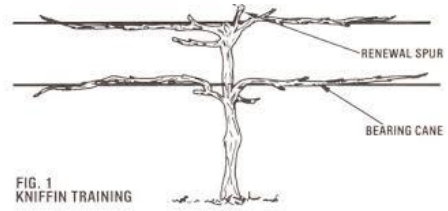


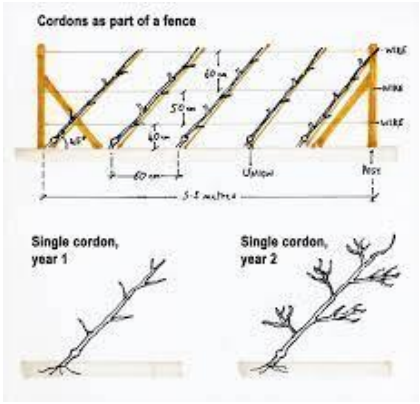
FIG. 1
KNIFFIN TRAINING

In this system, two trellis of wire are strongly supported by vertical posts. The vines such as grape when trained in this system has four canes one along each wire and the bearing shoot hangs freely with no tying being necessary.

Telephone system

This system consists of 3 or 4 wires usually kept at 45-60 cm apart fixed to the cross-angle arms supported by vertical pillars or posts. Vines are allowed to grow up to a height of 1.5 to 2.0 m and then trained on this system. Moderately vigorous cultivars with apical dominance are best trained on such system.

Head System: It is mostly used for spur bearing grape cultivars. In this system, vines are trained like a small bush. Vines are allowed to, grow up to 1.2 meters, and then headed back to produce laterals. Four laterals- one in each direction is allowed to grow and rest are thinned out. In next dormant season, these laterals are cut back to 2 buds and further two arms of 20-30 cm are allowed on each secondary arm. After 3-4 years these vines will give a dwarf bush like appearance and requires no staking.

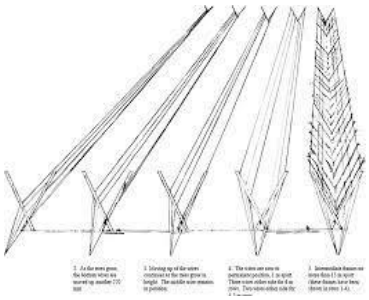


Other training systems which require no staking are Palmette, Spindle bush, Dwarf pyramid and Head and spread systems.

Cordon and Espalier system: Plants are trained to grow flat on trellis or on horizontal wires by training

the branches perpendicularly to the main stem on both the sides, and trained horizontally on the wires. Plants trained in this system are called 'espaliers'. An espalier with one shoot or two shoots growing in opposite or parallel directions are called a ‘cordon'.

Tatura trellis: In this system, trees are trained to a multi-layered wire trellis. The trellis is V-shaped, supported by two long, stout poles embedded into the soil angles of 600 from the horizontal. Five wires at 60cm intervals are fastened to these poles. This system is being now followed for pome fruits, nut fruits and grapes. The trees are grown as double leader. Trees with each leader inclined at an angle of 600 from the horizontal.



Student’s activities:

1. Differentiate between training and pruning. What are the principles of training and pruning?
2. Write down the steps for training and pruning in mango, citrus and guava.
3. What are the different training systems followed in grape. Draw neat and clean diagram.

Exercise No. 4

Selection of Site and Planting System

4.1 Selection of Site

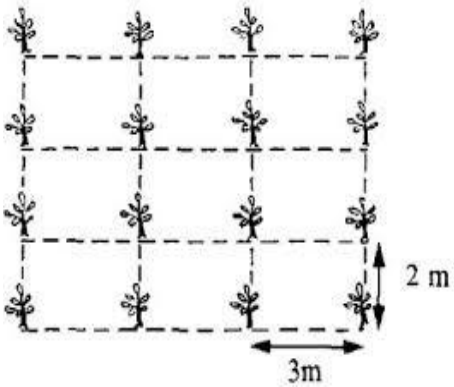
Proper selection of site is pre requisite for establishing the fruit orchard. As the phenotypic characters of plant are affected by the combining effect of the genotype and the environment the grower must select the crop to grow according to the particular climatic conditions. Selection of site must be based on the following parameters:

- Location of orchard should be in well established fruit growing regions as one could get the benefits from the experienced growers, easy market facility etc.
- Proper transportation facility must be there as horticultural produces are perishable (decay or destroyed quickly) in nature
- Market area should be close to the orchard.
- The climate of the region where, one wants to develop its orchard, should be specific to the crop grown. There should be well distributed rain fall, availability of optimum sunlight with less diurnal variation. The climate should not be more humid, which may allow the growth of diseases and pests. For example in grape high humidity favours the growth of powdery mildew fungus.
- Adequate supply of water throughout the year.
- Suitability of soil, its fertility, soil depth and nature of subsoil must be observed. Soil with a pH at neutral range, along with loose sub soil is the best for the root environment. There should not be fluctuating water table, which may hinder the physiological activity of the root.
- Site must have proper drainage during the rainy season.
- Irrigation water must of good quality free from metals and other impurities causing harm to micro irrigation systems.
- Proper and efficient analysis of seasonal gluts (demand of the produce is more than supply) and over production in the particular season of the year in the locality.
- The local demand on some specific crops must be looked and taken into consideration.
- Land should be cheap and in plenty nearer to the site for future expansion of the orchard.
- Sufficient availability of manure in cheap rate in the locality.
- Site must be free from all kind of natural disasters like flood, drought, heavy winds, frost etc.
- Availability of skilled labour plentily and in cheap rate in the locality of orchard.

Orchard Lay out

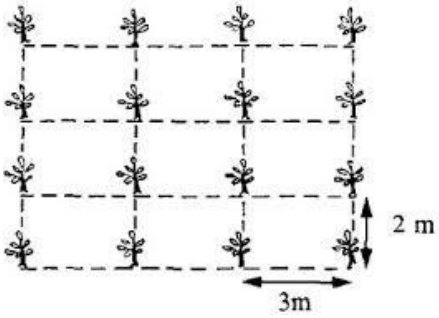
The plan showing the arrangement of plant in an orchard is known as plant layout. Although several systems of planting are followed, but selection of a suitable system, depending on soil, climate, plant type, system of training and pruning is very important. Adoption of improper system results in over lapping of plant parts and competition for water, light, nutrient and unequal distribution of water etc. There are several planting plans or systems which can be adopted for planting an orchard. The different system of planting is as follows:

1. Square system

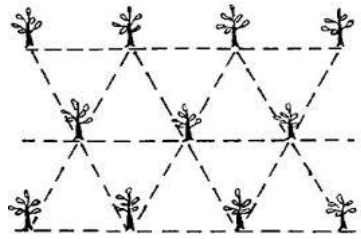


It is the most easy and popular method of planting fruit plants. In this system row to row and plant to plant distances are kept similar. The plants are planted exactly at right angle at each. Thus, every four plants make one square. Intercultural operations can be done in both directions as the distances between trees and rows are similar. Adequate space is there to for inter-cultivation of remunerative crops like vegetables

2. Rectangular system: The field is laid out into rectangular shape plot keeping more space between row and row. The plant to plant distance is kept comparatively less. Thus, rectangular system accommodates more plants in rows. Inter-cultural operations can be carried out through both ways. The plants get proper space and sunlight for their growth and development.



3. Hexagonal system: This system accommodates 15 % more plants than square system. It allows three directionals cultivation in the orchard. In this system, the orchard is laid out similar to rectangular system. The diagonals of rectangles are intersected to form equilateral triangles. The trees are planted at the vertex of each equilateral triangle. Thus, six trees form hexagon with the seventh tree in the centre. Hence, this system is also called as “septule’ as it accommodates seventh tree in the centre.

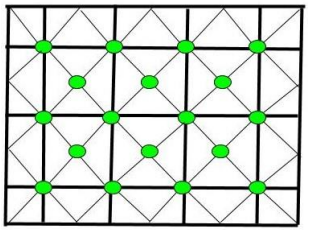


The hexagonal system is considered as a grid of contiguous equilateral triangle in which the length of each arm of the triangle is desired tree to tree distance. This is very

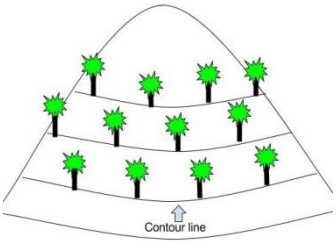
intense method of planting and hence requires fertile land. In the suburb of cities where land is costly, this system is worth adoption. However, the laying out of system is hard and cumbersome

4. Quincunx system

This system is similar to square system except one additional plant is planted in the centre of each square. The plants that are planted in the centre of each square along with tall growing plants at the corners of squares are termed as 'filler' plants. These plants are planted with a view to generate income when the main orchard plant is under non-bearing stage.



5. Contour system: It is adopted in hilly areas for planting fruit plants where land is undulated and soils erosion is a great threat. Under such circumstances, contour terrace is developed by scratching and leveling the hill-slope. The width of contour terrace varies according to the slope of the hill. At stiff hill slope, the width is kept narrower.



Calculation of Number of Plants in different Systems of Planting

The number of plants that can be accommodated by each of the systems in a unit area should be calculated by the formula shown against each system as under:

1. **Square System** = $\frac{A}{L \times P}$

   A= Field Area

   L= Row to Row spacing

   P= Plant to Plant spacing

   Example- Area is 10000 sq. metre and planting distance is 10x10 (m) then

2. **Rectangular System** = = $\frac{A}{LXP}$

   A= Field Area

   L= Row to Row spacing

   P= Plant to Plant spacing

   Example- Area is 10000 sq. metre and planting distance is 10x 8 (m) then- Number of plants=10,000/10 × 8 = 125 Plants

3. **Quincunx System-** As the plants are planted additionally in the centre of the square, hence first the number of plants is calculated for square system of planting

   which is- No of Plants= Area in square meter/Planting distance in metre square=10,000/10 X 10 = 100 Plants.

   Additional plants = (No. of rows length wise - 1) × (No. of rows width wise -1)

   In 100 × 100 sq. metre field if planting distance is10 × 10 m. then number of rows length wise and width wise will be 10. Hence, No of additional plants (10-1) × (10-1) = 9 × 9 = 81

Total number of plants = Pants planted in Square system of planting + additionally planted plants in the centre of square ie. 100 + 81 = 181

4. **Hexagonal system** = $\frac{\text{Area x 115}}{\text{Spacing 100}}$
5. **Triangular system** = $\frac{S}{D\ 2x0.8666}$

S= unit surface

D = Length of the triangle side

Student's activities

1. Write down the criteria for selection of sites for an establishment of an orchard.
2. What are the different systems of layout of fruit crops? Draw the schematic diagram of different planting systems.
3. Calculate the plant population of amrapali mango planted at spacing of 2.5m x 2.5 m in square system of planting.
4. Calculate the plant population of Mallika Mango planted in hexagonal system at spacing of 3m x 3m.

Exercise No. 5

Objective: Pre-treatment of Banana before planting.

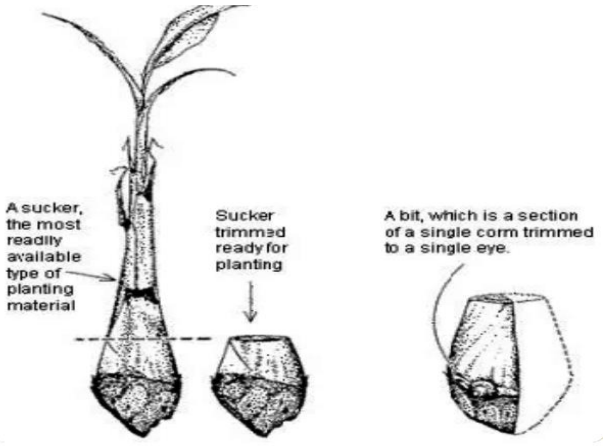
Banana is commonly propagated by sword suckers. A sucker is a lateral shoot/ shoots that develops from the rhizome and emerges from the soil usually near the parent plant. Most farmers used sword suckers obtained from own farm or from neighbors to extend existing or establish new banana orchard. The practice of using infected sword suckers has continuously perpetuated the spread of banana diseases and pests. To mitigate this problem suckers need to be disinfected before planting.

Materials required:

- Healthy and disease free planting material (Sword suckers)
- Emisan (fungicide)
- Vermiwash
- Trichoderma viride and pseudomonas
- Water
- Sharp knife
- Thermometer
- Hot water

Steps for Chemical treatment

- Care should be taken to select the disease free suckers.
- Select the sword suckers of 1.5 to 2 kg weight which are free from diseases and nematodes.
- Trim the roots and decayed portions of the corm, cut the pseudostem leaving 20 cm from the corm and grade the suckers to size.



- To avoid the wilt disease in some cultivars Rasthali, Monthan and other wilt susceptible cultivars infected portions of the corm may be pared and dipped for 5 minutes in 0.1 % Emisan solution 1 g in 1 liter of water
- OR
- Suckers should be soaked for 10 minutes in a solution prepared by mixing 100 liters of water with 3 liter vermiwash with trichoderma viride and pseudomonas to avoid nematode attack.
- Alternatively, dip the corm with 0.75 % monocrotophos and shade dry for at least 24 hours and plant.

A. Steps for Suckers disinfection through Hot water treatment

Hot water treatment is generally done to eliminate nematode and banana weevil.

Hot water treatment at 50°C of peeled (pared) suckers for 20-25 minutes will effectively reduce nematode and weevil infestation in the plant crop and successive cycles (ratoons) of both plantain and cooking banana. The method has been difficult for smallholder farmers to manage and implement because of the delicate balance needed to achieve a temperature that is lethal to nematodes and weevils in the corm tissue without causing permanent damage to the plant. For commercial plantations and organized cooperatives, for example, this method of sucker sanitation remains a useful and effective technique. For smallholders the method is time-consuming, cumbersome, and tricky to regulate.

The process involves the following:

- ✓ Trimming of all the roots.
- ✓ Cutting of 1 cm of tissue around the corm until you get clean white tissue.
- ✓ Prepare hot water.
- ✓ Immerse the trim corm in the hot water bath at 50 -55 ^{o} C for 20 minutes.

B. Boiling water treatment:

To improve the adoption of the hot water treatment, the technique of using boiling water and immerse suckers for a short and easily measurable time, in farm situation where there is no thermometer, suckers are dipped in boiling water for between 20 and 30 seconds. They should preferably be peeled, but can be used with the roots still attached. Water can be boiled in any suitable container that is large enough, over an open fire on a temporary or purpose-made frame. Used oil drums are perfect for this purpose, either cut in half or used whole. Suckers are submerged using a basket or net.

The boiling water technique has proved a promising alternative to the use of hot water, reducing the length of time needed for the operation, and simplifying the temperature and timing measurements. It also effectively disinfested suckers of various sizes of plantain and banana without detriment to sucker germination. A period of 30 seconds is viewed as an optimum duration; a longer time has risks of sucker damage for especially small suckers, and a shorter time may be less effective for especially larger suckers. Treatment of suckers with boiling water will improve plant quality and productivity through the elimination of pests and the consequent long-term improvement of root health. Smallholder farmers have relatively few options for nematode and weevil management so this treatment offers a suitable mechanism for disinfesting planting material of banana which could prove essential in reducing losses among smallholders.

Sodium hypochlorite dip method

In order to avoid nematode damage suckers can be treated by dipping in a diluted household bleach solution consisting of one part bleach (6.0% sodium hypochlorite or NaOCl, unscented and without other additives) and nine parts water—for 10 minutes prior to planting. Dipping in bleach may reduce plant vigor, but it is an easily accessible method for most farmers.

Exercise to be done

1. What is the different method of sucker's treatment in banana?
2. Carry out the chemical treatment of banana suckers before planting and write down the steps involved.
3. Carry out the hot water treatment of banana suckers and write down the steps involved.

Exercise No. 6

Objective: To study about the de-suckering in Banana.

During the life cycle, banana produces number of suckers from the underground stem. If all these suckers are allowed to grow, they grow at the expense of the growth of the main plant and hence the growth of the sucker should be discouraged. Otherwise these suckers compete with the main plant for its food and nutrients. It may also lead to incidence of leaf spot disease due to congestion in the interspaces, lack of aeration, sunshine and high dampness. Thus, controlling these suckers is a must to maintain normal bunch weight and quality. Removal of unwanted suckers is one of the most critical operations in banana cultivation and is known as de-suckering. Such suckers are removed either by cutting them off or the heart may be destroyed without detaching the sucker from the parent plant. Removal of suckers with a portion of corm at an interval of 5-6 weeks hastened shooting and increased the yield.

Materials required

- ✓ Sharp sickle/knife
- ✓ Crow bar or Iron rod of 1.3m long and 1.2 cm diameter.
- ✓ Kerosene oil

Purpose of de-suckering

1. To select best flowers suckers and to prevent competition.
2. To conserve the homogeneity of plant layout in field.
3. To maintain the plant population per unit area.
4. To increase the banana bunch weight.

Steps for de-suckering:

- o Dig up sucker and cut it off from its point of attachment to mother plant.
- o Desuckering should start 45 days after planting of banana. The side suckers should be removed from the mother plant by cutting at their base.
- o Leave 3- 5 main stem of varying age per stool. This arrangement gives continuous crop throughout the year. The fewer the number of stems the bigger the size of bunches.
- o Thereafter, a few drops of kerosene should be poured inside to restrict further growth. This process should repeat every 45 days till the plant flowers.
- o De-suckering of banana can also be done by using chemicals like 2,4D. A pruning paste consisting of mixture of 2, 4D, fuel oil and grease may also be applied for Desuckering.

- Remove all the suckers of the mother plant till flowering and allow only one sucker at the time of 50 % flowering.
- In order to prevent sprouting inserting of peg on growing part is recommended.
- At the time of harvest of the first crop, the set sucker will become ready for the next ratoon.

Precautions to be taken while de-suckering:

1**.** Suckers are to be periodically removed otherwise they compete with the mother plants for nutrients, resulting in lower bunch weight vis a vis yield.

2. During the process of de-suckering care is taken not to damage the mother plants.

3. Once the plant starts flowering mother plants should not be disturbed.

4. Do not pour diesel of kerosene over the pseudo stem instead water them.

5. Removal of all suckers up to flowering of the plant and maintaining only one follower is the best de-suckering practice.

Exercise the following:

1. What is the purpose of de-suckering in banana?
2. Write down the steps for de-suckering in banana.
3. What precautions have to be taken care while de-suckering?
4. Practice the de-suckering in banana field.

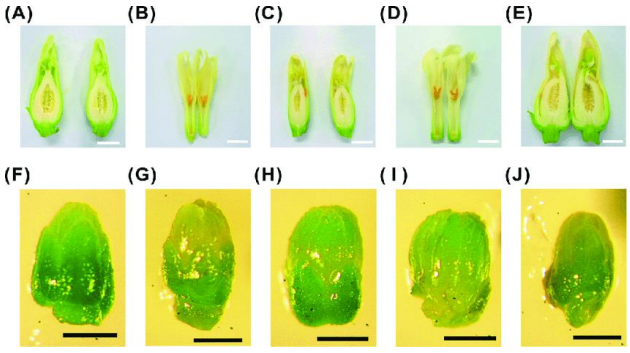
Exercise No. 7

Objective: To study about sex expression in Papaya.

In nature, papaya is dioecious plant where both male and female flowers are separately located but due to interference and proper selection by human, gynodioecious plants have been originated with female, male and perfect flower which is also known as hermaphrodite flower. Female flower bears fruit in papaya so female ratio should be high as compare with male plant for proper and high production. In India, gynodioecious cultivars are mostly preferred for plantation of papaya due to high female: male ratio but constraint regarding gynodioecious cultivars are that these are costly but dioecious plants or cultivars which are very cheap in cost as compared with gynodioecious plants are less preferred for plantation due to low female: male ratio.

Sex form in *Carica*

All members of Caricaceae are dioecious except *C. monoica* (Monoecious), *Carica papaya* and *C. pubescens* having three sex forms ie., Pistillate, staminate and hermaphrodite where hermaphrodites are ambivalent and show seasonal sex reversal to produce all the three sex forms at different seasons of year. Thus, *Carica papaya* is trioecious plant species where sex expression is defined by sex chromosomes. Hofmeyr's hypothesis based on Genic balance theory (1939, 1967) confirmed triallelic genic regulation of sex form in Carica where M_1 is dominant for maleness, M_2 is dominant for hermaphroditism and m is recessive for femaleness. Thus, M_1m is staminate; M_2m is hermaphrodite; and mm is pistilate whereas, M_1M_1, M_2M_2, and M_1M_2 are lethal. Dioecious varieties of papaya are cheaper than that of gynodioecious but the main problem regarding dioecious plants are that the female:male ratio which is lower and growers who grow dioecious plant comes in big loss.



Flowers of the different sex types of papaya. (A) female; (B) male; (C) normal hermaphrodites; (D) carpellody hermaphrodite; (E) female degradation hermaphrodite; (F) 0.2 cm female buds; (G) 0.2 cm male buds; (H) 0.2 cm normal hermaphrodite buds; (I) 0.2 cm carpellody hermaphrodite buds; (J) 0.2 cm female degradation hermaphrodite buds.
Source publication: https://doi.org/10.1371/journal.pone.0194605.g001

Method of seed production: Sib mating/selfing

- To maintain the purity of papaya seeds, sib-mating is necessary ie., mating of sister and brother plants from the same parent.
- In this method, seeds from the fruits of a tree which show the typical parental qualities of the tree, i.e. leaves and fruits are first selected.
- The seeds of these fruits are sown and the seedlings transplanted in the main field and when these plants put forth flowers, progenies conforming to the characters which formed the basis for the original selection are marked among the female as well as male plants.
- Pollens from the male plant is taken and put on the stigma of female flowers one day ahead of opening of the flowers.
- The female flowers are then covered with butter paper bags to prevent their contamination with other flowers. It is marked with a tag.
- The fruit sets in about five to seven days when the bag is removed. When these sib-mated fruits mature, they are harvested and the seeds are extracted from raising second generation of plants.
- This process is continued from generation to generation while the entire population
- Raised from the in-breds show uniformity of characters for which selections were originally made.

Exercise No -8

Use of plastics in fruit production

Plastic has become a popular material in our daily life due to its structural integrity, chemical property and versatile nature. Plastic has many valuable applications in high-tech horticulture includes drip irrigation, plastic mulches, packaging and storage for superior quality of produce and in post-harvest management. The plastic films are easily available, easy to handle, transport and lay. In fruit production, right from nursery raising to harvest including transport and packaging at every step plastic products are utilized. Due to multiple reasons, it is quite easy to use but difficult to dispose of in safe and eco-friendly way. Here are some fruit production related activities where use of plastic has been described for students in their practical classes:

Propagation

In the propagation plastics are generally used in layering and grafting. In grafting polythene strips are used to tie stock and scion. Different colours of poly-wrappers used in layering. Red, blue and black poly-wrappers having higher success in rooting and survival by increasing physiological activities (etiolation effect) which is essential for cell division and cell enlargement.

In Nursery Raising

In nursery plastics are used in form of nursery bag, plug tray, crate and hanging basket. It is easy to handle, planting, transplant and transport. This plastic nursery bags can be used in different size and thickness depend on crop.

Use of Plastic in Soil Solarisation

Soil Solarisation is normally done during summer months when the air temperature more than 35°C. This is done by covering the moist soil with a transparent polyethylene film exposed to sunlight. Soil solarisation can prevent weeds growth, occurrence of bacteria, fungi, nematodes and other soil borne pathogens and pests, helps in reducing usage of weedicides/herbicides and pesticides. The effectiveness of soil solarisation enhances plant growth by improving soil colour, structure, temperature, moisture etc. Soil moisture, day length, temperature and intensity of sunlight are the factors effecting soil

solarisation. Suggested polyethylene film for soil solarisation is 25 micron transparent polyethylene film

Plastic Mulches

Black plastic film does not allow sunlight to pass through onto the soil. Thus, photosynthesis does not take place in soil in absence of sunlight below the black film. Hence, it arrests weed growth completely. The black plastic mulch is helpful in conserving moisture and controlling weed growth. However, it may increase the soil temperature. While the black plastic film has proved to be effective in plains to keep crop cool during summer, the transparent plastic film is effective in hilly areas for raising soil temperature in cold climatic conditions during winter. In wavelength selective or photo-selective films (also known as two-side coloured) are designed to absorb specific wavelengths of sun's radiation, which changes the spectrum of the sunlight passing through the film or being reflected back into the plant canopy.

Strawberries are cultivated either in open fields or in greenhouses. Many types of polyethylene films (plastics) are utilized in heating, water conservation, and plant protection, which all affect plant and fruit development. Different types of plastics are also used during field cultivation for overhead covering and protection. Strawberry fruiting fields may be completely protected by plasticulture, whether grown under low tunnels (cloches) or walk-in greenhouses. Drip-irrigation using plastic piping is widely used during all stages of strawberry production, primarily to conserve water, but also to reduce moisture and consequent disease incidence.

White Film Mulching: White film mulching, by reducing the amount of transmitted radiation, lowers the soil temperature.

Black Film Mulching: Black film mulch is opaque to incoming solar radiation and actsυ like black body absorber (UV, visible, and infrared) and radiator (infrared).

Infrared Transmitting Film Mulch: Infrared transmitting (IRT) film mulch isυ discovered recently in polymeric mulch technology and selectively transmits a section of electromagnetic spectrum.

Colored Film Mulches: Red color mulch gives best results in tomato while blue coloru mulch produces best result for peppers by reflecting photosynthetic active wavelengths.

Silver mulch is reported to control whitefly, whereas yellow-brown plastic mulch is reported to delay the incidence of yellow leaf curl.

Water Management

Plastic plays a major role in water management technology in the rural sector

Minor irrigation system: Plastic pipes, tubings and components particularly fromυ PVC/HDPE/LDPE have been found to offer most effective techno-economics solution for viable minor irrigation widely all over the world in the following irrigation system.

Sprinkler system:

Sprinkler system raises water utilization efficiency to 60-85 per centυ as against other irrigation methods which are 25-35 per cent. Crops like wheat, gram, pulses, vegetables groundnut, sugarcane, cotton, soybean, fruits etc. can be effectively irrigated by plastic sprinkler irrigation systems.

Drip/trickle irrigation:

The water saving can amount up to 60-70 per cent implying an almost 3-fold extension of the area of crop possible from a well, canal, etc. This method involves laying plastic next to the base of the plants through which water drips or trickles at a predetermined rate through emitters. The lateral line is made of flexible PVC or LDPE whereas rigid PVC/HDE is used for subsurface lines only. It connects LDPE/HDPE micro tubes or distributors to the sub-main line. The latter is usually made of MDPE or rigid PVC and connects with laterals with HDPE/rigid PVC main line.

Tube wells: The usage of plastic for tube wells in irrigation is essentially as casing and strainer pipes of HDPE/PVC

Flow irrigation/lift irrigation:

Plastic pipes and tubing (HDPE/PVC/LDPE) haveυ effectively replaced flood irrigation and open channel irrigation for better and more efficient water management.

Drainage: Water logging usually results in salinity problems as they water evaporatesυ with time leaving behind salty oil unfit for agriculture. Hence, good irrigation plans need to have a parallel drainage system. HDPE and rigid PVC pipes are widely for drainage of land and lowering water tables.

In post Harvest Management

The following are the important plastic materials that can be used for packaging of fresh fruits and vegetables.

1. Polypropylene boxes

Polypropylene corrugated board can be used easily for horticultural produce. Added advantage of this material is that it can be reused quite a few times.

2. Stretch/cling wrap

This is actually a polyethylene or polypropylene film which has the property that under tension it stretches and when the tension is released it comes back to its original form. This property helps in packaging the product tightly. The whole operation can be carried out without application of the heat eg. cabbage, fresh cut vegetables etc.

3. Moulded plastics (Plastic crate)

Reusable boxes moulded from high-density polythene are widely used for transporting produce in many countries. They can be made to almost any specifications. They are strong, rigid, smooth, easily cleaned and can be made to stack when full of produce and nest when empty in order to conserve space. Despite their cost, however, their capacity for reuse can make them an economical investment.

4. Plastic Bags

Plastic bags (polyethylene film) are the predominant material for fruit and vegetable consumer packaging. Besides the very low material costs, automated bagging machines further reduce packing costs. Film bags are clear, allowing for easy inspection of the contents, and readily accept high quality graphics. Plastic films are available in a wide range of thicknesses and grades and may be engineered to control the environmental gases inside the bag. The film material "breathes" at a rate necessary to maintain the correct mix of oxygen, carbon dioxide, and water vapour inside the bag. Since each produce item has its own unique requirement for environmental gases, modified atmosphere packaging material must be specially engineered for each item that respond to temperature and control the mix of environmental gases.

5. Shrink Wrap

One of the newest trends in produce packaging is the shrink wrapping of individual produce items. Shrink wrapping has been used successfully to package potatoes, sweet potatoes, onions, sweet corn, capsicum and cucumbers. Shrink wrapping with an engineered plastic wrap can reduce shrinkage, protect the produce from disease, reduce mechanical damage and provide a good surface for stick-on labels. In this method, vegetables are wrapped in heat-shrinkable plastic film. The main advantages of film wrapping of vegetables are

- reduced weight loss and extended shelf life,
- reduced chilling injury,
- minimized vegetable deformation,
- reduced decay by preventing secondary infection of packed produce.

***6.* Rigid Plastic Packages**

Packages with a top and bottom that are heat formed from one or two pieces of plastic are known as clamshells. Clamshells are gaining in popularity because they are inexpensive, versatile, provide excellent protection to the produce and present a very pleasing consumer package. Clamshells are used extensively with pre-cut produce and prepared salads.

Paper or plastic film is often used to line packing boxes in order to reduce water loss of the contents or to prevent friction damage.

8. Paper pulp trays

Containers made from recycled paper pulp and a starch binder is mainly used for small consumer packages of fresh produce. Pulp containers are available in a large variety of shapes and sizes and are relatively inexpensive in standard sizes. Pulp containers can absorb surface moisture from the product, which is a benefit for small fruit and berries that are easily harmed by water. Pulp containers are also biodegradable, made from recycled materials, and recyclable.

Use of Plastic in Protected Structures

Low Tunnel Also called 'miniature greenhouses', low tunnels generally cover rows of plants in field and, therefore, they are also known as row covers. Clean plastic films or nets are stretched over low wire hoops (arcs up to 1.0 m high) to protect plants against frost, wind, insects and pests.

Walk-in tunnel

It is a temporary structure made by using GI pipes or bamboo, and is covered with different cladding material depending upon the season in which the cultivation is proposed. Walk-in tunnels are used for off-season cultivation of vegetables and flower seedlings. They give an advantage of better prices of the off-season produce, giving more profit per unit area.

Shade Net House

It is primarily constructed to protect plants from highly intense solar radiation. The structure is made of wood, stone, bamboo or GI pipes. When wood or bamboo are used, the poles are treated with turpentine and tar on one side before inserting them in the ground. Cladding material used on the top and sides of the structure is generally a shade net.

Greenhouse

It is a framed or covered structure with a transparent or translucent material which permits ample sunlight for crop production and has provisions for at least partial control of plant environment. A greenhouse, depending upon the transparency of the glazing material, admits sunlight which is absorbed by the crop, equipment, structure and the floor. These objects in turn emit thermal radiation which is only partially transmitted out of the greenhouse. As a result of this, a part of the solar energy is continually retained in the greenhouse, leading to a temperature increase. This natural temperature rise in the greenhouse is utilised during winters to grow crops with or without supplementary heat. During summers, the greenhouses are cooled as per the crop requirement.

Farm Pond plastic lining sheets

In drought-prone regions, rainfall is highly unpredictable, which makes rainwater harvesting

systems dependent on storage of water. In these areas, water seepage and evaporation pose major challenges. Ponds are sealed with conventional plastic linings in order to avoid this loss of stored water. It reduces seepage in an effective and cost-effective manner. Plastics like HDPE (high density polyethylene), PVC (polyvinyl chloride) and polyethylene are extensively used to make these pond linings.

Students' activities

1. Write down the different uses of plastic as mulches with their effects on crop.
2. How plastics can be used for water harvesting.
3. Write down the different kinds of plastic used in horticulture.

Exercise No. 9

Visit to Commercial Citrus Orchards and Diagnosis of Maladies

Sikkim has very rich diversity of citrus fruits and almost all types of citrus fruits are grown in the state. Among all citrus, Sikkim orange is cultivated in an area of about 13.26 (000) hectares, with a total average annual production of about 26.65(000) MT during 2020-21. It occupies more than 65 percent area of total fruit crops grown in the state. The average productivity in the state is 2.0tonnes per hectare. The important orange producing areas are the Tista and Rangeet river valleys within the elevation range of 600 to 1500 m above mean sea level.

Decline in mandarins usually happens when plants are infested with diseases like *Phytophthora* foot rot or virus diseases at the beginning itself and proper selection of plant material i.e. its freedom from diseases, has not been done. Also in many cases, decline starts because of intercropping of mandarin orchards at young stage, which draws heavy amounts of nutrients from the soil. In addition to this, frequent irrigation, intensive intercrops increases the infestation and spread of *Phytophthora* foot rot. Intercropping predisposes the mandarin plants for attack of insect pests and diseases. Generally, there is not a single cause but is the effect of many causes, which may vary from field to field or area to area. Some of the factors are beyond the control of the orchardist like, soil characters, drainage, salt concentrations, water logging, frost injuries, etc. In this context practical exposure of horticulture students about diagnosis of major diseases and pest of citrus orchard is very much essential. Students while visiting the orchard following problems may notice and can guide to growers to manage the problem:

1. **Citrus canker**

Citrus canker disease in India appears to be a serious problem wherever acid lime (*C. aurantifolia*) is grown on a large and commercial scale and has become a major permanent problem for citrus growers.

Symptoms:

Leaf Lesions: Canker lesions are evident on the leaves' underside, and then on the upper surface, about 7–10 days after infection. With the elevated margin and sunken middle, the pustules are corky. The yellow halo around it is a common symptom of the disease on the leaves.

Fruit and Stem Lesions: In fruit and roots, citrus canker lesions range up to 1 mm in size and are close to those on leaves. Crop deficiency results in the premature fall of the crop. Usually, the fruit's internal quality is not affected but individual lesions penetrate the rind deeply enough to expose the fruit's interior to secondary microorganism infection. Stem lesions allow the bacteria to live in the long term.

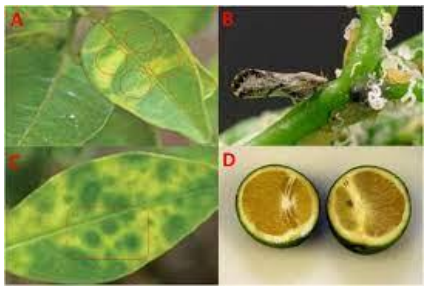
Casual Organism: *Xanthomonas campestris* pv. Citri

Disease Cycle and Epidemiology: Bacteria grow on leaves, stems, and fruit in lesions. The bacteria ooze out when free moisture is present on the lesions. Rain splash is the principal dispersal agent and wind helps to penetrate bacteria through natural openings or wounds created by thorns, pruning, and insects (leaf miner). Bacterial death increases when exposed to direct sunlight. These bacteria can live in infected tissues of plants that have been kept dry and free from the soil for years.

Management Tips

- Complete eradication of infected trees is advised.
- Remove contaminated branches from pruning scissors and then spray the trees with 1% of the Bordeaux mixture at regular intervals. Falling infected leaves and twigs should be gathered and burned. • Spray 1 g streptocycline and 30 g copper oxychloride in 10 L of water at intervals of 15 days in nurseries and at intervals of fortnight in orchards during rainy season.

2. Greening or Huanglongbin (HLB)



In sweet oranges, kinnow, lemons, and other members of the citrus family, citrus greening/huanglongbing disease also occurred. Citrus-greening disease is a major citrus disease in India.

Symptoms:

- Stunting of leaves, scant foliage, twig dying back, bad harvest of mostly greenish, useless fruits. The twigs are upright and grow smaller leaves.
- Young leaves appear normal but soon assume an upright position, become leathery, and develop prominent veins and a slender green color.
- Small, curved fruit columella. Low in juice, and solids soluble, high in acidity.

Casual Organism: *Candidatus Liberobacter asiaticus* (Fastidious Phloem limited Bacterium), obligate Gram-negative bacterium.

Mode of Spread: The disease is transmitted by *Diaphorina citri*, an infected wood bud and citrus psylla. The illness is also transmitted through the dodder from the citrus to the Periwinkle (*Catharanthus roseus*).

Management Tips

- Control psyllids with insecticides.
- Use healthy bud wood for propagation.

3. Gummosis

Gummosis is a common disease which occurs as frequently in NEH region. Lemons are more vulnerable than lemons and whole grapefruits. It is very popular in sweet orange and mandarin orange.

Symptoms: Symptoms appeared when large patches of water soaked nearly ground level on the basal portions of the stem. Bark of such parts of stem/trunk showed symptoms in lengthwise vertical strips such as dries, shrinks, and cracks and shreds. Stem/trunk bark profuse later stage gum exudation.

Casual Organism: *Phytophthora parasitica, P. palmivora, P. citrophthora, P. hibernalis, P. syringae, P. cactorum.*

Disease Cycle and Epidemiology: Species of phytophthora can spread in many ways, including soil movement with nursery stocks, irrigation water, and infected root sections. Irrigated citrus often suffers as runoff water can carry the pathogen into channels, streams, or rivers. Water from those sources can then contaminate areas that were previously uninfected. On farm machinery, the fungus may be brought into the soil. Seeds taken from contaminated fruits are rarely contagious (Graham and Menge, 1999).

Management Tips

Preventive Measures:

- ❖ Selecting of field for planting of citrus fruits with well developed drainage system for water.
- ❖ Citrus plant must be planted with little higher than the ground level.
- ❖ Avoiding excess irrigations.
- ❖ Range of planting material (30–45 cm or above) with large budded grafts.
- ❖ Prevent mechanical damage to the crown roots of citrus trees or stem base during cultural activities.
- ❖ To propagate popular/commercial varieties, use resistant sour orange or trifoliate orange rootstock.
- ❖ Citrus trees paint root at almost ground level with Bordeaux paste at least once a year
- ❖ Apply *Trichoderma viride* multiplied on neem cake.

Curative Measures:

- o Injuries to coronary roots or stem base should be avoided during cultural operations.
- o Scrape/chisel the sick part out.
- o Protect the Bordeaux paste cut surface.
- o Covering the entire plant canopy and basin of the affected plant at a 40-day interval from the onset of the monsoon provided considerable control (Anonymous, 2018b).

Menace Fruit fly in Citrus Orchard

Fruit fly is one of the most serious pests of citrus. It causes the fruit to turn yellow and drop early. The fly is as big as housefly. It is yellow in colour with dark brown to black markings on the segment where the wings are attached. Mated females deposit eggs within the flesh of the fruit on a host plant. Larvae hatch after a few days and burrow inside the fruit to feed on the pulp for 4 - 12 days. The larvae then drop from the fruit to pupate in the soil. There are holes on the surface of the dropped fruit and white larvae found inside. The pupae survive in the soil during the winter and emerge as flies after winter.

Management Tips

- ✓ Regularly collect the infected fallen fruits and destroy by deep burial to kill the larvae and prevent adults emerging
- ✓ Hoe the orchard in the winter season to disturb the pupae. This brings them to the surface and birds will pray on them. This reduces the population of adult flies for the coming season.
- ✓ Use pheromone traps between April and September to trap the males so that females lay sterile eggs. This leads to a reduced fly population. To prepare the trap, put 5 drops of methyl eugenol and 5 drops of Malathion 50% EC onto a piece of cotton. Put the cotton into a transparent 1/2 kg bottle with thumb size holes in both the lid and base of the bottle. Hang the bottle on the trees 2-3 meters above the ground. One trap is required for 4 plants.

Exercise No.10

Manure and Fertilizer Application including Bio-Fertilizer in Fruit Crops

Livestock manure can be a valuable source of nutrients, but it also can be a source of human pathogens if not managed correctly. Organic certification programs currently include strict requirements on the handling of raw manure. Even though these requirements are designed to minimize environmental risks, it is important that all farms using manure follow good agricultural practices to reduce any microbial risk that may exist. Proper and thorough composting of manure, incorporating it into soil prior to planting, and avoiding top-dressing of plants are important steps toward reducing the risk of microbial contamination.

Steps for Manure Application in Perennial Fruit Trees

- Select site for produce based on land history and location
- Use careful manure handling
- Keep good records. Consider the source, storage, and type of manure being used on the farm
- Store manure as far away as practical from areas where fresh produce is grown and handled. If manure is not composted, age the manure to be applied to produce fields for at least six months prior to application
- Where possible, erect physical barriers or wind barriers to prevent runoff and wind drift of manure onto plants.
- Store manure slurry for at least 60 days in the summer and 90 days in the winter before applying to fields.
- Actively compost manure. High temperatures achieved by well-managed, aerobic compost can kill most harmful pathogens.
- Remember to optimize temperature, turning, and time to produce high quality, stable compost.

Application of Bio-Fertilizers

Generally, fruit crops have now received more attention than vegetables and ornamental crops. Glomus fasciculatum, Glomus mosseae, Azospirillum, Azotobacter and PSB are found useful for different horticultural crops. Use of biofertilizers, particularly inoculation with Azotobacter, could substitute 50% of the nitrogen requirement of banana and could produce higher yields over full doses of nitrogen application. The absorption of mobile nutrients like nitrogen also increases in association with VAM fungi. Manjunath et al. (2001) reported that VAM fungi (Glomus fascicuatum) was found to be effective in papaya in increasing the plant height, stem girth, petiole length and number of leaves. Rupnawar and Navale (2000) conducted an experiment on pomegranate and observed that mycorrhizal

treatment was superior over non-mycorrhizal treatment in pomegranate. They reported that the *Glomus epigaeum* (GE) + *G. mosseae* + *Gigaspore calospora* mixture recorded the maximum height, root length, number of leaves, dry weight, of shoot and roots and mycorrhizal dependency percentage in pomegranate.

In banana, Jeeva *et al.* (1988) in Tamil Nadu found that the inoculation of *AzospiriIlum* in combination with the nitrogenous fertilizer increased the yield up to 13.1% in variety Poovan. The increased bunch weight was also found associated with corresponding increase in length of bunch, number of hands, length, girth and weight of fingers.

Suresh and Hasan (2001) in West Bengal evaluated the response of inoculation with *Azospirillum* and phosphobacteria on fruit quality of banana (Musa MA) cv. Giant Governor by manipulating the doses of nitrogen and potassic fertilizers. The results revealed that inoculation of biofertilizers along with the application of recommended dose of fertilizer proved most effective in improving fruit quality of Dwarf Cavendish banana cv. Giant Governor. Rana and Chandal (1999) reported that the plant growth, yield and fruit quality of strawberry were significantly increased with the application of biofertilizer and nitrogenous fertilizers. Maximum TSS content was observed with Azotobacter inoculation along with 80 kg N/ha.

Commercial Bioformulation of Bio fertlizer

Arka Microbial Consortium

Microbial Constituents: Azotobacter tropicalis PAN MC1 (NAIMCC-B-01336) (Nitrogen fixer), Bacillus aryabhattai Bel 6 (NAIMCC-B-01335) (P & Zn solubilizer) and Pseudomonas taiwanensis Mpf2 (NAIMCC-B-01337) (K-solubilizer and PGPR)

Type: Carrier based formulation; 1 × 108 cfu/g of each; Liquid formulation; 1x 109 cfu/mL of each.

Shelf life: 06 months at 25°C to 35°C

Target crops: All annual and perennial horticultural and plantation crops.

Methods of Application

- ✓ **Seed Treatment:** 10-20g inoculum is sufficient to treat 100-200 g vegetable seeds.
- ✓ **Coco Peat Enrichment:** One Kg Arka Microbial Consortium (AMC) is sufficient to enrich 1000 Kg (1 Tonne) of Coco Peat.
- ✓ **Soil Drenching:** AMC can be mixed with water @ 20 g/ lit and then applied near to the root zone on the 10th day after transplanting.
- ✓ **Main Field Application;** for the main field application of one acre of land, five kg of amc can be mixed with 500 kg of FYM and applied near the root zone of standing crop.

Target Agroecological zones/states: Karnataka, Tamil Nadu, Kerala, Telangana, Andhra Pradesh and Maharashtra

Validation: AICRP on Fruits with guava and papaya for two years; ATARI, Zone VIII for two years on a variety of vegetables; on different horticultural crops at ICAR-IIHR, Bengaluru for three years y

Commercialization: Commercialized in 2013; Licensed to 13 entrepreneurs/ KVKs/State departments

Exercise No. 11

Preparation and Application of Growth Regulators in Banana, Grapes, Mango and Citrus

Application of PGR in Grape

Studies have shown that gibberellin, multi-effect azole, α-sodium naphthalene acetate, Compound sodium nitrophenolate and diethyl aminoethyl hexanoate etc., are widely involved in the regulation of plant growth and development[8-13]. Gibberellin can promote plant growth, destroy the apical dominance, promote the growth of lateral branches, and break the dormancy, and regulate the flowering. Morphologically praying gibberellin on the crops would significantly promote the stem elongation, and within a certain range of concentration, as concentration is increased, the enhancement is increased (Deng Huihui *et al.*, 2016)4. Dipping the seedling root in Multi-effect azole can increase the survival rate. During seedling stage, spraying it on the stems can control the growth of the top, promote the growth of the lower part of the seedling, control the height of the seedling, promote root growth, improve the quality of the seedlings [Li et al., 2007). High purity of α-sodium naphthalene acetate can reduce the premature flower and fruit abscission rate, promote flowering and fruit setting, effective improve resilience of crops (Zhang Hong *et al*., 2013; Hu Zhao *et al*., 2013)

Application of PGR in Grape

The effect of GA was studied from the late 1950s with timing and concentration being major factors. In ‘seedless’ grapes, application of GA to increase berry size is performed at a fruitlet diameter of 4–6 mm because earlier application can have negative impacts on fruit-set and berry shot (berry set too high and presence of very small berries) and later application is less effective. The effective concentration of GA can vary markedly according to sensitivity of the variety to the hormone. For example, ‘Thompson Seedless’ requires multiple applications and large cumulative amounts of GA exceeding 100 ppm, while a single application of 10 ppm of GA can triple the size of ‘Black Finger’ berries. GA is also known to potentially delay maturity, increase pedicel thickness, and increase berry abscission depending on the application time. If applied on the whole vine on sensitive varieties, GA can also harm reproductive meristems and reduce subsequent yield. The molecular aspects of the synthesis, signal perception, and transduction of GA in grapes have been reported.

Application of PGR Mandarin

Ingle *et al.* (2001) revealed that foliar application of GA3 @ 25 ppm increased the fruit weight, volume, TSS, ascorbic acid, peel and yield over control in ‘Nagpur’ mandarin. Yeshayahu *et al.* (2001) stated that spray of 300 ppm NAA increased fruit size in ‘Myovaze

Satsuma' mandarin and NAA also thinned the fruit-lets and decreased total yield. Ghawade *et al.* (2002) studied of physico chemical characters of the fruits in Nagpur mandarin located at different sides of trees and found that, fruits located inside the tree contain less TSS and acid whereas, those exposed in the sun had more total soluble solids, ascorbic acid and rapid colour development resulting in early ripening.

Application of PGR in Mango

Foliar sprays of growth regulators (NAA and GA3) could be used as one of these horticultural practices that reduce fruit drop enhance yield and fruit quality of mangoes (Anila and Radha, 2003). Chattha *et al.* (1999) indicated that NAA application induced high positive effect in reducing fruit drop. Moreover, NAA application reduced flowers drop, and gave high flowers retention and increased yield as well as improved fruit quality of mango (Hairdy *et al*., 1997 and Vejendla *et al*., 2008). Furthermore, foliar spray of NAA and GA3 enhanced yield and fruit quality as well as reduced fruit drop of mango trees (Muarya and Singh, 1981)

Recommended Doses of PGR

Table (10.1). Plant growth regulators in ripening of fruits

Crop	**Chemical**	**Dose**	**Response**
Mango	Ethephon	1000 ppm	Accelerated fruit ripening and improves surface colour
Citrus	Ethrel	1000 ppm	Induce yellow colour with in seven days
Banana	Ethrel	1000 ppm	Accelerated ripening by two days
Papaya	Ethephon + NaOH	2000 ppm	Ripening within 24 hours

Table (10.2). Plant growth regulators in flowering and fruit set

Crop	**Chemical**	**Dose**	**Time of spray and number of spray**	**Response**
Coconut	2,4-D	30 ppm	One month after opening of spathe, through micro sprayer	Fruit setting percentage increased to 32.5% against 23% in control
Banana	2,4-D	25 ppm	Within a week after opening of last bud	Prevents seediness in poovan
Mandarin orange	2,4-D or NAA	20 ppm, 100 ppm	Spray at flowering.	Increase fruit set
Thompson seedless	GA3	25 ppm	Dip cluster at calyptra falling stage	Increase fruit set

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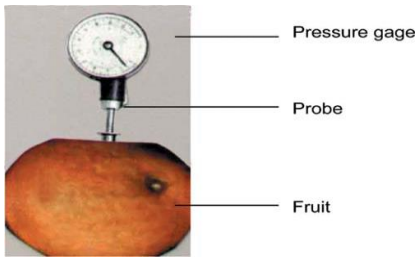
Exercise No. 12

Ripening of Fruits, Grading and Packaging

The principles dictating at which stage of maturity a fruit should be harvested are crucial to its subsequent storage and marketable life and quality. Post-harvest physiologists distinguish three stages in the life span of fruits: maturation, ripening, and senescence. Maturation is indicative of the fruit being ready for harvest. At this point, the edible part of the fruit is fully developed in size, although it may not be ready for immediate consumption. Ripening follows or overlaps maturation, rendering the produce edible, as indicated by taste. Senescence is the last stage, characterized by natural degradation of the fruit, as in loss of texture, flavour, etc. (senescence ends at the death of the tissue of the fruit). Some typical maturity indexes are described as under:

- **Skin colour:** This factor is commonly applied to fruits, since skin colour changes as fruit ripens or matures. Some fruits exhibit no perceptible colour change during maturation, depending on the type of fruit. Assessment of harvest maturity by skin colour depends on the judgment of the harvester, but colour charts are available for cultivars, such as apples.
- **Optical methods:** Light transmission properties can be used to measure the degree of maturity of fruits. These methods are based on the chlorophyll content of the fruit, which is reduced during maturation. The fruit is exposed to a bright light, which is then switched off so that the fruit is in total darkness. Next, a sensor measures the amount of light emitted from the fruit, which is proportional to its chlorophyll content and thus its maturity.
- **Shape:** The shape of fruit can change during maturation and can be used as a characteristic to determine harvest maturity. For instance, a banana becomes more rounded in cross-sections and less angular as it develops on the plant. Mangoes also change shape during maturation. As the mango matures on the tree the relationship between the shoulders of the fruit and the point at which the stalk is attached may change. The shoulders of immature mangoes slope away from the fruit stalk; however, on more mature mangoes the shoulders become level with the point of attachment, and with even more maturity the shoulders may be raised above this point.
- **Size:** For bananas, the width of individual fingers can be used to determine harvest maturity. Usually a finger is placed midway along the bunch and its maximum width is measured with callipers; this is referred to as the calliper grade.
- **Aroma:** Most fruits synthesize volatile chemicals as they ripen. Such chemicals give fruit its characteristic odour and can be used to determine whether it is ripe or not. These doors may only be detectable by humans when a fruit is completely ripe, and therefore has limited use in commercial situations.

- **Abscission:** As part of the natural development of a fruit an abscission layer is formed in the pedicel. For example, in cantaloupe melons, harvesting before the abscission layer is fully developed results in inferior flavoured fruit, compared to those left on the vine for the full period.
- **Firmness:** A fruit may change in texture during maturation, especially during ripening when it may become rapidly softer. Excessive loss of moisture may also affect the texture of crops. These textural changes are detected by touch, and the harvester may simply be able to gently squeeze the fruit and judge whether the crop can be harvested. A force is applied to the surface of the fruit, allowing the probe of the penetrometer or texturometer to penetrate the fruit flesh, which then gives a reading on firmness. Hand held pressure testers could give variable results because the basis on which they are used to measure firmness is affected by the angle at which the force is applied. Two commonly used pressure testers to measure the firmness of fruits and vegetables are the Magness-Taylor and UC Fruit Firmness testers (Fig.1).



- **Juice content:** The juice content of many fruits increases as the fruit matures on the tree. To measure the juice content of a fruit, a representative sample of fruit is taken and then the juice extracted in a standard and specified manner. The juice volume is related to the original mass of juice, which is proportional to its maturity. The minimum values for citrus juices are presented in (1.3).

Table (1.3). Minimum juice values for mature citrus

Citrus fruit	Minimum juice content (%)
Naval oranges	30
Other oranges	35
Grapefruit	35
Lemons	25
Mandarins	33
Clementines	40

- **Sugars:** In climacteric fruits, carbohydrates accumulate during maturation in the form of starch. As the fruit ripens, starch is broken down into sugar. In non-climacteric fruits, sugar tends to accumulate during maturation. A quick method to measure the amount of sugar present in fruits is with a brix hydrometer or a refractometer. A drop of fruit juice is placed in the sample holder of the refractometer and a reading taken; this is equivalent to the total amount of soluble solids or sugar content. This factor is used in many parts of the world to specify maturity. The soluble solids content of fruit is also determined by shining light on the fruit or vegetable and measuring the amount transmitted. This is a laboratory technique however and might not be suitable for village level production.

- **Starch content:** Measurement of starch content is a reliable technique used to determine maturity in pear cultivars. The method involves cutting the fruit in two and dipping the cut pieces into a solution containing 4% potassium iodide and 1% iodine. The cut surfaces stain to a blue-black colour in places where starch is present. Starch converts into sugar as harvest time approaches. Harvest begins when the samples show that 65-70% of the cut surfaces have turned blue-black.
- **Acidity:** In many fruits, the acidity changes during maturation and ripening, and in the case of citrus and other fruits, acidity reduces progressively as the fruit matures on the tree. Taking samples of such fruits, and extracting the juice and titrating it against a standard alkaline solution, gives a measure that can be related to optimum times of harvest. Normally, acidity is not taken as a measurement of fruit maturity by itself but in relation to soluble solids, giving what is termed the brix: acid ratio.
- **Specific gravity:** Specific gravity is the relative gravity, or weight of solids or liquids, compared to pure distilled water at 62°F (16.7°C), which is considered unity. Specific gravity is obtained by comparing the weights of equal bulks of other bodies with the weight of water. In practice, the fruit or vegetable is weighed in air, then in pure water. The weight in air divided by the weight in water gives the specific gravity. This will ensure a reliable measure of fruit maturity. As a fruit matures its specific gravity increases. This parameter is rarely used in practice to determine time of harvest, but could be used in cases where development of a suitable sampling technique is possible. It is used however to grade crops according to different maturities at post-harvest. This is done by placing the fruit in a tank of water, wherein those that float are less mature than those that sink.

Grading and packaging of fruits

Agricultural produce particularly fruits and vegetables form an important part of trade both nationally and internationally. Among the post-harvest operations applied during handling of fruits and vegetables, grading plays an important role to remove undesirable or foreign matters from the harvested crops into various fractions. Grading is sorting or categorization of fruits and vegetables into different grades according to the size, shape, colour, and volume to fetch high price in market. Besides grading, the other post-harvest operations such as pre-cooling of produce to remove field heat, post-harvest treatments and packaging etc are also critical to marketing success.

Produce brought in many markets often has variable characteristics and sometimes it may be delivered immature or contain shriveled, damaged and rotten materials. Delivering such

produce generally results in lower prices. Thus, systematic grading is pre-requisite for efficient marketing of fruits and vegetables. The bruised, damaged and misshapen produce should be sorted out and healthy fruits or vegetables should be graded according to their size, weight, shape, colour, maturity etc. The fruits or vegetables can be graded in extra fancy, superior and standard grades or class I, II and III, respectively. Various advantages of grading are outlined below:

Advantages of Grading

- The graded produce fetch better price in the market.
- Grading helps to develop greater confidence between buyers and growers.
- Increase the marketing efficiency by facilitating buying and selling a produce without personal selection.
- Heavy marketing cost in packing and transportation can be avoided by grading.
- Increasing distributors' profits.
- Increasing producers' profits.
- Grading improves product uniformity within a particular grade and serves as the basis for price.

Methods of Grading

Grading of fruits and vegetables is generally done on the basis of physical characteristics like weight, size, colour, shape, specific gravity, and freedom from diseases. For fresh marketing, the known methods of grading of fruits and vegetables are manual grading, or machine grading. In both the methods, the produce is graded on the basis of size. However, electronic grading systems are gaining impetus in the horticultural sector and have been used successfully in pilot scale studies. Grading process is fully mechanized but in India it is still done manually. Basic process behind mechanical grading consist of a conveyor belt with a bag at the end wherein smaller produce fall through the chain making grading process less extensive. Fruits and vegetables are generally graded on the basis of state, federal, and international standards. Every country has set their own standards of different grades as per the market requirements. However, for international market three general grades are considered as: Extra class, Class I and Class II.

Extra Class: The extra class is of superior quality poses the shapes and colour of the variety and without internal defect likely to affect the inherent texture and flavour. A 5 per cent tolerance is allowed for errors. It must be carefully presented taking into accounts the uniformity of the produces in size, colour, and condition arrangement of the produce in the package, quality and appearances of the packing or pre-packing material.

Class I: Almost having a same quality is like the Extra Class except that a 10% tolerance is allowed. Individual fruit is allowed a slight defect in shape, colour and minor skin defect which do not affect the general appearance for keeping qualities.

Class II: This class product may exhibit some external or internal defects provided they are fit for consumption while fresh. This class is the best fitted for local or short distance market. This category will satisfy the needs of customers who are not too demanding and for whom price is more important than quality.

of different fruits as suggested by Directorate of Marketing and Inspection (DMI)

Grapes		
Grade	Size of berriers	
	Large bunch weight (g)	Small bunch weight (g)
Extra Class	200	150
Class I	150	100
Class II	100	75

Litchi	
Grade	Diameter (mm)
Extra class	33
Class I	28
Class II	23

Kinnow		
Size code	Diameter (mm)	No. of fruits in 10 kg pack
A	60-64	84
B	65-69	72
C	70-72	60
D	72-74	54
E	75-79	51
F	80-85	45

Apple		
Size code	Weight (g)	Diameter (mm)
A	More than 241	More than 80
B	211-240	76-80
C	181-210	71-75
D	151-180	66-70
E	121-150	61-65
F	91-120	56-60

Guava		
Size code	Weight (g)	Diameter (mm)
A	>350	>95
B	251-350	86-95
C	201-250	76-85
D	151-200	66-75
E	101-150	54-53
F	61-100	43-53

Mango	
Grade	Weight (g)
A	200-350
B	351-500
C	551-800

Pear	
Grade	Diameter (mm)
Extra class	60
Class I	55
Class II	50

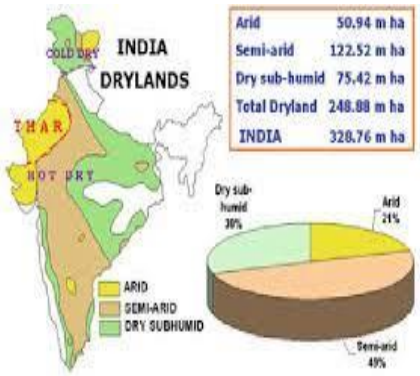
Directorate of Marketing and Inspection (DMI) under Ministry of Agriculture and Farmers Welfare, Government of India was set up in the year 1935 to frame the grade standards in a scientific manner. The different grades used in some important fruits and vegetables with respect to weight, diameter or length as applicable are given as under. For grading information on other fruits and vegetables, following site i.e. www.dmi.gov.in can be accessed.

Manually grading is costly and grading operation is affected due to shortage of labour in peak seasons. Human operations may be inconsistent, less efficient and time consuming. New trends in marketing as specified by World Trade Organization (WTO) demand high quality graded products. Farmers are looking forward to having an appropriate agricultural produce-grading machine in order to alleviate the labour shortage, save time and improve graded product's quality. Grading of fruits is a very important operation as it fetches high price to the grower and improves packaging, handling and brings an overall improvement in marketing system. The fruits are generally graded on basis of size and graded fruits are more welcome in export market. Grading could reduce handling losses during transportation.

Exercise No. -13

Mapping of arid and semi-arid zones of India

An agro-ecosystem is a complex entity comprising a number of elements which interact



with one another to form and stabilize the system. Severe climate and weather events have caused significant disruptions to modern and past societies (Coumou and Rahmstorf, 2012; Ross and Lott, 2003; Lubchenco and Karl, 2012), and there is concern that anthropogenic climate change will increase the occurrence, magnitude, or impact of these events in the future (Meehl *et al.* 2000; Rahmstorf and Coumou, 2011). The agriculture in India mainly depends on monsoon rainfall; about 80% of total annual rainfall receives as southwest monsoon during June-September. Drought is one such extreme phenomenon, and is vital because of its long-term impacts on water resources, agricultural production, and economic activity (Ding *et al.* 2011). Drought is generally defined as a deficit in soil moisture (agricultural) or streamflow (hydrologic); as such, it can be caused by declines in precipitation, increases in evapo-transpiration, or a combination of the two. Regional changes in precipitation and evapo-transpiration, and the dynamics that drive such changes, are nevertheless more uncertain. Ninety-nine districts in 14 states are declared as drought prone districts by the Central Water Commission (2002). Most of them are concentrated in Andhra Pradesh, Maharashtra, Tamil Nadu, Karnataka, Gujarat and Rajasthan. Low and erratic rainfall coupled with extreme temperatures and intense solar radiation makes these regions the most vulnerable regions in India.

Table (14.1)Bio-climatic classification based on moisture index

Bio-climate class	**Synchronized moisture index (Mather, 1956)**
Arid	<-66.7
Hyper arid	<-88.3
Typic arid	-66.7 to -83.2
Semi arid	-33.3 to -66.6
Semi arid (dry)	-50.0 to -66.6
Semi arid (moist)	-33.4 to -49.9
Sub-humid	-0.20 to -33.3
Sub-humid (dry)	0 to -33.3
Sub-humid (moist)	0 to +20
Humid	+20 to +100
Perhumid	> +100

Climate change moving towards drier and wetter side in different arid and semi arid dry regions will have an economic impact on agriculture, including changes in farm profitability, prices, supply, demand and trade. Agriculture is sensitive to short-term changes in weather and to seasonal, annual and long-term variations in climate. Hence, there is an increased possibility of climate extremes, such as the timing of onset of monsoon and intensities and frequencies of droughts and floods, which will pose serious risks to crop production systems and food security in general (Sahu *et al*., 2021)

Table (1.1). State wise Arid and Semi arid zones of India

State	Arid Zone Km^2	Sem Arid zone Km^2	Arid Zone	Semi Arid Zone
			Percentage	
Rajasthan	1,96,150	1,21,020	61	13.0
Gujarat	62,180	90,520	19.6	9.0
Punjab and Haryana	27,350	58,650	9	6.0
Maharashtra	1,290	1,89,580	0.4	19.0
Karnataka	8,570	1,39360	3.0	15.0
Andhra Pradesh	21,550	1,38670	7.0	15.0
Tamilnadu	-	95,250	-	10.0
Uttar Pradesh	-	64,230	-	7.0
Madhya Pradesh	-	59,470	-	6.0

Biodiversity of Tropical and Sub -Tropical fruit crops

Fruit species have higher adaptation to variable agro-ecological conditions and are suitable diverse agri-horticultural systems and fruit based cropping systems.The nature has provided innumerable plant species of which only about 5000 plant species are being used by human beings globally. Today only about 150 plant species are important in respect of food for mankind. There is greater dependence of very few plant species i.e. about 20-30 worldwide. This gradually, resulted in the loss of native genetic resources which are otherwise essential as building blocks of genetic diversity. It is estimated that there are about 500 species of tropical fruit trees under 30 families and 59 genera in Asia Pacific Oceana region (Arora, 1998). In Southeast Asia alone, there are 120 major fruit species and 275 minor fruit species (Verheij and Coronel, 1991). In Asia 50-60 species belong to the most important indigenous fruits.Citrus, banana, mango, jackfruit, litchi and durian occupy 80 per cent of total fruit production in the region. India is an important centre of origin and diversity of many horticultural crops including fruit crops like mango, citrus and banana. The sub-continent has tropical, subtropical and temperate climate. Therefore, a variety of fruits originating in tropics, subtropics and temperate

regions of the world have been introduced in India and many of them are commercially grown in the country.

Table (1.2).: The main centre of diversity for tropical and sub tropical fruits in India

Region	Species
Eastern Himalayas	Fragaria indica, Morus spp., Myrica esculenta, Prunus acuminata, P. cerasiodes, P. jcirkinyii, P. nupauiensis, Rubus lineatus, R. ellipticus, R. lasiocarpus, R. moluccanus, R. reticulatus
North-eastern region	Citrus assamensis, C. ichangensis, C. lndica, C. jambiri, C. la//pea, C. macroptera, C. media, C. aurantium, Docynia indica, D. hookeriana, Eriobotrya angustifolia, Mangifera sylvatica, Musa accuminata/M, balbisiana complex, M. manii, M. nagensium, M. sikkimensis, M. superba, M. velutina, Pyrus pyrifolia, P. pashia, Prunus cerasiodes, P. cornuta, P. jenkinsii, Ribes graciale, Rubus ellipticus, R. moluccanus, R. reticulates, R. lasiocarpus, Myrica esculenta.
Gangetic plains	Aegle marmelos, Cordia myxa, C. rothii, Emblica officinalis, Grewia asiatica, Morus spp.; Phoenix spp.; Syzygium spp.; Zizyphus nummularia and other spp.; and Manilkara hexandra (more in North-Western plains
Indus plains	Meagre occurrence of Syzygium, rich variaton in Carissa congesta.
Western peninsular	Artocarpus heterophyllus, A. lakooCha, Garcinia indica, Diospyros spp., Ensete superba, Mangifera indica, Mimosops elengii, Spondias pinnata, Vitis spp., Zizyphus oenoplia, Z. rugosa. Ruhus ellipticus. R. laeiocarpus.

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Exercise No. 14

Botanical Description and Identification of Tropical Fruits

14.1 Ber *(Ziziphus mauritiana* Lamk)

Ber the Indian jujube probably originates in the Middle East or the Indian subcontinent. Scientific name *Ziziphus mauritiana* Lamk, belongs to family Rhamnaceae, Chromosome number: 2*n*= 48 (tetraploid), 60 (pentaploid), 96 (octaploid). *Ziziphus* Miller is often also written as *Zizyphus* . The fruit of almost all *Ziziphus* species is edible. Indian jujube is often confused with the Chinese jujube, *Ziziphus jujuba* Miller (synonym *Ziziphus vulgaris* Lamk), a species of ancient culture in northern China and widely grown in mild-temperate, rather dry areas of both hemispheres. Taxonomic position of the genus *Zizyphus* is given as under:

Taxonomic position of the genus *Zizyphus*

Kingdom	Plantae
Subkingdom	Viridiplantae
Infrakingdom	Streptophyta
Superdivision	Embryophyta
Division	Tracheophyta
Subdivision	Spermatophytina
Class	Magnoliopsida
Superorder	Rosanae
Order	Rosales
Family	Rhamnaceae
Genus	*Ziziphus* Mill.

Morphological Description

Tree or bushy shrub, up to ca. 15 m tall, erect or spreading with drooping branches; twigs zigzag, tomentose; stipules spinous, solitary and straight (5-7 mm) or in dimorphic pairs, the second shorter and recurved, spines sometimes absent; trees evergreen or semi-deciduous. Leaves alternate, simple, elliptic-ovate to oblong-elliptic, 2-9 cm × 1.5-5 cm, slightly crenate or entire, glossy and glabrous above, densely white-tomentose beneath,

with 3 conspicuous longitudinal veins; petiole 8-15 mm long. Inflorescences axillary cymes, 1-2 cm long, with 7-20 flowers, peduncles 2-3 mm long. Flowers 2-3 mm across, yellowish, faintly fragrant; pedicels 3-8 mm long; calyx with 5 deltoid lobes, hairy outside, glabrous within; petals 5, subspathulate, concave, reflexed; stamens 5; ovary 2-celled, styles bifid, disk 10-lobed or grooved. Fruit a drupe, globose to ovoid, up to 6 cm × 4 cm in cultivation, usually much smaller when wild, skin smooth or rough, glossy, thin but tough, yellowish to reddish or blackish; flesh white, crisp, juicy, subacid to sweet, becoming mealy in fully ripe fruits. Seed in a tubercled and irregularly furrowed stone, containing 1-2 elliptic brown kernels.

14.2 Fig *(Ficus carica L.)*

The cultivated fig (Ficus carica L.) belongs to the Moraceae family. Chromosome number and morphology of the genus *Ficus* has been reported by Condit (1928 & 1934). Chromosomes of the various fig species are similar to each other in appearance and 2n = 26 is the basic chromosome number in all figs. The genome size of fig is small, less than three times that of Arabidopsis (Ohri and Khoshoo, 1987). The Taxonomic position of genus *Ficus* is given as under:

Taxonomic position of genus *Ficus*

Kingdom	Plantae
Sub-kingdom	Tracheobionta
Super-division	Spermatophyta
Division	Magnoliphyta
Class	Maghnoliosida
Subclass	Hamamelididae
Order	Urticales
Family	Moraceae
Genus	*Ficus*
Species	*carica*

Morphological Description

Tree of *Ficus carica* L is usually 15 to 20 ft tall, with numerous spreading branches and a trunk rarely more than 7 ft in diameter. The latex of the plant is milky white mainly contains, ficin (a protein digesting enzyme). The root system in the plant is typically shallow and spreading, sometimes covering 50 ft of ground, but in permeable soil some of the roots may descend to 20 ft. Many *Ficus* produce aerial roots that descend to the ground. In some species originating in the rainforests, the small *Ficus* plant takes up residence in a tree top, and dropping aerial roots, gradually overcomes and strangles its host. The leaves of the plant are broad, ovate or nearly 3-5 lobed, rough above and pubescent below. Fruits are axillary, usually pear shaped, variable in size and color. Although considered a fruit, the fig is actually a flower inverted into it. The fig is juicy and sweet when ripe, gummy with latex before ripening. There is a dynamic within the syconium, the name for the fruit sac of the fig, in which pistils can accommodate either a wasp egg until it hatches or seed of the fig, but not both. Seeds vary greatly in size and number from 30 to 1600 per fruit. The seeds are the real fruits in figs. These are the only fruits to ripen fully or semidry on the tree and are stored for later consumption.

Types and Cultivars: The figs are classified into four types based on the nature of flowers and the methods of pollination.

1) **Common Fig:** The flowers are pistillate, fruits develop by parthenocarpy viz., without the stimulation of pollination and fertilization. Kadota, Mission, Adriatic, Brown Turkey, Celeste and Conadria are some cultivars of this type. Poona is one of the most important commercially grown figs. Introduction and evaluation of exotic figs from California at IIHR, Bangalore reveals that varieties like ‘Deann’, ‘Conadria’ and ‘Excel’ have superior fruit and plant characters. These new varieties when grown on ‘Brown Turkey’ root stock (through chip budding) hold great promise for exploiting marginal lands in arid and semiarid regions.

2) **Capri fig:** This type has short styled pistillate and functional staminate flowers. Most caprifigs are not edible, but are grown because they harbour a small wasp viz., *Blastophaqa psenes* which is necessary for pollination and fruit set in other types like Smyrna fig by transferring the pollen grains from caprifig.
3) **Smyrna fig:** It is commercially the most important one. However, the fruits develop only when the flowers are pollinated with pollen from the male flowers of the caprifig transmitted by the *Blastophaga* wasp. Calimyrna is the common cultivar of this type.
4) **Sanpedro fig:** In this type, the first crop is completely parthenocrpic, but the second crop develops only if the flowers are pollinated. The common cultivars of this type are Sanpedro, King and Gentile. In India, common fig is mostly grown. Some of the cultivars

grown are Black Itchier, Brown Turkey, Turkish White, Kabul and Marseilles. Yercaud Timla fig is a drought tolerant cultivar. Fruit are large and reddish purple in colour.

14.3 Jamun (*Syzygium cuminii* Skeels)

Jamun (*Syzygium cuminii* Skeels) belongs to the myrtle family Myrtaceae and has basic chromosome number (x = 11) of eleven. In the Myrtaceae, diploid (2n = 22) is the most common ploidy level but polyploidy has been documented, mainly in *Syzygium jambos* and *S. paniculatum*. The polyembryonic species, *Syzygium jambos* and *S. paniculatum*, have been found to be tetraploid (2n = 44). However, Jena *et al.* (2003) recorded a somatic chromosome number of 66 in *Syzygium cuminii* (2n = 66), and 2n value of *S. aqueum* has 44 and *S. malaccensis* has 2n = 22. *Syzygium* species can be distinguished on the basis of fruit size and colour, leaf and flower characteristics. Genus *Eugenia differs from Syzygium.* Floral anatomy now provides additional, strong evidence confirming the distinctness of the mainly New World *Eugenia* s. s. and the strictly Old World *Syzygium* s. I. Most significantly, species of *Eugenia* s. s. have a transeptal vascular supply to the ovules whereas those of *Syzygium* s. l. have an axile one. Other features of floral histology and vasculature also support such a division. In addition, a review of the taxonomic literature revealed three hitherto neglected organographic criteria-nature of bracteoles, presence or absence of pubescence, and presence or absence of pseudopedicels-that sharply distinguish between *Eugenia* s. s. and *Syzygium* s. I. (Schmid, 1972). Genus *Syzygium* consists of about 75 indigenous species of which only a few are of commercial significance. The *Syzygium cuminii* Skeels is a large evergreen tree producing dark purple date-like fruits with prominent elongated seeds. Other related species is *S. jumbos* (rose-apple or safed jamun). It is found in the lower ranges of the Himalayas up to an elevation of 1300 meters and in the Kumaon hills up to 1600 m. It is widely grown in the larger parts of India from the Indo-Gangetic plains in the North to Tamil Nadu in the South. Its fruits are light yellow in colour with good aroma and sub-sweet taste. Other species *S. fruiticosum* and *S. unifl*ora bear small-sized edible fruits, whereas *S. densiflora* is free from termite attack, thus, making it suitable for use as rootstock for *S. cuminii* (Singh *et al.*, 1999). Taxonomic position of the genus *Syzigium* is given as under:

Taxonomic position of the genus *Syzigium*

Kingdom	Plantae
Subkingdom	Viridiplantae
Infrakingdom	Streptophyta
Superdivision	Embryophyta
Division	Tracheophyta

Subdivision	Spermatophytina
Class	Magnoliopsida
Superorder	Rosanae
Order	Myrtales
Family	Myrtaceae
Genus	*Syzygium P. Br. ex Gaertn.*

Morphological Description

It is a long lived large and evergreen tree attaining height up to 25-30 metre. The trunk is thick and grayish white. The trunk has 3 to 4 m circumference with a semi spreading crown up to 10 m in diameter. The branches are often wide spreading and drooping at the ends. It has deep tap root system. Main root is wiry, while the lateral roots are numerous, moderately long and distributed down the main root. Leaves opposite, simple and glossy, elliptic, pinnately veined with lateral veins close together. It bears with a few flowers in a panicle. Flowers are hermaphrodite and light yellow, borne in the axils of leaves on branchlet; calyx lobes 4, calyx tube not extending beyond summit of ovary; petals 4, white, spreading, stamens many, ovary inferior and 2 celled (Bailey and Bailey, 1978). Fruit is a berry, purplish red, ovoid and edible.

14.4 Pomegranate

Two subspecies are recognized on basis of ovary colour; *P.subsp. chlorocarpa* and *P. porphyrocarpa*. Numerous cultivars, some dating to the 13th Century, are known. The specific epithet *granatum* derives from Latin *granum* "grain" and means "many-grained". Only two species, *P. granatum* and *P. protopunica*, are known for this monogeneric family with close

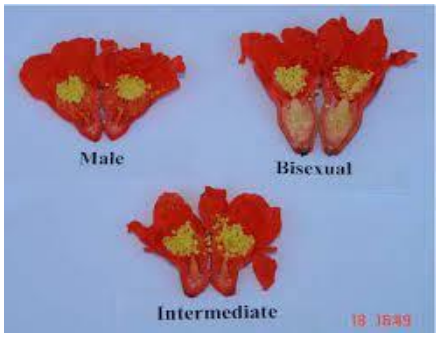
affiliations to the Lythraceae. *P. protopunica* is endemic to Socotra and is listed as an endangered plant in the IUCN Red List. Taxonomic position of the genus *Punica* is given as under:

Taxonomic position of the genus *Punica*

Kingdom	*Plantae*
Subkingdom	*Viridiplantae*
Infrakingdom	*Streptophyta*
Superdivision	*Embryophyta*
Division	*Tracheophyta*
Subdivision	*Spermatophytina*
Class	*Magnoliopsida*
Superorder	*Rosanae*
Order	*Myrtales*
Family	*Lythraceae*
Genus	*Punica L.*
Species	*Punica granatum L.*

Punica granatum is a small multi-stemmed shrub/tree 5-10 m tall. Canopy open, crown base low. Stem woody and spiny, bark smooth and dark grey. Leaves simple, 2-8 cm long, oblong or obovate, glabrous, oppositely placed, short-petioled surface shining. Flowers regular, solitary or in fascicles at apices, 4-6 cm. Petals lanceolate, 5-7, wrinkled and brilliant orange-red. Hypanthium coloured, 5- 8 lobed. Anthers numerous. Calyx persistent. Fruit a round berry, 5-12 cm, pericarp leathery. Interior compartmentalized with many pink-red sections of pulp-like tissue, each contains a seed grain. Fruits globose with persistent callipe and a coriaceous woody rind. Seeds numerous, angular with fleshy testa, 1.3 cm long.

This is a hermaphroditic species. Flowering is observed from mid-April to May in India. Fruiting begins in the 7th or 8th year and fruits take 6-7 months to mature. The number of fruits may vary from 20-25 for young.



14.5 Karonda (*Carissa carandas* L)

Karonda (*Carissa carandas* L.) belongs to the family Apocynaceae and its chromosome number 2n is = 22. It is highly heterozygous, cross-pollinated fruit crop. Taxonomic position of the genus is given as under:

Taxonomic position of genus *Carissa* L.

Kingdom	Plantae
Subkingdom	Viridiplantae
Infra-kingdom	Streptophyta
Super-division	Embryophyta
Division	Tracheophyta
Subdivision	Spermatophytina
Class	Magnoliopsida
Super-order	Asteranae
Order	Gentianales
Family	Apocynaceae
Genus	*Carissa* L.

Morphological Description: Cook (1904) described that the *C. carandas* is a large, ever green, branched, spinous shrub or small tree. *Carissa carandas* L. is a large evergreen shrub with a short stem grows to a height of 3-6 meters, glabrous except the inflorescence, generally with milky latex, bark light-grey, scaly, branchlets usually alternate with twin stout sharp horizontal glabrous spines 2.5-3.0 cm long at their base, branches usually without spines. Leaves are simple opposite, dark green, coriaceous, elliptic or obovate, obtuse, often shortly mucronate, glabrous and shining, base subacute, petioles 0.6 cm long, tan red at opening later leaves turn dark green in color. In the leaf axils slender to stout spines are present. Flowers are white fragrant, tubular, regular bisexual, complete and epigynous, solitary or in cymose clusters, scarcely odorous in pubsescent terminal corymbose cymes, pedicels very short, bracts linear, pubescent. Calyx pubescent, lanceolate, very acute, ciliate. Sepals 4-5, green in color almost free to the base, imbricate persistent ovate in shape. Petals are as many as sepals, lobes contorted in bud; the corolla often has hairy or scaly appendages or outgrowth of various kinds. Corolla-tube about 1.5 cm long, stamen as many as petals and alternate with them in one whorl, filaments short, anthers yellow and inserted on the corolla tube interpose, arrow shaped, often free or united in a cone. Disc often present, entire lobed or scaly. Stamens included within the corolla-tube; anthers linear-oblong. Style long simple, stigma thickened two lobed yellow colored and hairy below. Carpels usually 2, very rarely more than 2, united (connate) or united by

styles or stigma's only, but free at ovary. Ovary superior, bilocular, glabrous; ovules 4 in each cell; stigma slightly penicillate at the apex. Fruit is s drupe, ovoid to ellipsoid, 2-5cm long, colored with reddish pulp at skin, and lighter near the seed. Calyx persistent, latex present, flavor pleasant. Seeds 3-4, dark brown in color and hard, flat sometimes with endosperm and sometimes without endosperm.

14.6 Phalsa (*Grewia subinaequalis* DC)

Phalsa belongs to Tiliaceae family. Its chromosome number (2n) is =36. The botanical name of phalsa is *Grewia subinaequalis* The name *Grewia* was given due to Nehemiah Grew, one of the founders of plant physiology, while *asiatica* reflects the Asian origin of this species. *G. asiatica*, locally known as *phalsa*, is well-known for its nutritional and therapeutic attributes. The closet relative of phalsa is *Grewia elastica* var. Vastita, which is generally found in small hillocks and valleys. Apart from these two species, there are around 140 species in genus *Grewia*. The important ones are *Grewia glabra, Grewia micrococas, Grewia optiva, Grewia tilifolia,* and *Grewia belosa*. Taxonomic position of genus *Grewia* is given as under:

Taxonomic position of genus *Grewia*

Kingdom	Plantae
Clade	Tracheophytes
Clade	Angiosperms
Clade	Eudicots
Clade	Rosids

Order	Malvales
Family	Malvaceae
Genus	*Grewia*
Species	*subinaequalis* DC
Binomial name	*Grewia subinaequalis* DC

Morphological Description

The phalsa plant is a medium, drooping shrub, which may attain a height of 4 m if unprinted. The stem is gray in colour with rough bark. It bears several long, slender, drooping branches. The young branches are covered with dense hairs. The leaves are alternate, simple, and broadly cordate to ovate shaped with pointed tip. The leaves are 20 cm in length and 15 cm in wide with coarsely toothed with 1-2 cm petiole. The inflorescence is 3 to 5 flowered axillary cymes clustered in groups of 2 to 8 which are 16 to 25 cm long. The receptacle is 3 to 4 mm with hairy upper half. The flowers are small 1 to 2 cm diameter and bright orange-yellow in colour. There are five 5 oblong, 1-5 cm long glabrous sepals. The petals are also five in numbers but 5 to 7 cm long and orange - yellow in colour. The fruits are very small, purple to crimson red in color when ripe. The fruits have 2 to 3 cm long peduncle and are produced in clusters. Fruit is botanically a drupe. Fruits are 1.0 to 2.0 cm in diameter, 1.0 to 1.5 cm in length with average fruit weight of 1.0 to 2.0g. Fruits ripen 45 to 55 days after flowering. All fruits on a cluster do not ripe at a time. At ripening stage, fruits turn from light green to cherry red or purplish red, and finally in dark purple colour. The ripe fruit is covered with a very thin, whitish blush, and becomes soft and tender. The flesh is light greenish-white becomes colored purplish-red near the skin. The fruits are sweet acid in taste with mild pleasant flavour. 20.2.2 **Varieties**: There is no recognized variety of phalsa, but there are local favourites for different growing regions. In Hisar area of Haryana, two local varieties i.e. tall and short are grown. The dwarf variety is more productivity than tall variety. The dwarf variety has higher total sugar and non –reducing sugars while tall variety has more reducing sugar. The seed proteins of both are different (Dhawan *et al*., 1993). In Kanpur area, two varieties namely, Local and Sharbati are grown. Chundawat (1990) mentioned that much variability is not available in Phalsa. The fruit usually contain one seed, which are hemispherical and 5 – 7 mm in size.

Exercise No. 15

Botanical Description and Identification of Subtropical Fruits

15.1 Wood apple

Wood apple (*Limonia acidissima* L.) syn. *Feronia elephantum* Correa (1800), *Feronia limonia* (L.) Swingle (1914) belongs to the family Rutaceae and its chromosome number 2*n* is= 18. Feronia is a monotypic genus in the family Rutaceae. There are 2 forms, one with large, sweet fruits and the other with small, acid fruits. Flowers are normally bisexual. In India, the fruits ripen from early October through March. Seedlings will not bear fruit until at least 15 years old. Taxonomic position of genus *Limonia* is given as under:

Taxonomic position of genus *Limonia*

Kingdom	Plantae
Clade	Tracheophytes
Clade	Angiosperms
Clade	Eudicots
Clade	Rosids
Order	Sapindales
Family	Rutaceae
Subfamily	Aurantioideae
Genus	*Limonia* L.
Species	*L. acidissima*
Binomial name	*Limonia acidissima* L.

Morphological Description

Limonia acidissima is a moderate sized deciduous tree grown throughout India. It is an aromatic, slow growing up to 9 m tall, grows all over India in dry and warm areas up to 450 m elevation, often polygamomonoecious tree with rough, spiny bark. The spines are axillary, short, straight, 2-5 cm long on some of the zigzag twigs. The leaves are deciduous, alternate, dark-green, leathery, 3 to 5 inch long. Often minutely toothed, blunt or notched at

the apex, dotted with oil glands and slightly lemon- scented when crushed. Flowers small numerous, dull- red or greenish, born in small, loose, terminal or lateral panicles. The fruit is berry, round to oval, globose, large, 2 to 5 inch wide, with a hard, woody rind, which is grayish-white, scurfy rind about 6 mm thick. The pulp is sticky brown, aromatic odorous, resinous, astringent, acid or sweetish, white seeds scattered.

15.2 West Indian cherry

The West Indian cherry belongs to the family Malpighiaceae comprising 55 genera and genus *Malpighia* is one in the family and it contains about 45 species of shrubs or small trees (Janick and Paull, 2008). The West Indian cherry also known as Barbados cherry, previously, the plant was known by the synonyms *Malpighia glabra* L. and *Malpighia punicifolia* L., but recently taxonomic work has resulted in the acceptance its current scientific name as *Malpighia emarginata* D.C. (Carrington and King, 2002). *M. coccigera* L. and *M. urens* L. are also cultivated in South-East Asia (Orwa *et al*., 2009) while *M. punicifolia* is present as far north as Florida and Texas. Taxonomic position of genus *Malpighia* is given as under:

Taxonomic position of genus *Malpighia*

Kingdom	Plantae
Subkingdom	Tracheobionta
Superdivision	Spermatophyta
Division	Magnoliophyta
Class	Magnoliopsida
Subclass	Rosidae
Order	Polygalales
Family	Malpighiaceae
Genus	*Malpighia* L.
Species	*emarginata* D. C.

Other species under the genus *Malpighia*

1. *Malpighia aquifolia.*
2. *Malpighia cauliflora* Proctor & Vivaldi (Jamaica)
3. *Malpighia coccigera* L. - Singapore holly (Caribbean)
4. *Malpighia cubensis* Kunth - palo bronco de hojapequeha (Cuba)
5. *Malpighia emarginata* D. C. Barbados cherry, acerola, Malpighia fucata Ker Gawl. (Puerto Rico)
6. *Malpighia glabra* L.
7. *Malpighia harrisii* Small (Jamaica)
8. *Malpighia mexicana* A. Juss.
9. *Malpighia obtusifolia* Proctor (Jamaica)
10. *Malpighia polytricha* A. Juss.
11. *Malpighia proctorii* Vivaldi (Jamaica)
12. *Malpighia setosa Spreng*. bristly stinging bush (The Bahamas, Hispaniola, Puerto Rico)
13. *Malpighia suberosa* Small
14. *Malpighia urens* L. cowhage (Caribbean)

Morphological Description

Shrub or small evergreen tree, 2-3(-6) m tall, with spreading, more or less drooping branches on a short trunk. Leaves opposite, ovate to elliptic-lanceolate, 2-8 cm × 1-4 cm, entire or undulating, dark green and glossy above, petiole short. Inflorescences sessile or short-peduncled axillary cymes with 3-5 flowers. Flowers bisexual, 1-2 cm in diameter, pinkish to reddish; calyx with 6-10 large sessile glands; petals 5, fringed, slender-clawed; stamens 10, filaments united below buds usually opening at 4–5 a.m. (Oliveira and Schlindwein, 2009; Sazan *et al*., 2014). Flower pollination depends on external agents and the effect of pollination influences fruit yield as the number of established fruit may decrease due to self-incompatibility and the absence of an effective pollination.

Pollination: The main agents for pollination in Barbados cherry are bees. This was evidence by a significantly increase in fruit-set through maintenance of bee hives in Florida. In Hawaii, the pollination taking place through wind and insects is very little, and the inadequate population of insects resulted in often production of seedless fruits (Morton, 1987). The flowers of the members of the family Malphighiaceae have oil glands which are collected by certain species of the Anthophoridae family, such as *Centris*. *Centris* is known to be one of the most important groups of pollinators of Tropical America. The main species of *Centris* group observed in flowers of Barbados cherry are *Centris dirrhoda* (Raw, 1979), *Centris fuscata*, *C. aenea* and *C. sponsa* (Melo *et al*., 1997) and *Centris flavifrons* (Magalhaes and Oliveira, 1998). The population of the species varies with location, for example, *Centris aenea* was the most abundant (42.6%) in Bahia (Castro, 1998), while, *Centris* (Hemisiella) *tarsata* was the most abundant (71.4%) visitor of

flowers in the semiarid ecosystem of Caatinga. The self- and cross-incompatibiliy in Barbados cherry have been reported (Orwa *et al*., 2009).

Fruits: Fruit bright-red, juicy drupe, depressed-ovoid, 1-3 cm in diameter and weighing 3-5 g, usually in pairs or threes, obscurely 3-lobed; skin thin, flesh soft, orange, acid to sub-acid. Seeds 3, triangular, ridged. Fruits are having very delicate skin with juicy, mostly acidic or blending of sugar and acid in taste (depending upon the genetic type), with no distinct or pronounced flavour. Some think the flavour of thoroughly ripe acerola and the fresh, raw juice made from it resembles that of tart strawberries. Although commonly called a cherry, the odour and flavour of cooked acerola are more like that of tart apples or crab apples than cherries. The germination rate of the seed is low (5-50%).

15.3 Tamarind

Tamarind *Tamarindus indica*, Synonyms *Tamarindus occidentalis* Gaertn (1791), *Tamarindus officinalis* Hook (1851) belongs to the family Leguminosae and its chromosome number 2n is =24. Its taxonomic position is given as under:

Taxonomic position of *Tamarindus indica*

Kingdom	Plantae
Subkingdom	Tracheobionta
Super division	Spermatophyta
Division	Magnoliophyta
Class	Magnoliopsida
Subclass	Rosidae
Order	Fabales
Family	Fabaceae
Genus	*Tamarindus* L.
Species	*indica* L.

Tamarindus L. is a monospecific genus. In the past a distinction was made between tamarinds from the West and the East Indies:

- **West Indies: *T. occidentalis*:** pod up to 3 times longer than wide, containing 1-4 seeds;
- **East Indies: *T. indica*:** pod up to 6 times or longer than wide, containing 6-12 seeds.

There are several tamarind cultivars, differing mainly in colour and sweetness of the flesh. In Thailand named cultivars of the sweet type (makahm wahn) are grown in orchards, *e.g.* "Muen Chong", "Nazi Zad", “Si Chompoo". "Manila Sweet" is a cultivar of the Philippines.

Morphological Description

Tamarind is evergreen, large, long-lived tree, 20 to 30 meter tall with a thick trunk upto 1.5 to 2 meter across and up to 8 meter in circumference. The trunk forks at about 1 meter above ground and is multi-stemmed with widely spreading branches that formed the rounded crown drooping at the ends. The bark is rough, scaly and brownish-grey in colour. Young twigs are puberulent and slender. The leaves are pinnate and 3-6 inches (7.5 to 15 cm) in length each having 10-20 pairs of oblong leaflets half to 1 inch (1.25 to 2.5 cm) long and feathery foliage. Flowers attractive pale yellow or pinkish. Pedicel is 6-10 mm long slim articulate below the calyx. It is glabrous, bracts concave and 6-8 mm. long. Calyx is 1.3 cm long. Flowers are inconspicuous, one inch wide, borne in small racemes. They are 5-petalled, yellow with red or orange streaks. The flower buds are markedly pink because of the outer color of 4 sepals. When the flower opens, sepals shed (Naeem *et al.*, 2017).

Fruits: The fruits, flattish, beanlike, irregularly curved and bulged pods, are borne in great abundance along the new branches and usually vary from 2 to 7 in long and from 3/4 to 1 1/4 in (2-3.2 cm) in diameter. Exceptionally large tamarinds have been found on individual trees. The pods may be cinnamon-brown or grayish-brown externally and, at first, are tender skinned with green, highly acid flesh and soft, whitish, under-developed seeds. As they mature, the pods fill out somewhat and the juicy, acidulous pulp turns brown or reddish brown. Thereafter, the skin becomes a brittle, easily-cracked shell and the pulp dehydrates naturally to a sticky paste enclosed by a few coarse strands of fiber extending lengthwise from the stalk. The 1 to 12 fully formed seeds are hard, glossy-brown, squarish in form, 1/8 to 1/2 in (1.1-1.25 cm) in diameter, and each is enclosed in a parchment like membrane.

Seed: The seeds are very hard, shiny, reddish or purplish brown, non-arillate exalbuminous. They are embedded in the pulp, lined with a tough parchment-like membrane and joined to each other with tough fibres (Purseglove, 1987). Young seeds contain amber, sweet-tasting oil (10 to 15% by weight). This high-quality off has been used in varnishes and paints, for finishing Indian cloth, and as an illuminant. In India and Southeast Asia, tamarind seeds are also crushed and boiled to produce a paste that is used as a roofing material. This material is highly resistant to sea water and salt spray corrosion (PCRDF, 1993). There are about 720 seeds per kilogram of fruit (Hong *et al*., 1996). However, this number may vary from 700-1000 seeds per kilogram depending on the conditions under which the trees are grown (Little and Wadsworth, 1964; Chaturvedi, 1985).



15.4 Aonla

Aonla (Phyllanthus emblica) is a member of family Euphorbiaceae. *Phyllanthus* is a large genus and widely distributed in tropical and subtropical zones like tropical Africa, tropical America, Asia, and Oceania. This genus, consisting of more than 700 species, can be classified into 11 sub-genuses (Unander *et al*., 1995; Xia, 1997). The most popular 24 species are chiefly belonging to subgenus *Kirganelia*, *Cicca*, and *Phyllanthus* and they are traditionally used by different nationalities. Taxonomic position of genus *Phyllanthus* is given as under:

Taxonomic position of genus *Phyllanthus*

Kingdom	Plantae
Subkingdom	Viridiplantae
Infrakingdom	Streptophyta
Superdivision	Embryophyta
Division	Tracheophyta
Subdivision	Spermatophytina
Class	Magnoliopsida
Superorder	Rosanae
Order	Malpighiales
Family	Phyllanthaceae
Genus	*Phyllanthus* L.
Species	*Phyllanthus emblica* L.

Morphological Description

It is a medium sized, much-branched tree occupying height of 10-20 m. In the tropical region, it is supposed to be an evergreen tree but behaves as deciduous tree due to complete defoliation of leaves. However, before dropping of determinate shoots, side buds initiate to develop determinate shoots again in February-March. The tree bark is glossy and it cracks irregularly. Stem is smooth, greenish grey to brown, exfoliating bark, which peels off in thin flakes like that of guava. Branching in aonla tree is characterized by phyllanthoid

branching habit with two types of shoots. On the basis of growth characteristics, these have been characterized as long (indeterminate) and short (determinate) shoots. These are also referred as branch and branchlet. The indeterminate shoots are longer and continue to put new growth in the season. These shoots do not fall from the tree and also do not bear flowers, irrespective of period of their emergence. While on the other hand, determinate shoots appear on the nodes of indeterminate shoots and their number at each node may vary from 3 to 5 in different cultivars. These determinate shoots bear small sized leaves (10-13 mm length, 2-3 mm width), arranged so closely that apparently it appears to be a pinnately compound leaf.

Flowers: The internodes are much shorter in the determinate shoots. These nodes are barren or floriferous with imbricate leaves. First few proximal nodes on the determinate shoots are barren (without leaves), which are reduced to dark brown scarious cataphylls. Succeeding nodes are with green but reduced leaves. Subtending cymules of male flowers are followed by nodes each with cymule of one central female flower (rarely two) and several lateral males, distal half floriferous, determinate, shoots are normally sterile with typical leaves.

Inflorescence: Inflorescence is racemose type, flowers minute, unisexual, with short pedicel. Male flowers appear first in cluster; perianth 6, yellowish green or deep pink in colour with valvate aestivation. Androecium consists of 3 stamens, each profusely branched, and filament attachment is basi-fixed or innate type, short, and cohesion of anther is syngynecious. Female flowers have tiny green perianth and number of segments varies from 5 to 7 but commonly six. Ovary hypogynous, carpels 3-4, three chambered placentation axile two ovules perlocule, margin straight to crescent shaped, and ovarian chamber shallow to deep. Fruit Nearly pedicel less, fruits depressed, round globose or oblate, indented at the base. A capsular (drupaceous) berry with fleshy exocarp, smooth to obscurely 6 lobed.

15.5 Bael (*Aegle marmelos* Corr.)

Bael (*Aegle marmelos* Corr.) is an indigenous fruit of India belongs to family Rutaceae. *Aegle marmelos* contains 2n =18 chromosomes with 1.60 µm average size of chromosomes. Length of individual chromosomes varies from 1.08 to 2.62 µm. Total chromatin length of bael is calculated as 28.88 µm (Jha, 2014). Taxonomic position of genus Aegle is given as under:

Taxonomic position of genus Aegle

Kingdom	Plantae
Subkingdom	Viridiplantae
Infrakingdom	Streptophyta
Superdivision	Embryophyta
Division	Tracheophyta
Subdivision	Spermatophytina
Class	Magnoliopsida
Superorder	Rosanae
Order	Sapindales
Family	Rutaceae
Genus	Aegle Corrêa

Morphological Description

Bael is a small to medium deciduous tree and can grow up to 10-15 m in height with a 25-50 cm in diameter trunk. Old branches and stems are covered with sharp spines. The spines occur in singly or in pairs and are 1-2 cm long. The bark is greyish brown. Leaves are alternately arranged in a trifoliate pattern with 2-4 cm long petioles. The lateral petioles are up to 15 mm long. The lateral leaflets are ovate to elliptic, and up to 7 × 4.2 cm in size. The terminal leaflets are obovate, and up to 7.5 × 4.8 cm in size. The inflorescences are 4-5 cm long, are borne on the axillary racemes, and occur in clusters. The 1.5 mm long sepals are broadly deltoid. The greenish to white petals are oblong-obovate, and 14 × 8 mm in size. The white stamens occur in a group of 35-45, with 4-7 mm long filaments. The ovary is 8 × 4 mm in size with very short style. The fruit is a subglobose berry 5-12.5 cm in diameter with a hard woody shell. Inside the fruit, there are 8-16 (-20) segments, with 6-0 seeds in a clear, sticky, edible yellow pulp. At ripening the pulp contains scented mucilage, which has a sweet taste. The seeds are woolly-pubescent and are enclosed in a sac of adhesive mucilage, which solidifies on drying. The testa is white.

15.6 Genus *Annona*

Annona is a member of flowering family Annonaceae consisting of trees, shrubs, or rarely climbers with about 2300 to 2500 species and more than 130 genera and it is the largest family in Magnoliales (Bridg, Hannia, 2001). Seven genera, *Annona*, *Anonidium*, *Rollinia*, Uvaria, *Melodorum*, *Asimina,* and *Stelechocarpus* produce edible fruits. The family is concentrated in the tropics, with few species found in temperate regions. About 900 species are Neotropical, 450 are Afrotropical, and the other species Indomalayan. Compared to the species from the Neotropics, very little is known about many species from Indomalaya. Only a few attempts have been made for the phylogeny-based reclassification of the family, and those have been hampered by the Neotropic bias in the available information, with the most of the work having been done on genera and tribes (Chatrou, 2005).Taxonomic position of the genus *Annona* is given as under:

Taxonomic position of the genus *Annona*

Kingdom	Plantae
Subkingdom	Viridiplantae
Infrakingdom	Streptophyta
Superdivision	Embryophyta
Division	Tracheophyta
Subdivision	Spermatophytina
Class	Magnoliopsida
Superorder	Magnolianae
Order	Magnoliales
Family	Annonaceae
Genus	*Annona* L.

Description of species: Description of some of the important cultivated species of *Annona* is given as under:

1. ***Annona squamosa*:** It is a deciduous and much smaller than the *Annona muricata*, reaching a maximum of 6.0 m in height, with many lateral branches. The stems present lenticels, while the young shoots are pubescent and the oldest are smooth. It was domesticated in the circum-Caribbean or northern South American lowlands. It has deciduous leaves that are brilliant green above and bluish green below, with petioles 0.7 to 1.5 cm in length. The leaves are oblong-elliptical in form, measuring 5 -17 cm in length and 2-7 cm in width, with an obtuse or acuminate apex. The blade has 15 to 17 pairs of veins (Ochse *et al*., 1974). The flowers measure 2.0 -2.5 cm in length and are much smaller than *Annona muricata* flowers, being similar in size and form to those of cherimoya. Pollen

germination is low and may influence final fruit set, which varies from 5.4% to 5.6% (Thakur and Singh, 1965a). The fruit is rounded, heart-shaped, ovate or conical, 5 - 7.5 cm in diameter, 6 to 10 cm in length and weighing 120 to 330 g. Fruit size depends on cultivar, pollination, nutrition and other factors, but its form resembles a hand-grenade, with a tuberculate surface covered with a whitish bloom. The white, custard-like pulp has a pleasant sweet-sour flavour. The fruit contains 35 - 45 black seeds, each 1.5 - 2.0 cm in length and 0.6 - 0.8 cm in width. There are a few recognized cultivars of custard apple viz., 'Mammoth', 'Barbados', 'British Guinea', 'Balondegar', 'Red Sitaphal', and 'Sindhan', the last being local to Gujarat (Singh, 1992). A dwarf cultivar is 'Lal Sitiphal'.

2. ***Annona cherimola*** **(cherimola):** The name cherimoya derives from the Quechua name "chirimuya", which means "cold seeds" (Lizana and Reginato, 1990). It is a small, erect and/or somewhat spreading, deciduous tree, rarely reaching a height of more than 7.5 m. Its stem frequently divides at ground level into several stems (NRC, 1989). It was domesticated in the mid-elevation Andes of South America. It has simple, alternate, 2 to 4 ranked leaves, which are ovate-lanceolate to elliptical in shape, 10 to 25 cm long, glabrous on the ventral surface and pubescent dorsally, with leaf shedding in the spring. The single, protogynous, fragrant flower emerges from the leaf axils, and possesses a short peduncle, *ca* 2.5 cm in length. Flowering occurs once a year, the season depending on the environment and it starts when the tree is 3 to 4 years old. Flower anthesis starts in the early morning and it takes 8 h to attain complete opening. The fruit is normally heart-shaped, conical, oval or somewhat irregular in form due to irregular pollination. Fruits measure 7.5 to 12.5 cm in length and weigh from 200 to 700 g. The fruit surface is smooth in some varieties; in others, it is covered with small conical protuberances over the carpels. The fruit rind is delicate and thin, and is greenish-yellow when ripe (Popenoe, 1974). The white, sub-acid flesh has a fragrant, delicate flavour, like that of pineapple and banana. The fruit has numerous seeds (21 to 41 seeds/fruit), which are 1.5 to 2.0 cm in length and approximately 1.0 cm in width (Manica, 1997).

3. ***Annona muricata*** **(soursop):** The soursop has an erect growth habit with a high canopy height-to-diameter ratio (Pinto and Silva, 1996), although it tends to be low-branching and bushy, with upturned limbs (NAS, 1975). It is a small, slender, evergreen tree, 4 to 8 m tall when fully mature. It was domesticated in lowland South America as a garden plant. The stems are rounded, rough and not pubescent, with a dark-brown colour. The leaves have short petioles, and are oblong-ovate to cylindrical, 14 to 16 cm in length

and 5 to 7 cm in width. Because of similarities of plant canopy and leaf form, soursop and mountain soursop (*A. montana* Macf.) are often confused. The flowers of soursop are comparatively much larger measuring 3.2 to 3.8 cm in length. The flowers start to open in the early morning and complete anthesis takes approximately 6 h, depending on the climate. Flowering is more or less continuous. This species also experiences inefficient natural pollination (normally done by beetles) and frequently poor fruit set. Soursop produces an ovate, conical or heart-shaped fruit, that is dark green when unripe and a slightly lighter green when ripe. The rind has many short, fleshy, pointed carpel protuberances and is popularly regarded as 'spiny'. The soursop has the largest fruit in the genus, weighing from 0.9 to 10 kg, and averaging 4 kg. Its white, cottony-fibrous, juicy flesh resembles that of cherimoya in colour. The flavour is more acid and less sweet than cherimoya, and calls to mind a mixture of pineapple and mango. The fruit has 127 to 170 seeds, scattered throughout the pulp. Seeds are toxic and size varies from 1 to 2 cm in length and from 0.33 to 0.59 g in weight, with a black colour soon after harvest, but becoming dark-brown later (Pinto and Silva, 1996). Few cultivars of *A. muricata* exist, and comparisons among them have not been made to assess their validity. In particular, those with good-sized, low- fibre fruits need to be identified (NAS, 1975).

4. ***Annona reticulate*:** The tree reaches 6.0 to 7.5 m in height, with many lateral branches; stems are cylindrical, with lenticels and very short coffee-coloured hairs. It is thought to have been domesticated, even though the fruit is considered to be of inferior quality. It can be distinguished from cherimoya by its long, narrow, glabrous leaves (León, 1987). The leaves are oblong-lanceolate and dark-green, measuring 25 to 30 cm in length and 7 cm wide, with 10 to 20 vein pairs and a pubescent petiole. Flowers are grouped in a short inflorescence with 2 to 10 flowers, with pedicels measuring 1.5 to 3.0 cm in length. This species also presents inefficient natural pollination and poor fruit set. Fruits weigh from 0.1 to 1.0 kg and are commonly heart-shaped, but may be conical, ovate or irregular in form, and 10 to 12 cm in length. They are coriaceous and have a reddish-yellow surface colour, with impressed lines (around 5 to 6 angled areoles) above the carpels. The flesh is milk-white and sweet, although insipid in flavour, being considered the least tasty of the cultivated annonas. There are commonly more than 40 oblong, dark coffee- coloured seeds per fruit (León, 1987).

5. ***Annona senegalensis* (wild sour soup):** Wild sour soup is a spreading shrub or small, semi-deciduous tree, 1.5 to 11.0 m (averaging usually about 3.5 m) in height, with a stem diameter up to 28 cm at breast height (FAO, 1983, 1988). It has a greyish-black bark, often rough and corrugated, branching near the ground, with young stems mostly ferruginous, velvety to greyish or red-brown tomentose, later becoming glabrous. It is not strictly domesticated, but some trees are 'protected' due to preferred qualities. The leaves are ovate, oblong-elliptical or oblong-ovate in form, 8 to 17 cm by 4 to 10 cm, with an acute, obtuse, rounded or slightly emarginate apex, and upper surface smooth, lower surface pale brown and hairy. Like other annonas, the leaves are simple, alternate, with 0.5

to 2 cm long petioles. The flowers are inconspicuous, green, single or grouped on long smooth stalks (in fascicles with 2 to 4 flowers). They are fleshy, up to 3 cm diameter and usually fragrant. The fruit has an ovate, globose or subglobose form, measuring 2.5 to 5.0 cm in length and 2.5 to 4.0 cm in width. The unripe fruit is green with white specks turning yellow or orange when ripe. The white to yellow edible flesh, which has many seeds, has a pleasant aroma, resembling pineapple, but tasting of apricot. One hundred seeds weigh *ca.* 40 g. There is a recognized botanical variety, var. *posteide* (Bail.) Diels., and no known cultivars. There is a dwarf form in Malawi where the plant is so small that the fruits grow 'on the ground' and this form is thought to taste the best by the locals (Williamson, 1974).

Exercise No: 16

Economic Importance of Production of tropical and Subtropical Fruit Crops

High productivity:

- **High yield per unit area:** From a unit area of land more yield is realized from fruit crops than any of the agronomic crops. The average yields of Papaya, Banana and Grapes are 10 to 15 times more than that of agronomic crops.
- **High net profit:** Though, the initial cost of establishment of an orchard is high, it is compensated by higher net profit due to higher productivity or high value of produce.eg-Wheat/GN/Ragi-3.0-4.0tonnes/ha-25-35,000-00, Grapes/Mango/Banana-20-40t/ha-1.5-2.5 lakh/ha.
- **Source of raw material for agro based industries:** Fruit farming provides raw materials for various agro based industries- canning and preservation (fresh fruits), coir industries (coconut husk), pharmaceutical industry (Aonla, Papaya, Jamun) transporting and packaging industries etc.
- **Efficient utilization of resources:** Growing of fruits being perennial in nature, enables grower to remain engaged throughout the year in farm operations and to utilize fully the resources & assets like machinery, labour, land water for production purpose throughout the year compared to agronomic crops.
- **Utilization of waste and barren lands for production:** Although, most of the fruits crops require perennial irrigation and good soil for production, there are many fruit crops which are hardy in nature, Mango, Ber, Cashew, Custard apple, Aonla, Phalsa, Jamun etc. which are grown on poor shallow, undulated soils considered unsuitable for growing grain/ agronomical crops.
- **Foreign exchange:** Many fresh fruits, processed products and spices are exported to several countries earning good amount of foreign exchange.

Currently India occupies7.02 millin hectare area and the production is 107.02 million metric tones (2021-22). The country has got tremendous growth in fruit production. Students of Horticulture discipline always should be aware about the area production and productivity of different crops and always try to analyse the various factors influencing the growth rate in production, productivity and area also. Here some simple example has been given for calculating the growth rate.

Steps to use straight-line percent change

Calculate growth rate with these steps:

1. Use growth rate formula: It is necessary to know the original value and divide the absolute change with it. The formula is Growth rate = Absolute change / Previous value

2. Calculate the absolute change: Knowing the original value and the new value is essential for finding the absolute change. The formula is Absolute change = New value - Previous value
3. Use the original value for dividing the absolute change: You can get growth rate by dividing the absolute change by the previous value. The formula is Growth rate = Absolute change / Previous value
4. Find percent of change: To get the percent of change, you can use this formula the formula of Percent of change = Growth rate x 100

Straight-line percent change example

Suppose that a farmer has produced 300 tonnes of orange in year 2021 and in year 2022 , he has produced 350 toones of oranges the growth rate will be calculated by following equation

Growth rate= Yield produced in current year- Yield produced in previousyear

Yield produced in previous year

So = 350-300

300

=0.166

Percentage Change =(0.16x100)= 16

If you change the production figures in current year produced 300 tonnes and previous year 350 tonnes

Growth rate= Yield produced in current year- Yield produced in previous year

Yield produced in previous year

So= 300-350= -50/350

Percent change= -14.28

Steps to use average growth rate over time

The following steps will help you to calculate growth rate:

1. **Use growth rate formula:** Find growth rate by dividing the current value with the previous value, multiplying the result with 1/N and subtracting one from that result. The N in the formula stands for the number of years. The formula is Growth rate = (Current value / Previous value) x 1/N - 1
2. **Subtract the previous value from the current value:** Get the difference between the previous and current values by subtracting the previous value from the current one. The formula is Current value - Previous value = Difference

3. **Multiply the difference to the 1/N power:** N stands for the number of years. The formula is:(Difference) x 1/N = Result
4. **Subtract one from the result:** You can use the following formula to get growth rate: Growth rate = Result - 1
5. **Find percentage change:** The following formula can help you to find percentage change: Percent change = Growth rate x 100

For example: India's fruit production during 2019-20 to 2021-22 as given in the following table, its average growth rate will be calculated as below

Fruit Production in India

Year	**Production million Mt**
2019-20	102.08
2020-21	102.48
2021-22	102.92

Growth rate: 102.48-102.08=0.40/102.08 x100 =0.39

102.92-102.48=0.44/102.48x100=0.42

Average growth rate = 0.39+0.42=0.81/2=0.405%

College of Horticulture

CENTRAL AGRICULTURAL UNIVERSITY

Bermiok, South Sikkim-737134