Fundamentals Of Horticulture

- **Content Creator Name:** Dr. Kirtimala Balaji Naik, University of Horticultural Science Bagalkot
- **Content Reviewer:** Jitendra Singh, Agriculture University Kota, Kota

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Love the land, because it can give you everything.

Course Name	**Fundamentals of Horticulture**
Lesson 1	**Climate and Soil for horticultural crops**
Content Creator Name	**Dr. Kirtimala Balaji Naik**
University/College Name	**University of Horticultural Science,Bagalkot**
Course Reviewer Name	**Jitendra Singh**
University/college Name	**Agriculture University Kota, Kota**

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India is the seventh largest country in the world with a total geographical area of 328.73 mha and has second largest population (138 crores) after China. The total arable land available is 156.46 mha of which 70% is under rainfed cultivation. India population is equivalent to 17.7% of the total world population. Around 55-60 per cent of population depends on agriculture and allied activities. Horticulture crops constitute a significant component of total agricultural production in the country.

- **Definition:** Horticulture is a branch of Agriculture. The term horticulture is derived from Latin words: "*hortus*" meaning "garden" and "colere" meaning "cultivation". In ancient days the gardens were protected enclosures with high walls or similar structures surrounding the houses.
- The enclosed places were used to grow fruit, vegetables, flowers and ornamental plants. Therefore, in original sense "*Horticulture refers to cultivation of garden plants within protected enclosures*".
- Practically, horticulture may be defined as the science and technique of production, processing and merchandizing of fruits, vegetables, flowers, spices, plantations and medicinal and aromatic plants
- India is the seventh largest country in the world with a total geographical area of 328.73 mha and has second largest population 138 crores (2020) after China. India shares 7.7% of the total world population
- The total arable land available is 156.46 m. ha.
- Around 55-60 per cent of population depends on agriculture and allied activities.
- Horticulture crops constitute a significant component of total agricultural production in the country.

Branches of Horticulture

Horticulture is a wide field and includes a great variety and diversity of crops. The science of horticulture can be divided into several

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branches depending upon the crops it deals with. The following are the branches of Horticulture.

1. **Pomology**: Branch of Horticulture that deals with the study and cultivation of fruit crops.
2. **Olericulture**: Branch of Horticulture that deals with the study and cultivation of
   Vegetable crops.
3. **Floriculture**: Branch of Horticulture refers to study and cultivation of flower crops.

4. **Plantation Crops**: Branch of Horticulture which refers to the study and cultivation of crops like coconut, arecanut, rubber, coffee etc.
5. **Spices Crops**: Branch of Horticulture which refers to study and cultivation of crops
   like, cardamom, pepper, nutmeg etc.
6. **Medicinal and Aromatic Crops**: Branch of Horticulture which deals with study and cultivation of medicinal and aromatic crops.
7. **Post-Harvest Technology**: Branch of Horticulture which deals with post-harvest handling, grading, packaging, storage, processing, value addition, marketing etc. of horticulture crops.

Present scenario

Fruit crops

- India is the second largest producer of fruit after China. A large variety of fruit crops are grown in India. Of these, mango, banana, citrus, papaya, guava, pineapple, sapota, jackfruit, litchi, grapes, apple, pear, peach, plum, walnut etc. are important ones.
- The country ranks first in production of Bananas (25.7%), Papayas (43.6%) and Mangoes (including mangosteens and guavas) (40.4%).
- India accounts for more than 10 per cent of the global production of fruits. It leads the world in production of mango, banana, guava, acid lime and papaya besides recording highest productivity in grapes. The

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leading fruit growing states are Maharashtra, Karnataka, Andhra Pradesh, Bihar and Uttar Pradesh.

Vegetable crops

- More than 40 vegetables belonging to Solanaceaeous, cucurbitaceous, leguminous, cruciferous, root crops and leafy vegetables are grown in Indian tropical, sub-tropical and temperate region.
- India is the largest producer of ginger and okra amongst vegetables and ranks second in production of potatoes, onions, cauliflowers, brinjal, cabbages etc. India is second in vegetable production next to China in area and production contributing 13.38 percent to the total world production. India occupies first position in cauliflower, second in onion, third in cabbage in the world.
- West Bengal, Odisha U.P, Bihar, Maharashtra, Karnataka are the important states for Horticultural crop production.

Flower Crops

- Flower cultivation is being practised in India since ages as it is an important/integral part of socio-cultural and religious life of Indian people. It has blossomed into a viable industry only in recent years.
- India is known for growing traditional flowers such as jasmine, marigold, chrysanthemum, tuberose, crossandra, aster, etc. Commercial cultivation of cut flowers like rose, orchids, gladiolus, carnation, anthurium, gerbera and lilies etc under protected cultivation has now become popular.
- The important flower growing states are Tamil Nadu, Karnataka, AP, Maharashtra, West Bengal, Sikkim, J&K and Meghalaya.

Plantation crops

- This is one of the important sector contributing upto 5.5% to the total horticultural crop production. The major plantation crops include coconut, arecanut, oilpalm, cashew, tea coffee, rubber cocoa,

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betel vine, vanilla etc. The leading states are Karnataka, Kerala, Tamil Nadu, A.P., Maharashtra, Goa, Assam etc.

Spices

- They constitute an important group of low volume high value horticultural crops and are defined as vegetable products or mixture thereof free from extraneous matter used for flavouring, seasoning and imparting aroma in foods.
- India is known as home of spices producing a wide variety of spices like black pepper, cardamom, ginger, turmeric, chilli, Coriander etc.
- Major spice producing states are Kerala, A.P., Gujarat, Rajasthan, Maharashtra, Karnataka, Orissa and Tamilnadu.

Medicinal and Aromatic plants

- India has diverse collection of medicinal and aromatic plants species distributed throughout the country.
- It has more than 9500 species with medicinal properties. Demand for these crop is increasing progressively in both domestic and export market.

  Important medicinal plants are isabgol, periwinkle, coleus, ashwagandha, etc. and aromatic plants are mint, grasses, davana, patchouli etc.

Features of Horticulture

1. Horticultural produce are mostly utilized in the fresh state and are highly perishable
2. Horticultural crops need intensive cultivation requiring a large input of capital, labour and technology per unit area
3. Cultural operations like propagation, training, pruning and harvesting are skilled and specific to horticultural crops
4. Horticultural produce is a rich source of vitamins and minerals and alkaloids

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5. Aesthetic gratification is an exclusive phenomenon to horticultural science

Importance of Horticulture

- As per National Horticulture Database 2021, the total horticultural crops contributed to 30% to gross net value. India produced 334.60 million tonnes of horticulture crops. The production of fruits was 102.48 million tonnes and vegetables was 200.45 million tonnes. Requirements of export and processing industry further add to the requirements of horticultural produce. In view of these, there is lot of scope of increasing production and potentiality of horticulture crops.

- Apart from fruits and vegetables, floriculture industry in India comprising of florist trade, nursery plants, potted plants, seeds and bulb products is being observed as sunrise industry.

- Plantation crops are another potential sector with lot of opportunities of employment generation, foreign exchange earnings and overall supporting livelihood sustenance of mankind at large. These crops form the mainstay of lives especially in coastal areas of the country where predominating stands of plantation crops are found. Coconut has so much importance in the country that the state Kerala receives its very name on the basis of coconut, the Malayalam name of which is Kera. These cover a production of 16.12 million tonnes.

Horticulture is important for the following considerations

- As a source of variability in produce.
- As a source of nutrients, vitamins, minerals, flavour, aroma, alkaloids, oleoresins, fibre, etc.
- As a source of medicine.
- As an economic proposition as they give higher returns per unit area in terms of energy, money, job, etc.

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- Employment generation 860 man days/annum for fruit crops as against 143 man days/annum for cereal crops and the crops like grapes, banana and pineapple need 1000- 2500 man days per annum.
- Effective utilization of waste land through hardy fruits and medicinal plants.
- As a substitute of family income being component of home garden.
- As a foreign exchange earner with higher share compared to agriculture crops.
- As an input for industry being amenable to processing, especially fruit and vegetable preservation industry.
- Aesthetic consideration and protection of environment.
- Religious significance.
- In short horticulture supplies quality food for health and mind, more calories per unit area, develops better resources and yields higher returns per unit area.
- It also enhances land value and creates better purchasing power for those who are engaged in this industry.
- Therefore, horticulture is important for health, wealth, hygiene and happiness.

Scope of Horticulture

Scope of horticulture depends on incentive it has for the farmers, adaptability of the crops, necessity and facilities for future growth through inputs availability and infrastructure for the distribution of produce/marketing etc.

- India is bestowed with a great variety of climatic and edaphic conditions as we have climates varying from tropical, subtropical, temperate and within these humid, semi-arid, arid, frost free temperate etc. Likewise, there are varied types of soils like loamy, alluvial, lateritic, medium black rocky shallow, heavy black, sandy etc. Thus a large number of crops can be accommodated with very

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high level of adaptability. Thus, there is good scope for horticultural crops.

- Continued increase in demand for horticultural produce provides tremendous scope for the growth of this industry.
- Good land is under pressure for stable food, industry, housing, roads and infrastructure due to population explosion and only wasteland had to be efficiently utilized where cultivation of annuals is a gamble due to restricted root zone and their susceptibility of abiotic stress. These lands can be best utilized to cultivate hardy horticultural crops like fruits and medicinal plants.
- At present our share in international trade of horticultural commodities is less than one per cent of total trade. Moreover, these commodities (spices, coffee, tea) fetch 10-20 times more foreign exchange per unit weight than cereals and therefore, taking advantage of globalization of trade, nearness of big market and the size of production, our country should greatly involve in international trade which would provide scope for growth.

Export value

During 2019-20, India exported fruits and vegetables worth Rs. 9,182.88 crores/ 1,277.38 USD Millions which comprised of fruits worth Rs. 4,832.81 crores/ 668.75 USD Millions and vegetables worth Rs. 4,350.13 crores/ 608.48 USD Millions. Grapes, Pomegranates, Mangoes, Bananas, Oranges account for larger portion of fruits exported from the country while Onions, Mixed Vegetables, Potatoes, Tomatoes, and Green Chilly contribute largely to the vegetable export basket. Among flowers, roses, among plantation and spice crops black pepper, cardamom, ginger, turmeric, chillies, cashewnut, tea , coffee, coconut, arecanut, etc constitute the bulk of the export basket. The major destinations for Indian fruits and vegetables are Bangladesh, UAE, Netherland, Nepal, Malaysia, UK, Sri Lanka, Oman and Qatar. India has exported 16,949.37 MT of floriculture products to the world worth of Rs. 541.61 crores /75.89

USD Millions in 2019-20. Major Export Destinations (2019-20) : U S A, Netherland, Germany, U K, and United Arab Emirates were major importing countries of Indian floriculture during the same period.

Horticultural Crops and Human Nutrition

Fruits and vegetables play an important role in balanced diet.

These provide not only energy rich food but also provide vital protective nutrients/elements and vitamins.

Comparatively fruits and vegetables are the cheapest source of natural nutritive foods.

Since most of Indians are vegetarians, the incorporation of horticulture produce in daily diet is essential for good health.

With the growing awareness and inclination towards vegetarianism worldwide the horticulture crops are gaining tremendous importance.

Functions of Fruits and Vegetables

1. Fruits and vegetables provide palatability, taste, improve appetite and provide fibre thereby overcome constipation.
2. They neutralize the acids produced during digestion of proteins and fatty acids.
3. They improve the general immunity of human body against diseases, deficiencies etc.
4. They are the important source of vitamins and minerals used for several bio-chemical reactions that occur in the body.

Fruits

Fruits provide higher energy value per unit area compared to cereals. Some of the essential vitamins provided by different fruits are

Vitamins	Role in Human Health	Source
Vitamin **A**	1. Essential for growth and reproduction 2. Helps in resistance to infections, increases longevity	Mango, Papaya, perssimon, Dates, Jack fruit, Walnut, Oranges, Passion

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	3. Deficiency causes night blindness, xeropthalmia, retardation in growth, roughness in skin, formation of stones in kidney.	fruit, Loquat etc
Vitamin B_1	1. Essential for the maintenance of good appetite and normal digestion. 2. Necessary for growth, fertility, lactation and for normal functioning of nervous system. 3. Deficiency causes beri-beri, paralysis, loss the sensitivity of skin, enlargement of heart, loss of appetite and fall in body temperature.	Walnut, Apricot, Apple, Banana, Grapefruit, Plum & Almond.
Vitamin B_2	1. Important for growth, health of skin and for respiration in poorly vascularised tissue such as the cornea. 2. Deficiency causes pellagra and alopecia, loss of appetite, loss of weight, sore throat, development of cataract, swollen nose and baldness.	Bael, Papaya, Litchi, Pomegranate, Wood Apple and Pineapple
Vitamin **C**	1. Deficiency causes scurvy, pain in joints, swelling of limbs, unhealthy gums, tooth decay, delay in healing of wounds	Barbados cherry, Aonla, Guava, Lime, Lemon, Sweet oranges, Ber,

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	and rheumatism.	Pineapple & Pear.

Fruits are also a good source of enzymes which are helpful in metabolic activates leading to proper digestion of food. The fruits like jamun and papaya are the examples.

All fruits have one or the other medicinal value.

They should be eaten in adequate quantity.

Regular consumption of fruits reduces obesity, maintain health and increase the longevity of life.

Fruits are attractive in appearance, delicious in taste and easily digestible.

Therefore they are liked by young and old alike.

Horticultural and botanical classification

India is bestowed with rich Horticultural wealth comprising 356 domesticated species of the economic importance and 326 species of their wild forms or relatives. Indian subcontinent enjoys rich diversity of plant wealth. Out of these more than 50 types of individuals types of species, plantation crops, etc. are under commercial cultivation in different part of the country under different sets of growing conditions. Grouping of plants in different categories is referred to as classification. The overall objective of classification is to systemize the presentation and make the remembrance of the plants easy and convenient.

Classification:

Classification of plants means the grouping of different plants having characteristics in common. Classification of plants is a relatively dynamic process and undergoes change with change or increase in knowledge.

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Horticultural plants are classified on following basis:

(Classification of Horticultural crops)

1) On the basis of duration of life/life span.
2) On the basis of climatic requirements.
3) On the basis of growth habit and physiological characters.
4) On the basis of plant parts used for consumption.
5) On the basis of whether leaves are shed during the year.
6) On the basis of longevity.
7) Botanical classification

1) On the basis of duration of life/life span:

The horticultural crops on the basis of duration of life are classified as:

a) Annuals: Plants which complete their life cycle in one season or one year are called as annuals. e.g. Tomato, Balsam, Marigold etc.

b) Biennials: Plants which complete their life cycle in two seasons or two years are known as biennials. e.g. Onion, Cabbage, Tuberose etc.

c) Perennials: Plants which require more than two years to complete their life cycle are called perennials. The perennials necessarily do not die after flowering.

i. Woody perennials: These plants have hard and fibrous trunk and branches. e.g. Mango, Custard apple etc.

ii.Herbaceous perennials: These plants have soft succulent stems. e.g. Banana, Chrysanthemum etc.

2) On the basis of climatic requirements*:*

Temperature:

a) Temperate Horticultural crops:

In temperate regions, the temperature in winter season falls below freezing point. The crops shed their leaves and go into rest. These chilling temperatures help the plants to put forth new growth. Flowering and fruiting starts with the onset of spring. e.g.,

- **Fruits**: Apple, Pear, Almond, Walnut etc.
- **Spices**: Saffron, Kalajira, Asafoetida etc.

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• **Vegetables**: Cabbage, Cauliflower, European varieties of carrot and radish. These vegetables can be grown in sub-tropical regions, however they require temperate climate for seed production.

b) Sub-tropical Horticultural crops: In sub-tropical climate, the summers are hot and dry and winter are less mild. e.g.

• **Fruits**: Citrus, Guava, Pomegranate, Fig etc.
• **Spices**: Turmeric, Ginger, Onion, Garlic etc.
• **Vegetables**: Tomato, Brinjal, Chilli, Okra, Potato etc.

c) Tropical Horticultural crops: The climatic conditions in such areas are hot and humid in summer and mild in winter. e.g.

• **Fruits**: Mango, Banana, Pineapple, Sapota etc.
• **Spices**: Black pepper, Turmeric, Ginger, Cloves etc.
• **Plantation crops:** Coconut, Arecanut, Cocoa etc.
• **Vegetables**: Tomato, Brinjal, Chilli, Onion etc.

3) On the basis of growth habit and physiological characters: (Classification of Horticultural crops)

a) Trees: Trees are the plants which have a distinct stem or trunk which may be in most of cases woody or sometimes herbaceous.

i) Woody trees: These plants have hard and fibrous trunks and branches. e.g. Apple, Citrus, Guava, Mango etc.

ii) Herbaceous trees: These have soft succulent stems.

• **Herbaceous trees** (upright growth): e.g. Banana

b) Shrubs / bushes: Shrubs or bushes produce a large number of branches and are smaller in size than trees. e.g.

• **Fruits:** Phalsa, Coffee etc.
• **Ornamental shrubs:** Acalypha etc.

c) Climbers: These plants attach themselves to supports such as trellis, arches or lives plants.

• **Fruits:** Grapes, Passion fruit etc.
• **Spices:** Black pepper (live support) etc.

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• **Ornamental climbers:** Allamanda, Antigonan etc.

4) On the basis of plant parts used for consumption:

a) Fruits: (Edible Part)

1. Apple (Pome)= Fleshy thalamus

2. Banana (Berry)= Mesocarp and endocarp

3. Cashew nut (nut)= Peduncle and cotyledons

4. Coconut (Fibrous drupe)= Endosperm

5. Custard apple (Etaerio of berries) =Fleshy pericarp of individual berries

6. Fig (Syconus) =Fleshy receptacle

7. Guava (Berry) =Thalamus and pericarp

8. Grape (Berry) =Pericarp and placentae

9. Mango (Drupe) =Mesocarp

10. Orange (Hesperidium) =Juicy placental hair

11. Papaya (Berry) =Mesocarp

12. Pineapple (Sorosis) =Fleshy thalamus

13. Pomegranate (Blausta)= Aril

b) Plantation crops and spices: (Edible Part)

1. Coconut (Fibrous drupe) =Endosperm

2. Arecanut (one-seeded ovoid drupe) =Seed (Fresh and dried)

3. Cocoa (5-ribbed drupe) =Beans (Seeds)

4. Coffee (Fleshy (drupe)= Seed (Bean)

5. Black pepper (One-seeded spherical drupe) =Dried wrinkled fruit

6. Clove (Fleshy drupe)= Unopened flower bud

7. Cinnamon (Fleshy berry) =Bark

8. Chilli (berry)= Fruit and seeds

9. Turmeric =Rhizome

10. Ginger (Capsule) =Rhizome

11. Onion =Leaves and Bulb

12. Garlic =Cloves

c) Vegetables: (Edible Part)

1. Radish, Carrot, Turnip, Beetroot, Sweet potato= **Roots**

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2. Knolkhol, Potato =**Stem**
3. Palak, Methi, Amaranthus =**Leaf**
4. Cauliflower, Broccoli =**Flower**
5. Tomato, Brinjal, Okra, Cucurbits =**Fruit**
6. Beans and Pea =**Pod**
7. Onion =**Bulb**

5) On the basis of leaf shedding:

a) Deciduous: the plants that are leafless or which shed their leaves during winter are referred to as deciduous. e.g. Apple, Fig, Grape etc.

b) Evergreen: The plants whose leaves persist the year round or grow continuously all the year round are known as evergreen. The evergreens actually loose their leaves annually but not until a new set of leaves is developed. e.g. Arecanut, Coconut, Banana, Mango, Sapota etc.

6) On the basis of longevity:

The longevity of trees is very variable and plants can be classified on the basis as under:

Life span: Plants

a) 1000 years: Sweet chestnut
b) 100-300 years: Walnut
c) 50-100 years: Persimmon, Avocado
d) 30-70 years: Apricot, Fig
e) 20-40 years: Peach, Plum, Pomegranate
f) 25-30 years: Currant, Gooseberry and Raspberry
g) 4-5 years: Strawberry

7) Botanical classification:

A) Botanical classification of vegetables:

a) Monocot:

i) Araceae – Colocassia
ii) Alliaceae – Onion, Garlic
iii) Diascoreaceae – Yam

b) Dicot:

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i) Chenopodiaceae – Spinach
ii) Cruciferae – Cole crops, Turnip, Radish
iii) Leguminosae – Pea, Beans, Fenugreek
iv) Euphorbiaceae – Tapioca
v) Malvaceae – Okra
vi) Umbelliferae – Carrot
vii) Convolvulaceae – Sweet potato
viii) Solanaceae – Tomato, Brinjal, Chilli, Potato
ix) Cucurbitaceae – Gourds, Melons, Pumpkin
x) Compositae – Lettuce

B) Botanical classification of fruits:
a) Monocot:
i) Musaceae – Banana
ii) Bromeliaceae – Pineapple

b) Dicot:
i) Rhamnaceae – Ber
ii) Sapotaceae – Chiku
iii) Rutaceae – Citrus and Bael
iv) Annonaceae – Custard apple
v) Moraceae – Fig, Jackfruit
vi) Vitaceae – Grape
vii) Myrtaceae – Guava
viii) Apocynaceae – Karonda
ix) Anacardiaceae – Mango, Cashew nut
x) Caricaceae – Papaya
xi) Punicaceae – Pomegranate

C) Botanical classification of plantations and spices:
a) Monocot:
i) Arecaceae (Palmae) – Coconut
ii) Arecaceae (Palmae) – Arecanut

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iii) Alliaceae – Onion, Garlic
iv) Zingiberaceae – Turmeric, Ginger

b) Dicot:
i) Lauraceae – Cinnamon
ii) Mytraceae – Clove
iii) Piperaceae – Black pepper
iv) Rubiaceae – Coffee
v) Solanaceae – Chilli
vi) Sterculiaceae – Cocoa

8) Classification based on Rate of Respiration
(A) Climacteric
Sharp rise in respiration after harvesting
1. Mango
2. Banana
3. Sapota
4. Guava
5. Papaya
6. Apple
7. Fig
8. Peach
9. Pear
10. Plum
11. Annona

(B) Non-climacteric
Steady respiration at the time of harvesting
1. Citrus
2. Grape
3. Pineapple
4. Pomegranate
5. Litchi
6. Jamun

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7. Cashew
8. Cherry
9. Strawberry

Climacteric fruits produce much larger amount of ethylene than non climacteric fruits.

Highest ethylene production :

(i) Apple- (25-2500L/L)

ii) Passion fruit (466-530 L/L)

9. Classification based on Photoperiodic responses

Long day plant

Passion fruit
Banana
Potato
Onion
Cabbage
Cauliflower
Raddish
Lettuce
Spinach
Palak
Turnip
Carrot
Beet

Short day plant

Strawberry
Apple Pineapple
Sweet Potato
Indian spinach
Dolichos Bean
Cluster Bean
Winged Bean
Coffee

Day neutral plant

Papaya

Guava

Banana

Brinjal

Chilli

Okra

Cucurbits

Amaranths

French Bean

Cowpea

Sweet pepper

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Climate and soil play very important role in the growth and development stages of a crop. Fruit growers should have knowledge of the effect of various soil and climatic conditions on fruit growing. Horticulture crops cannot be grown in all type of soil and climate. Hence zone wise cultivation is made. Climate includes a number of parameters like temperature, rainfall, atmospheric humidity, wind, hail, light, whereas soil covers such factors as moisture supply, texture, chemical composition and soil temperature.

SOIL

Soil is the main growing medium of any crop. It provides mechanical support, nutrients and water to the plant growth. To ensure development of an efficient root growth the soils must contain adequate supply of air, water and low bulk density. Most of the horticultural crops need well drained soil and cannot tolerate water logging. Therefore deep and well drained soils, free from hard sub soils are needed for growth of the plant. Soil may defined as “superficial earth crust which functions as store house of reservoir of water and nutrients at the same time providing the necessary physical support to the plant”.

Classification of Soils

1. **Alluvial soil:** This type of soil is mostly available soil in India which covers an area of 143 sq.km. It is widespread in Northern plains of India and river valleys. It is highly fertile soil as it is rich in humus, lime and organic matter. Colour of this soil ranges from light grey to ash grey with sandy to silty loamy texture. Alluvial soils are rich in potash and poor in phosphorous.
2. **Black soils:** Black soils are also known as cotton soils. These soils are known for its mature nature. Black soils have a high water retaining capacity. These soils often swell when wet and shrink when dried. Black soils are rich in Iron, lime, calcium, potassium, aluminium and magnesium and poor in nitrogen, phosphorous and organic matter. The colour of black soil varies from deep black to light black. Black soils generally have a clayey texture.
3. **Red soils:** Red soils are found in low rainfall areas in eastern and southern parts of Deccan Plateau. These soils are poor in nitrogen, phosphorous and

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humus. These soils develop reddish colour due to iron and turn yellow when hydrated. These soils are normally fertile except in dry upland areas where the fertility decreases.

4. **Laterite soils:** The laterite soils develop in areas with high temperature and high rainfall. Lateritic soils have low humus content because most of the microorganisms, particularly the decomposers, like bacteria, get destroyed due to high temperature. Laterite soils are suitable for cultivation with adequate doses of manures and fertilizers.
5. **Arid Soils:** Arid soils are commonly found in the state of Rajasthan. These soils are

   generally brown in colour. In the lower horizons of Arid soils calcium content is in increasing range which leads to formation of layers known as Kankar. These soils are rich in salt content. After proper irrigation these soils become suitable for cultivation.
6. **Saline Soils:** Saline soils contain a large proportion of sodium, potassium and magnesium. These soils lack in nitrogen and calcium. These soils are poor in fertility. They have more salts, largely because of dry climate and poor drainage. They occur in arid and semi-arid regions, and in waterlogged and swampy areas. Gypsum is added to soil to solve the problem of salinity in the soil.
7. **Forest soils:** Forest soils are loamy and silty on valley sides and coarse-grained in the upper slopes.These soils are acidic in cooler parts of the country with low humus content. These soils are heavy and black in colour. These soils are found in the hilly and mountainous areas where sufficient rain forests are available. The soils found in the lower valleys are fertile. The soils vary in structure and texture depending on the environment where they are formed.

Grouping of fruits according to their tolerance to salinity:

(i) **High salt tolerance:** Date palm, ber, aonla

(ii) **Medium salt tolerance:** Pomegranate, fig, grape

(iii) **Low salt tolerance:** Apple, orange, almond, lemon, avocado.

In making choice of soil for fruit crops physical properties should he emphasized more as chemicals can be added from outside to improve

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nutrient status and chemical properties of the soil. Generally it is the depth and the drainability is important considerations.

To upkeep soils for sustainable production following needs to be done before and after planting a crop:

1.Soil analysis in terms of its physica1 and chemical attributes.

2.Bring the soil to its optimum potential by applying organic matter, chemical fertilizers, micronutrient, amendments depending on soil analysis report

3.Adoption of soil conservation technique like green manuring on regular basis.

4.Use of improved water management techniques like drip irrigation and check basin or Furrows.

5. Incorporation of large quantity of bulky organic matter each year

6.Creation of appropriate drainage around the plot.

7.Scrapping of salts, and reclamation of soil by application of gypsum, iron pyrites, pressmud etc. on regular basis in case of salinity problem.

8.Replenishment of nutrients harvested by the crop on regular basis by preparing a balance sheet for nutrients.

9.Recycling of organic waste.

10.Soil is the most important natural resource for fruit culture and it needs to be protected and improved.

CLIMATE

Climate is the most important factor on which choice of the crop for a region depends and therefore, our understanding about climate and its requirement for different crops for optimum production on sustainable basis is important.

Climate is defined as the average atmospheric phenomena for a certain region. The climatic parameters are calculated for a average of thirty to ascertain a particular type of climate in a particular region. Light, water, temperature, air etc are important determinants of climate.

Light:

Electromagnetic radiation to which the organs of plant react ranges in wavelength from 4000 to 7700 angstrom units, and is propagated at a speed

of about 540 kilometers per second. It is essential for the process of photosynthesis and therefore, growth and development of plants. There are two aspects of light, its intensity and duration which are important for plant development. The light intensity can be estimated from the number of hours of bright sunlight or from the cloudiness of sky. Generally horticultural crops need a lot of light and must be grown in sunny climate, but there are some crops which can tolerate shade like turmeric, and ginger. There are others crops like young mangosteen, coffee; cocoa and tea need shade during part of their development. A third group requires permanent shade like palm, duku and carambola.

The duration of light for the time elapsing between dawn and dusk referred as photoperiod or day length, may exert considerable influence on flowering and based on the response by plants. Classified in nine classes (Table 2.2) but the major classes, are following. However, fruit crops for such categories are not known.

(i) Long day plants: Cabbage, cauliflower, onion, beet, radish, carrot, spinach, potato, Dill, Plantago.

(ii) Short day plants: Strawberry, pineapple, chrysanthemum, poinsettia; Aster, Balsam, Salvia, Euphorbia, Xanthium.

(iii) Day neutral plants: Tomato, most fruit crops, pepper, cucumber, snapdragon, Mirabilis, certain varieties of peas.

For fruiting in photosensitive crops this requirement needs consideration or flowering and fruiting may not take place as in potato, cabbage, cauliflower, in tropics.

Table: 1 Plants according to photoperiodic requirements

Sl.No.	Classification according to photoperiodic requirements	Crops
1	Short day plants	Strawberry, Chrysanthemum, Cosmos, Aster, Poinsettia, Impatiens, Salvia, Euphorbia
2	Long day plants	Spinach, Beet, Radish, Potato, Hibiscus
3	Day neutral plants	Most of the fruit crops, Tomato, Pepper,

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		Cucumber, Mirabillis, Peas

Heat:

Heat is a non-mechanical energy transfer with reference to a temperature difference between a system and its environmental surrounding. It is measured as temperature by thermometers. Daily, monthly and yearly averages are computed, as-well as, mean low and high temperatures and their extremes. The yearly average at sea level on equator is 26—27°C and the range is small; it usually amounts to 2—3°C between months and 6—10°C between day and night. Farther away from equator range increases and altitude also has the effect on lowering the temperature by 5-6^{0}C for every 1000 m. The growth of the plants depended primarily on temperature. This means a plant which grows normally at sea level will grow slowly in the mountains e.g. 'Lacatan' banana has a growth cycle of 13 months at sea level takes one more month at 100m altitude. Availability of heat units decide the crop for a given place and the average temperature of a place gives idea about heat units available on the basis of which crop can be decided.

Temperate fruit crops like apple, pear, peach, plum and almond become dormant due to short day conditions in the region and need chilling of various lengths to break dormancy. In general they need 250—101) 0 hrs of temperature below 7°C.

Frost and chilling are harmful for tropical and subtropical region plants. On the other hand extremely high temperatures found in arid region cause wilting, sunscald, necrotic spot and even death of plants.

Therefore, under such conditions appropriate choice of plants and provision of protection become important.

Based on the temperature variations on the surface of the earth we have following climates.

Tropical equable climate with no distinct winter.

Subtropical Climate with distinct winter and summer.

Temperate: Distinct winter, summer, and autumn with temperature below freezing during winter is common.

Frigid: Very cold in temperature throughout Polar Perpetual ice and snow.

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However, in these zones temperatures may vary under the influence of altitude.

For each of these situations plants/trees are there which can be grown but under frigid and polar situation vegetation is not possible.

Tropical : Mango, banana, papaya, sapota, pineapple, coconut, cashew, arecanut, breadfruit, jackfruit, avocado.

Subtropical: Guava, grape, citrus, date palm, phalsa, pomegranate, litchi, loquat.

Temperate: Apple, pear, peach, plum, quince, apricot, walnut, almond, strawberry, cherry.

However, this choice is not very rigid as some tropical crops which can be grown in subtropics and vice versa. There are low chilling temperate crops which can grow in sub-tropics like peach, pear, strawberry etc. Short duration crops like vegetables and flower crops are classified as warm season and cool season crops accommodated in various types of climates depending on temperature variations within a year. Flower and vegetable crops have been depicted in **table 2** according to their season of growing.

Table: 2 Classification of vegetable and flower crops according to season

Crops	Warm season	Cool season
Vegetables	Bottlegourd, Watermelon, Brinjal, Tomato, Clusterbean, Okra, Sweet Potato	Cabbage, Cauliflower, Peas, Beans, Potato, Onion, Carrot, Radish
Flowers	Marigold, Zinnia, Chrysanthemum, Sunflower, Gomphrena, Gaillardia, Portulaca, Kochia, Amaranthus, Celosia, Coreopsis	Aster, Poppy, Dianthus, Dahlia, Salvia, Petunia, pansy, Phlox, Coreopsis, Verbena, Diamorphotheca, Calendula, Brachycome, Candytuft, Sweet allysum, antirrhinum, Sweet Pea

Water

Water is a transparent, odourless and tasteless liquid compound of hydrogen and oxygen (H_20) with 11.91 % hydrogen and 88.81% oxygen. It is

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essential for plant growth and development as a substrate in photosynthesis, regulation of plant temperature, distribution of metabolites and nutrients. It comes through precipitation of rain and snow. Near equator the total rainfall is 2000 mm per year and away from it, it reduces but again influenced by a number of factors like mountain ranges. Water requirement of plant is dependent on soil type and evapotranspiration rate. For crop production it is not the total rainfall but its distribution is more important and in Indian subcontinent we have rains mainly confined to June to September, thereby fruit culture in India had to be supported by irrigation or one has to select crop where fruiting is confined to water availability periods and trees remain dormant during stress.

Water is also present in the atmosphere as vapour and we call it as humidity. This atmospheric humidity also influences growth and development of plants: Low humidity has drying effects and enhances water requirement whereas high humidity favours fungal diseases. Plants which require high humidity and low humidity are as under:

High humidity; Sapota, banana, mangosteen, jackfruit, breadfruit

Low humidity (Dry): Ber, grape, date palm, pomegranate, citrus, annona, guava

Air: It is a mixture of oxygen, nitrogen and other gases that surrounds the earth and forms its atmosphere. It is also one of the climatic factors influencing plant growth. If its quality is polluted by the accumulation of gases like hydrocarbons, SO_2, $C0_2$, CO, NO ethylene and methane the plant growth is adversely affected but the movement of air (wind) causes great damage to crops in deserts, coastal areas, valleys for which provision of windbreaks and shelterbelts are suggested and such situations sometimes have to be avoided for plantation.

Storm has a wind speed of 50 km/hr whereas, hurricane has a wind speed of more than 100km/hr.

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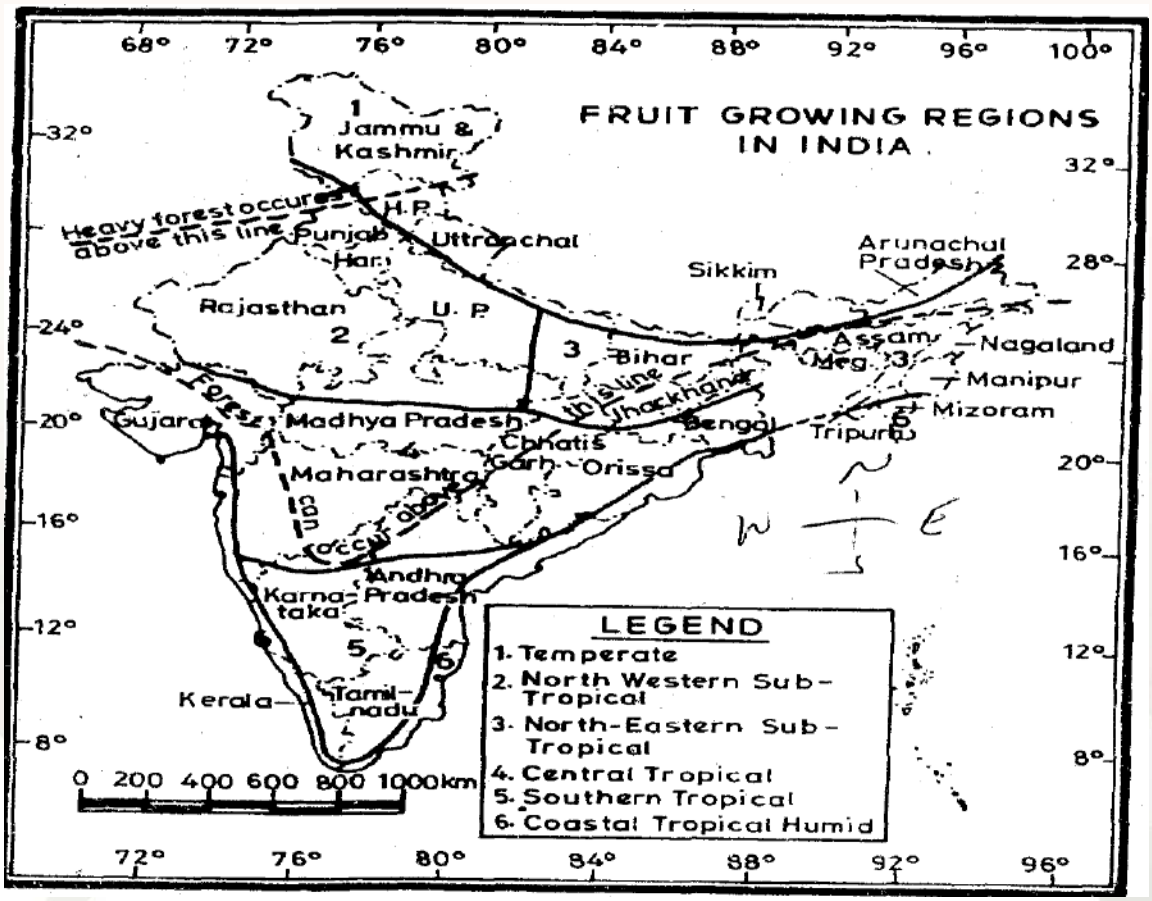
Horticultural Zones of India

The Indian subcontinent is bestowed with a great variety of climate and soil conditions. Broadly the country can be divided into tropical, subtropical and temperate regions. Within each broad category there are differences due to rainfall, humidity, altitude etc and considering these aspects six different horticultural zones have been identified so that appropriate choice of the crops can be made and development is planned. They are:



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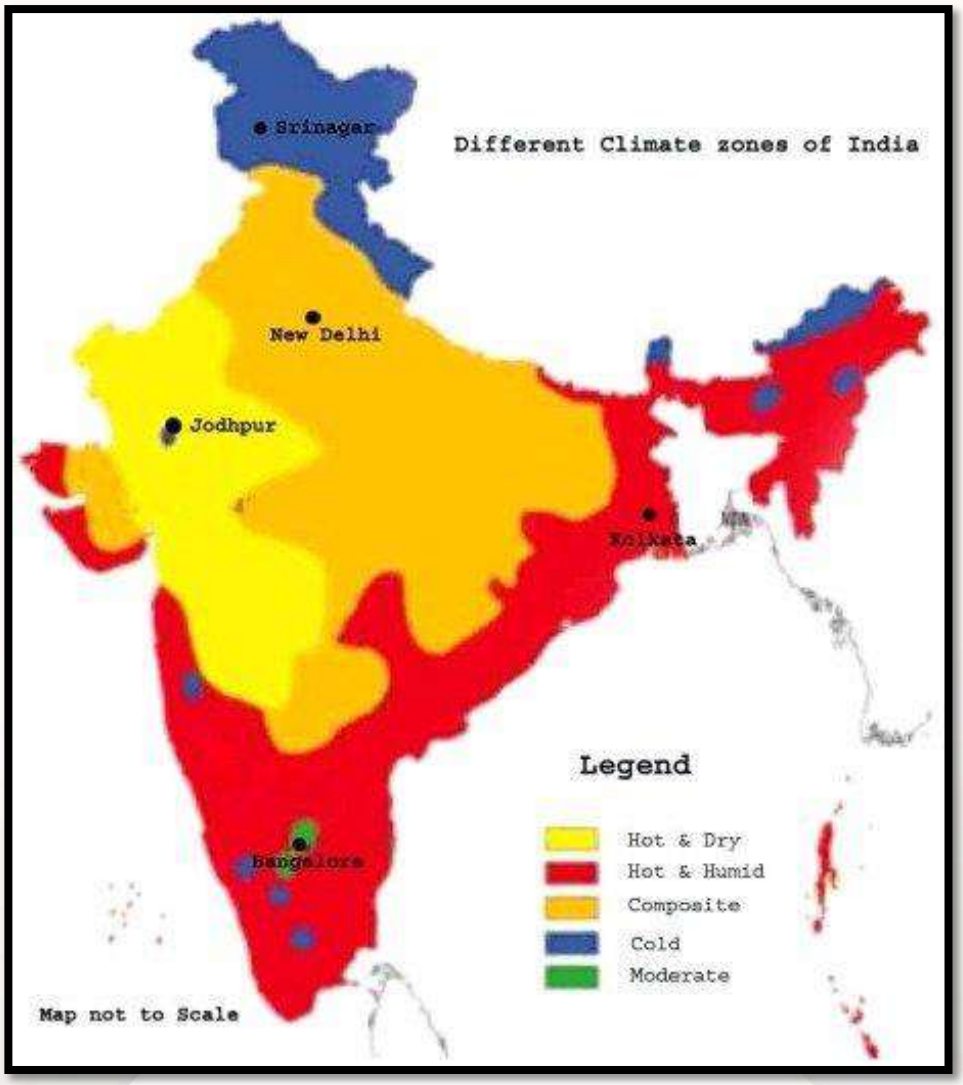


(i) **Temperate:** Kashmir, Ladakh, parts of Uttarakhand, Sikkim and part of Arunachal Pradesh.

(ii) **N.W.Subtropical**: Punjab, Haryana, Rajasthan, Central Uttar Pradesh and North M.P.

(iii**) N.E.Subtropical**: Bihar, Jharkhand, Assam, Meghalaya, Nagaland, Manipur

(iv) Central Tropical: South Madhya Pradesh, Chhatisgarh, Gujarat, Maharashtra, Odisha, West Bengal.

(v) **Southern Tropical**: Karnataka, Andhra Pradesh, Tamil Nadu.

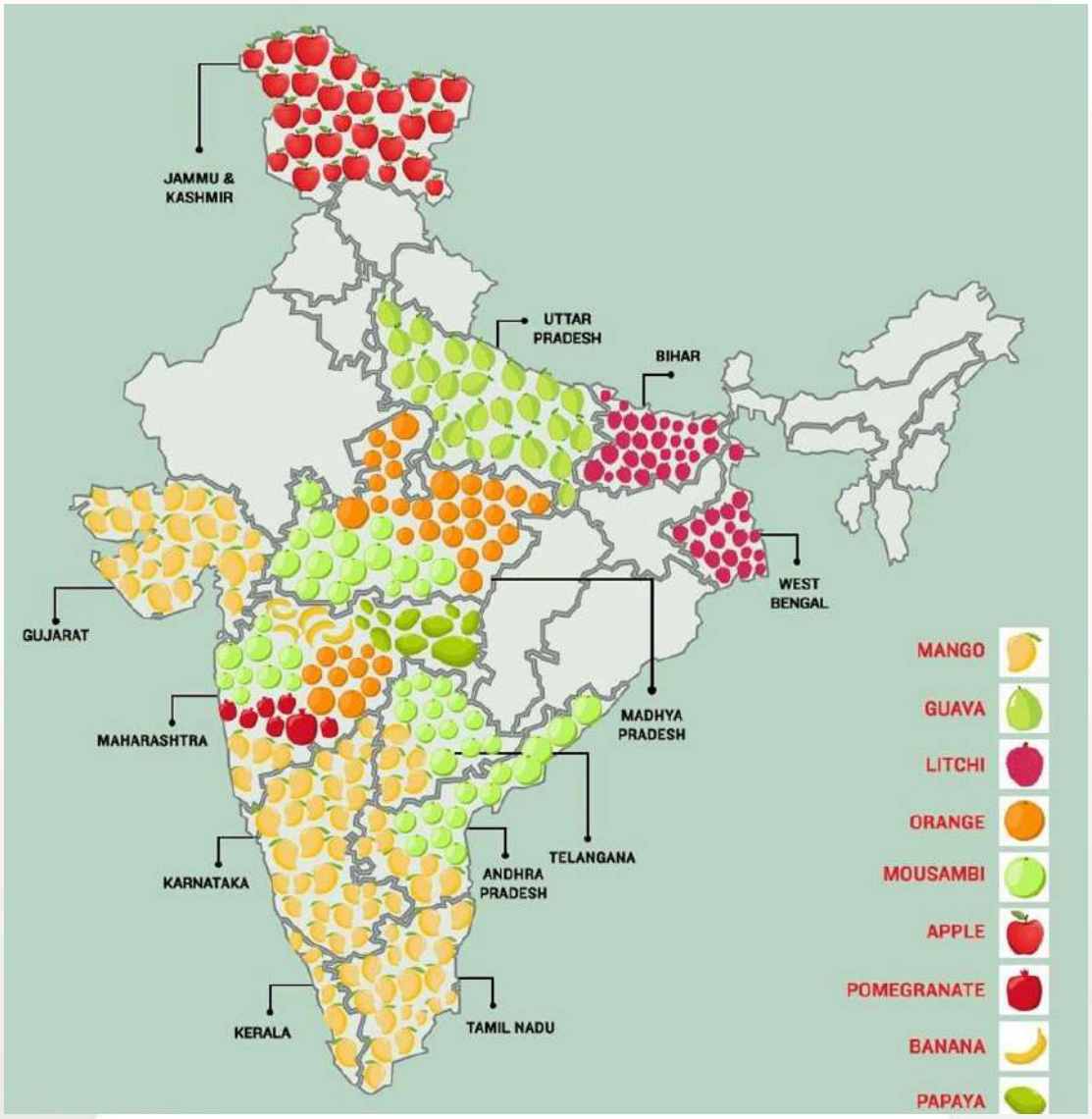
(iv) **Coastal Tropical humid:** Konkan, Goa, Kerala, Western Ghats, Eastern Ghats in Tamil Nadu, Andhra Pradesh and Odisha.

To exploit potential of a crop and its sustenance, right choice based on climate and soil is necessary otherwise the management of the crop becomes

difficult and the cost of cultivation increases. To be precise, most adaptable crop should be chosen for sustenance.

Table: 3 Climatic requirements for important fruits of India

Fruit crops	Suitable climatic zones
Mango	Tropical and Sub-tropical
Citrus	Tropical but can be grown under temperate
Grapes	Temperate but can be grown under tropical and subtropical
Peaches	Temperate but low chillling vraieteis can grow under subtropical conditions
Sapota	Tropical but low chilling varieties can grow under frost free zones
Papaya	Tropical and mild subtropical climate
Banana	Tropical but can be grown under subtropical climate provided it is free from frost
Almond	Temperate but some low chilling varieties can be grown under subtropical climate
Apple	Temperate but some low chilling varieties can be grown on lower hills



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Course Name	**Fundamentals of Horticulture**
Lesson 3	**Plant propagation**
Content Creator Name	**Dr. Kirtimala Balaji Naik**
University/College Name	**University of Horticultural Science,Bagalkot**
Course Reviewer Name	**Jitendra Singh**
University/college Name	**Agriculture University Kota, Kota**

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Plant propagation can be defined as the reproduction or multiplication of a plant from a source that is often referred to as a mother plant. Some plants are easier to multiply than others. Each plant responds differently to different methods of propagation.

Plants can be propagated by sexual and asexual means. Sexual propagation includes propagation by seeds, while asexual propagation is based on the utilisation of vegetative parts of plants for raising new ones. Different vegetative parts of plants like shoots, leaves, roots, stem, buds and underground parts are used in different ways for reproducing new plants. Most common asexual propagation methods include cutting, layering, grafting and budding which need specialised skills and are done differently in different plants.

Different methods of propagation are described here as under:

1. Seed propagation

Seed is the most common means of propagation for self-pollinated and cross pollinated plants. Seed is the most widely used method of propagation than any other propagation methods. Most vegetables, ornamental annuals, flowering trees and many fruits are usually propagated by seeds. Horticultural crops are grown from seeds for three main reasons *viz*., (i) to grow crops commercially (ii) to develop new varieties and (iii) to grow rootstocks for grafting and budding.

The seed is a mature ovule enclosed within the ovary or fruit. The seed basically contains three essential parts. (i) embryo, the end product of the sexual cycle which develops into a new plant, (ii) food storage tissues, like endosperm, cotyledon or perisperm and supply the embryo and young seedlings necessary food materials during their early stages of growth, and (iii) seed coverings, which provide mechanical protection for the embryo and play an important role in seed germination.

Seed germination

Germination can be defined as the process whereby the dormant embryo resumes growth and the radical and plumule breaks through the seed

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coat. Germination process involves complex sequence of biochemical, physiological and morphological changes. Three conditions must be fulfilled before the resumption of germination. First, the seed must be viable, that is, the embryo must be alive and capable of germination. Second, the dormancy inducing internal conditions, the physical or chemical barriers to germination must have disappeared. Third, the seed must be subjected to appropriate environmental conditions. Not all seeds germinate readily although the environmental conditions are favourable.

Many seeds may have protective mechanisms (embryo dormancy), protective chemicals (inhibitor dormancy), water repellent or very thick seed coats (seed coat dormancy), in nature, this prevents seed from germinating at the wrong time of the year, insuring subsequent successful growth.

Selection of seeds: For successful cultivation, selection of good seed is very important. The qualities of good seeds are

1. Seeds must be healthy
2. Seeds should be of improved type
3. They should have higher percentage of germination
4. Seeds must be free from diseases, weed seeds, seeds of other crops, inert material etc.
5. Seeds should be vigorous and have optimum moisture content
6. Seeds should be obtained from reliable sources.

Seed treatments

I. Scarification

Scarification is a process to modify the hard or impervious seed coat. Scarification can be done mechanically or by using acid.

1. Mechanical scarification

It is a process of mechanically altering the seed coat by breaking or scratching the seed coat to make it permeable to water and gases. This is possible by rubbing the seeds on sand paper or with a file and also by cracking the seed with a hammer. Care must be taken not to injure the

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embryo. Mechanical scarification is useful for large sized seeds in small quantities. **e.g. :** Ber, gulmohar, sapota.

2. Acid scarification

This is done to modify the hard or impervious seed coat by using concentrated sulphuric acid which is strongly corrosive. The seeds are soaked in concentrated sulphuric acid for duration of 10 minutes to 6 hours, depending upon the temperature and nature of the seed coat. **e.g. :** Ber, gulmohar, sapota.

II. Stratification (moist chilling)

This is a process of exposing the seeds to low temperature and moisture. This treatment is necessary to induce prompt and uniform germination in certain seeds as it permits physiological changes known as after ripening to occur within the embryo of the seed. The seeds are exposed to low temperature [0 to 10^{O}C] in the presence of moisture and air for certain period of time. The time may very from one to four months depending upon the kind of seeds. **For example:** Apple, pear, peach, plum, rose etc.

III. Soaking seeds in water

Soaking seeds in water may modify hard seed coat, remove inhibitors, soften seeds and reduce the time of germination. Some impermeable seed coats can be softened by placing the seeds in 4 to 5 times their volumes of hot water (77^{O} to 100^{O}C) for 5 to 10 minutes. Inhibitors present in seeds may be leached out by soaking or washing the seeds in cold water for 12 to 24 hours.

Sowing of seeds

Before sowing, nursery beds should be prepared properly and seed must be given proper treatment. Small and light seed should be mixed with sand / wood ash to facilitate uniform seed distribution. Generally seeds are sown during spring / summer depending upon kind of crop, nursery practices and location of nursery.

Seed rate varies from crop to crop.

For example: Tomato : 250 g / acre

Chilli : 500 g / acre

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Brinjal : 300 g / acre

Seed should be always sown in lines. Furrows of 2-3 cm depth and 5-7 cm apart are opened across the width of bed. Depth of sowing is 2.5 times the diameter of the seeds. If seeds are small, sowing depth should not exceed 1-1.5 cm. after sowing, they should be covered with thin layer of well decomposed organic matter preferably FYM / Compost.

Need for raising the seedling:

1. In many crops, higher yields are obtained upon transplanting rather than direct sowing.
2. It is possible to get healthy seedling in the nursery bed.
3. Seedlings are provided with good condition for their growth and development.
4. It is easy and convenient to manage seedling in nursery bed compared to main field.
5. Timely and effective plant protection operation can be done.
6. Land can be utilized more economically as more number of seedlings can be raised per unit area.
7. It is possible to use seeds more economically as most of seeds are rather costly.

Raising of seedling in the nursery beds

Some important operations are

1. **Mulching:** Immediately after sowing, beds are covered with thin layer of dried straw, grass or leaves. It prevents loss of soil moisture and growth of weeds. It protects seeds from bird's damage and beating effect of rain.
2. **Watering:** It should be done uniformly at regular intervals. Excessive watering should be avoided and there must be provision for draining excess water.
3. **Partial shade:** Young seedlings should be protected from intense sun's heat during summer. Pandals can be erected over each nursery bed to

provide partial shade. Pendals should allow sufficient sun light pass through it.

4. **Thinning:** Very essential operation in which weak, thin, diseased seedlings are removed. Thinning provides sufficient space to other seedlings for better growth.
5. **Weeding:** Weed should be removed manually by hand carefully. If infestation of weed is high, application of pre-emergence herbicides may be used. E.g. Glyphosate, Alachlore, Atrazine etc.
6. **Plant protection:** Damping off is an important disease in nursery caused by fungus due to excess of water. It can be controlled by drenching beds with solution of 0.2 % Captan / Difolaton during germination and after germination of seeds. Insect pest can be effectively controlled by spraying Rogar / Melathion. Infested seedling must be removed and destroyed as soon as they are noticed.
7. **Hardening:** Seedlings can be uprooted 6-10 weeks after sowing. Before 7-10 days of uprooting, the number of watering should be reduced and seedling should be exposed to full sun light. This enables the seedlings to withstand uprooting and transplanting shock.

Method of propagation by cutting

Cutting is a method of asexual propagation in which a portion of any vegetative part such as a stem, root or leaf is cut from the parent plant and is placed under certain favourable environmental conditions to form roots and shoots thus producing a new independent plant. Generally, partially shaded place is ideal for rooting of cuttings.

Types of cuttings

1. Stem cutting

This is the most important type of cutting used in plant propagation. In propagation by stem cuttings, segments of shoots containing lateral or terminal buds handled under proper conditions develop adventitious roots and thus form independent plants. The cuttings are usually prepared during the dormant season and from the wood of the present

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to previous season's growth. In some cases as in olive or fig, two-year or older wood is used.

Stem cuttings can be divided into 3 types based on the degree of maturity and lignifications of wood used in making the cuttings i.e. hardwood, semi-hard wood and softwood cuttings.

A. Hard wood cuttings

This is the least expensive and easy method. Hardwood cuttings are not readily perishable and may be shipped safely over long distances.

For example: Acalypha, Fig, Grape, Mulberry, Olive, Pomegranate, Rose rootstocks

Preparation and planting

1. Select a fully matured shoot with normal internodes from a healthy, vigorous plant growing in full sunlight.
2. Remove all the leaves without damaging the axillary buds.
3. Give a slant cut just below the basal node of the selected shoot.
4. Measure the required length (about 15 to 25 cm and containing 3 to 4 nodes) from the base of the shoot and give a horizontal cut 1 to 2.5 cm above the top node.
5. Repeat this procedure and prepare as many cuttings as possible from the shoot.
6. In case of difficult-to-root species treat the prepared cuttings with the recommended growth regulators to induce rooting.
7. Make holes in the prepared bed or pot with the help of a stick or dibbler.
8. Insert the cuttings in the hole such that at least two nodes are inside the soil. Take care of the polarity while planting cuttings.
9. After planting press the medium firmly around the cutting and water immediately.

B. Semi hard wood cuttings

Semi hard wood cuttings are prepared from new shoots just after a flush of growth which is partially matured.

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For example: Camellia, Geranium, Hibiscus, Jasmine, Lemon, Olive

Preparation and planting

1. Select partially matured shoots from a healthy and vigorous growing plant and take out the terminal 7 to 15 cm portion by giving a horizontal cut just below a basal node.
2. Remove all the leaves towards the base of the shoot and retain only the terminal leaves.
3. If the retained leaves are very large, reduce their size by cutting the top half portion. This facilitates planting the cuttings closer and also minimizes the loss of water from cutting.
4. Plant the cuttings in the same way as hardwood cuttings are planted.

C. Softwood cuttings

Soft wood cuttings are made from soft, succulent, fresh growth from herbaceous plants.

For example: Coleus, Magnolia, Pilea, Tea

Preparation and planting

1. Select healthy shoots from vigorous growing plants and take out the terminal 7 to 12 cm portion by giving a horizontal cut just below a basal node.
2. Remove two or three basal leaves just to facilitate planting
3. If the leaves are large reduce their size to lower the transpiration rate and to accommodate more cuttings in the bed.
4. Plant the cuttings as indicated for the hard wood cuttings.

D. Herbaceous cuttings

Herbaceous cuttings are made from succulent, non woody plants like geranium, chrysanthemum, coleus, carnation and many foliage crops.

Preparation and planting

1. Select a healthy and vigorous plant

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2. From the selected healthy shoot cut 7-15 cm portion by giving a slanting cut just
3. below the basal nodes.
4. Remove 2-3 basal leaves just to facilitate planting. In case of *Diffenbachia* sp. All leaves are removed wherein which the latent buds develop in to shoots along with the formation of adventitious roots.
5. Planting method is similar to previous types.

II. Leaf cuttings

In leaf cuttings, the leaf blade with or without petiole and axillary bud is used for starting new plants. Adventitious roots and adventitious shoots form at the base of the leaf and develop into a new plant. However, the original leaf dose not becomes a part of the new plant.

Frequent watering, high humidity and bottom heating are desirable for better and rapid rooting of leaf cuttings. Sand or peat moss (1:1) is satisfactory as rooting media for leaf cuttings.

Types of leaf cuttings

1. Leaf blade cutting: For example: Sansevieria

Preparation and planting

a) Select a healthy leaf
b) Give a slanting cut towards the base of the leaf.
c) Measure a length of about 7 to 10 cm and give a horizontal cut towards the terminal end
d) Prepare as many cuttings as possible from the selected leaf.
e) Insert up to ¾ of the prepared leaf cuttings into the medium. Take care of the polarity while planting the cuttings.
f) Compress the soil around the leaf cuttings and water immediately.

2. Leaf vein cutting: For example: *Begonia rex*

Preparation and planting

a) Select a healthy and fully mature leaf and detach it from the plant
b) Give cuts to the alternate veins closer to the petiole on the lower surface of the leaf.

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c) Keep the leaf flat on the rooting medium in such a way that the lower portion comes in contact with the medium.

d) Pin or hold down the leaf so as to expose the upper surface of the leaf and to maintain the contact between the cuts on the vein and the rooting medium.

e) Water the cuttings carefully.

3. Leaf margin cutting: For example: *Bryophyllum pinnatum, Kalanchoe tubifolia*

Preparation and planting

a) Select a healthy and mature leaf with the foliar embryos intact.

b) Keep the leaf flat on the rooting medium. If the leaf is folded, just cut along the midrib so that the leaf can be kept flat on the medium.

c) Keep some weight on the leaf or partially cover it with soil so that the margin comes in contact with the medium.

d) Water the cuttings carefully.

4. Leaf-bud cutting: For example: Blackberry, Camellia, Lemon, Raspberry

A leaf-bud cutting consists of leaf blade, petiole and a short piece of the stem with the attached axillary bud.

Preparation and planting

a) Select a healthy and mature shoot with well developed buds and healthy actively growing leaves.

b) Separate each leaf along with the axillary bud and a small portion of the stem.

c) Repeat the process until possible numbers of leaf-bud cuttings are made.

a) Treat, if necessary, the cut surface of the prepared cuttings with the recommended root promoting substance to stimulate rapid root production.

b) Insert the prepared cutting in the rooting medium so that the bud is 1.5 to 2.5 cm below the surface.

c) Compress the medium around the cutting and water immediately.

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III. Root cuttings: For example: Breadfruit, Clerodendron, Raspberry, Tea

Preparation and planting

a) Select a healthy and matured root from the plant.
b) Cut the root into pieces of 7 to 15 cm long.
c) Give a slanting cut towards the distal end to identify the polarity.
d) Plant the cuttings in the pot or raised bed.

Note: If the cutting is planted horizontally, it should be planted about 5 cm deep in the soil. If planted vertically, the proximal end of the cutting should be upward and in line with the surface of the soil.

Methods of propagation by layering

Layering is the development of roots on the stem while it is still attached to the parent plant. The rooted stem is then detached to become a new plant growing on its own roots. Such rooted stem is known as a layer.

Material required

1. Plant material
2. Knife
3. Secateur
4. Media
5. Polyethylene sheet
6. Gunny thread

Types of layering

1. Simple layering

In this method, a branch is bent to the ground and some portion of it is covered by soil leaving the terminal end of the branch exposed. Root initiation takes place at the bent and buried portion. After allowing sufficient time for root formation, the rooted stem is separated from the mother plant.

For example: Pomegranate, Bougainvillea, Jasmine, Rangoon creeper etc.

Procedure

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a) Select a healthy, flexible and sufficiently long (50 to 60 cm) branch towards the base of the plant. The selected branch should be closer to the ground.
b) At a distance of about 15 to 30 cm back from the tip give a sharp, slanting inward and upward cut of 1.5 to 2.5 cm below a node and insert a small wood splinter.
c) Bend the shoot gently to the ground so that the treated part can be conveniently inserted into the soil.
d) Cover the treated region with soil.
e) Peg down the shoot or keep a stone or brick on the covered soil to keep the layered shoot in place.
f) Drive a vertical stake into the soil by the side of the layered branch and tie the terminal portion of the branch to keep it upright.
g) Water the layered portion regularly so as to keep it moist all through till root initiation takes place.
h) After sufficient root formation separate the layer by cutting just below the rooted zone.

2. Compound or Serpentine layering

Compound layering is essentially the same as the simple layering except that the branch is alternatively covered and exposed along its length. The branch for compound layering must be long and flexible so that it can be layered at different places along its length.

For example: Bougainvillea, Jasmine, Rangoon creeper.

Procedure

a) Select a healthy, flexible and sufficiently long (100 to 250 cm) basal branch that is close to the ground.
b) Give a sharp slanting, inward and upward cut of 1.5 to 2.5 cm below a node at 30 cm interval starting from the tip leaving 3 to 4 buds in between two such cuts.
c) Bend the shoot gently to the ground and insert and cover the cut portions with the soil exposing the uncut portions.

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d) The remaining steps are same as in simple layering.

3. Mound layering or stooling

In this method a plant is cut back to the ground level during the dormant season and soil is heaped around the base of the newly developing shoots. After allowing sufficient time for root initiation, individual rooted layers are separated from the mother plant and planted.

For example: Apple rootstocks, Guava, Litchi, Quince

Procedure

a) Select the plant to be mound layered, or plant a rooted layer in a trench and allow it to grow for a year.
b) Cut back the plant to 2.5 cm from the ground level just before growth begins. Allow the new shoots to develop.
c) When these shoots have grown to 7 to 15 cm tall, girdle them at the base, treat the girdled portion with the recommended growth regulator and draw up the loose soil around each shoot to half of its height.
d) When the shoots are 20 to 25 cm tall add soil again to half of their height.
e) Add soil again when the shoots grow to a height of about 35 to 45 cm.
f) Water the heaped soil regularly and allow sufficient time for the initiation of roots. A depression can be made in the centre of the heap to hold water.
g) After sufficient root formation remove the heaped soil and cut the rooted shoots individually to their bases.
h) Transplant the rooted shoots in pots or suitable containers.

4. Trench or continuous layering

Trench layering consists of growing a plant or a branch of a plant in a horizontal position in the base of a trench and filling in soil around the new shoots as they develop, so that the shoot bases are etiolated. Roots develop from the base of these new shoots. Trench layering is used primarily for woody species difficult to propagate by mound layering.

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For example: Apple rootstocks, Litchi, Quince

Procedure

a) Dig small trenches of about 25-30 cm deep and in about 1 m wide rows.
b) Plant rooted layers or one year old nursery – budded or grafted plants in the trenches in rows at an angle of 30^{O} to 45^{O} and 50 to 60 cm apart with in the row. The rows should be 1.2 to 1.5 m apart.
c) Just before growth begins, lay the plant flat on the bottom of the trench. Plants must be kept completely flat with wooden pegs or wire fasteners.
d) Cut back the shoots lightly and remove the weak branches.
e) Add rooting medium (sand or sawdust or peat moss) or their mixture at intervals to produce etiolation on 5 to 10 cm of the base of the developing shoots. Apply first 2.5 to 5 cm layer before buds swell and repeat as shoots emerge and expand.
f) At the end of the season remove the medium and cut off the rooted shoots close to the parent plant.
g) Transplant the rooted shoots in pots or suitable containers.

5. Air layering

In air layering roots form on an aerial shoot. The rooting medium is tied to the shoot for getting root initiation. Sphagnum moss is the best rooting medium for air layering as it holds large quantities of water till root initiation and through the root development.

For example: Croton, Ficus, Fig, Guava, Phalsa, Pomegranate, Aonla etc.

Procedure

a) Select a healthy branch of previous season's growth.
b) At a point 15 to 30 cm back from the tip of the shoot make a girdle just below a node by completely removing a strip of bark 2 to 3.5 cm wide all around the shoot.
c) Scrape the exposed surface lightly to remove traces of phloem or cambium to retard healing.

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d) In difficult-to-root species treat the girdled portion with the recommended growth regulator to induce better rooting.
e) Cover the girdled portion with moist propagating medium.
f) Tie the medium around the girdled portion using a polyethylene sheet. Tying should be perfect so that no water can enter the treated part.
g) After observing the fully developed roots through the transparent polyethylene sheet, separate the layered shoot from the parent plant by gradually deepening the cut below the root zone and transplant the layer appropriately.

Layering procedure may be repeated annually.

6. Drop layering

It is a combination of crown division and layering and is practiced in dwarf Rhododendrons, conifers, berberis, box wood, etc. Well grown well branched plants are planted deeply in a hole or trench leaving the tips. New growth comes from tips and the bases of the older branches which are branched. At the end of the season the plants are uprooted and new plant lets are obtained by division.

7. Natural layering

1. Tip layering	:	Black berry, Dew berry, Raspberry
2. Runners	:	*Chlorophytum*, Strawberry
3. Stolon	:	*Cynodon dactylon*
4. Offsets	:	Date, Pineapple
5. Suckers	:	Banana, Chrysanthemum
6. Crown division	:	Lily (*Hemerocallis*)

Selection of mother trees, curing and raising of rootstock

Propagation of plants in specific species requires either a supply of propagules throughout the year (some flower crops, such as carnations, chrysanthemum, foliage plants) or at specific times of the year (fruit and

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nut crops, woody ornamentals). To achieve this a separate block should be created in a commercial nursery which acts as a source for perennial supply of scions. Scion banks should be a collection of popular and new varieties of mother plants which are in great demand in that area.

The source material (mother plants) must be

1. Plants with known pedigree.
2. Produce true-to-type plants.
3. Free from pest and disease infections.

The mother plants should be managed in such a way that sufficient propagating material should be available at the time when it is needed.

Scion: Short piece of detached shoot containing several buds which when grafted or budded

on to the rootstock forms shoot system of a graft.

Stock / rootstock: It is the lower portion of grafted plants which develop in to root system.

A quality rootstock should have following characteristics.

1. it should have uniform and vigorous growth habit
2. it should be healthy, high yielding and resistant to pest, diseases and frost
3. it should have deep root system
4. it should withstand wide range of soil and climatic conditions.
5. it should be easy to propagate
6. it must have bark thicker enough to hold the bud and to budded plants

Importance of rootstocks

Rootstocks are known to have significant effects on vigour, productivity, fruit quality, tree longevity etc. They also have known to prevent susceptibility of scion plant to various diseases, insect pest and other infestations. Therefore, selection of right kind of rootstock is very important in addition, raising of rootstock in proper manner.

Categories of rootstocks: Rootstock may be a seedling or rooted cutting, layered or micro propagated plants. Root stocks are of two types.

1. Seedling rootstock: They are developed through seeds. Easy, economical and commonly adopted in the crops like mango, citrus and

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sapota. But there is a disadvantage of genetic variability in case of poly embryonic crop varieties.

2. Clonal rootstock: these are obtained through vegetative means like cutting, layering or micro propagation. These root stocks are true-to-type and commonly followed in case of rose, apple and grapes.

Raising of Rootstocks for grafting and budding: Rootstocks are normally raised by seeds or cuttings in the beds and then transplanted in the nursery at proper spacing for grafting and budding. They are also raised in small pots (about 15 cm x 8 cm) or polyethylene bags. The plants so raised are used as rootstocks in grafting and budding when they attain appropriate stage of maturity and size.

Curing and separation of scion: Curing of scion is desirable for all the methods of grafting except approach grafting to achieve maximum success. It is nothing but awakening or activating dormant buds on the selected shoots to facilitate better sprouting after grafting.

Procedure: A dormant terminal shoot about 3 to 4 months old from a proven mother plant is selected as a scion. Such a shoot is pre-cured on the plant about a week prior to grafting by removing the leaf blades and leaving the petioles intact. In a week's time the petioles will drop and the buds will swell. Such pre-cured shoots are used as scions for grafting.

Stock blocks / Scion bank / Scion block:

A scion block includes source plants maintained in a more or less permanent location separate from commercial propagation blocks and manage to produce cuttings, bud-wood, scion-wood or divisions. Management of these blocks consists of severe annual pruning geared to the production of scions, buds and cutting material. Fruit tree nurseries establish scion or bud-wood orchards where trees are planted relatively close together and pruned for the production of propagation material rather than for fruit. Nurseries sometime maintain some trees or a branch of each tree as check for verification of cultivar and type. Individual plants in stock blocks need to be examined for trueness-to-cultivar and trueness-to-type prior to their use. Maintaining stock blocks is expensive, time-consuming and may require much space. Unless these blocks are

protected against infection and / or tested for diseases periodically, the disease contamination problems may develop.

Mango: Rootstocks used for grafting from stones of polyembryonic seedling trees. The polyembryonic cultivars are Vellaikolamban, Chandrakaran, Nileshwar dwarf, Olour, Salem, Bellary, Bappakai, Goa etc.

For raising rootstocks, the ripe fruits are collected from the healthy, vigorous and high yielding seedling trees of above mentioned cultivars. Then stones are removed from the fruits and immersed in water. Only those stones which sink in water should be chosen as they are viable. The stone should be sown immediately as they loose viability upon storage. The stones are then planted in beds / pots / directly in the field. Usually stones are to be planted in beds in line with the spacing of 10-15 cm x 45 cm, depth of sowing should not exceed 5 cm and they should be covered with mixture of sand and FYM. Mulching with paddy straw significantly improves germination of stones. Immediately after planting, beds should be watered. Stones start germinating after three weeks of planting. In order to enhance the growth of seedling ammonium sulphate or calcium ammonium nitrate (CAN) should be applied two weeks after germination at the rate of 110 Kg / ha. The seedling will be ready for grafting when they attain height of about 45 cm and thickness of 0.75-1.50 cm at 20 cm height from the ground level. The seedlings which are raised in the beds are transplanted in the polythene bags and then used for grafting.

Citrus: Following are the important rootstocks used for propagation of citrus.

Rough lemon (Jatti katti), Trifoliate orange (*Poncirus trifoliate*),
Cleopatra mandarin,Rangpur lime

Rough lemon is most currently used rootstock. It is tolerant to viral diseases like Tristeza and Exocortis. Scion plants raised on rough lemon produces good quality fruits and are vigorous.

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Trifoliate orange is resistant to cold and have a tendency to dwarf the scion plant. For raising rootstock, matured fruits are collected from healthy vigorously growing rough lemon tree. Then the seeds are extracted, washed in water and dried under shade. Immediately after extraction seeds should be sown as they lose viability during storage. The seeds should be sown on raised beds. After two months the seedlings are transplanted to polybags. They will be ready for budding in 6-8 months. "T" budding is most successful.

Sapota: The following are the rootstocks that can be used for grafting in sapota

1. Sapota seedling (*Achras zapota*)
2. Rayan / Khirni / Pala (*Mimumsops hexandra / Manilkara hexandra*)
3. Mee tree, Adam's apple, Mahua, Star apple.

Among all of them *Khirni* is ideally suited and widely used as they impart vigour, drought resistance and wider adoptability.

For raising rootstock, the mature fruits collected from healthy and vigorously growing Ryan / Sapota tree. Seeds should be extracted, washed in water to remove pulp and they should be dried in shade. To get easy and quick germination, the seeds should be soaked in water for 12 h or GA_3 – 200 ppm. Seeds are sown in bed in lines. The seeds will germinate in four weeks after sowing. They are transplanted in to polybags. The seedlings will be ready for grafting when they attain a height of 15 cm and thickness of 1.0 cm. There is also a practice of collecting the self sown seedlings of rayan from wild forest.

Grape : Salt creek (Ramsey) and Dogridge are important rootstocks used for propagating grapes. These are resistant to nematodes. St. George, AXRI, 99-R, 1202 are other important rootstocks resistant to Phylloxera beetle.

Grape is best propagated by hardwood cutting. The cuttings are prepared in the month of April or October from pruned plant material from healthy, vigorously growing and mature vines. Cuttings are planted on raised nursery bed with a spacing of 15 x 30 cm. after every two rows; 60

cm space is left to facilitate easy cultural operations. The cuttings are allowed to remain in bed for about one year. Later they are transplanted to polybags and used for budding or grafting.

Rose :

Following are the clonal rootstocks used for rose propagation.

Dog rose (*Rosa canina*), Edward rose (*Rosa borboniana*)

Other important rootstocks are

Rosa indica, Rosa laxa, Rosa multiflora, Rosa suposa

Apple

Apple seedling rootstocks: Delicious, Golden delicious, Yellow Newton

Clonal rootstocks: Malling merton (mm series) - M_{7a}, M_9, M_{26}, M_{27}, M_{106}

Cherry

Seedling rootstocks: Mahaleb, Mazzard

Ber

Seedling rootstocks: *Zizyphus mauritiana, Z. rotundifolia, Z. xylocarpa, Z. oenoplia*

Methods of propagation by grafting

Grafting is an art of uniting or joining the parts of two independent plants in such a manner that they unite together and develop into a single independent plant. The part of graft combination which is to become the upper portion or the shoot system or top of the new plant is termed the Scion or Cion and the part which is to become the lower portion or the root system is termed the rootstock or under stock or sometimes stock. The single plant obtained as a result of union between the stock and scion is termed stion.

Raising of Rootstocks for grafting and budding

Rootstocks are normally raised by seeds or cuttings in the beds and then transplanted in the nursery bags at proper time / stage for further usage in grafting and budding. They are also raised by direct sowing in polyethylene bags / clay pots. The plants so raised are used as rootstocks in grafting and budding when they attain appropriate stage of maturity.

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Curing of scions: Curing of scions is desirable for all the methods of grafting except approach grafting to achieve maximum success. It is nothing but awakening or activating dormant buds on the selected shoots to facilitate better sprouting after grafting.

Procedure: A dormant terminal shoot about 3 to 4 months old from a proven mother plant is selected as a scion. Such a shoot is pre-cured on the plant about a week prior to grafting by removing the leaf blades and leaving the petioles intact. In a week's time the petioles will drop and the buds will swell. Such pre-cured shoots are used as scions for grafting.

Methods of grafting:

A. Attach method of grafting:

1. Approach grafting: The distinguishing feature of this method of grafting is that two independent plants on their own roots (self-sustaining) are grafted together. This method provides a means of establishing a successful union between certain plants which are difficult to graft by any other method as the two plants will be on their own roots till the formation of successful graft.

For example: Guava, Mango, Sapota etc.

Procedure

a) Select a healthy shoot (3-5 cm girth) on the selected mother plant which is to be used as a scion source.

b) Select a rootstock (raised in pot/polybag) having approximately the same size as of the selected shoot on the mother plant.

c) On the internodal region where the union takes place a slice of bark and wood 2.5 to 5 cm long is cut from both the selected stock and scion shoots. These cuts given on the stock and the scion should be of the same size. The cuts should be perfectly smooth so that a close contact of the cambial layers of stock and scion is brought about when they are pressed together.

d) Tie the two cut surfaces together tightly with banana leaf sheath/gunny thread/cloth.

e) Cover the tied portion with grafting wax

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f) After healing of the graft joint, separate the scion by cutting the top of the stock plant above the graft union and base of the scion below the graft union.

2. Inarching: It is a synonym of approach grafting in the sense that both stock and scion plants are on their own roots at the time of grafting. However, it differs from approach grafting in that the top of the root stock plant does not extend above the point of graft union as in approach grafting. It is generally used for repairing or replacing damaged root system and hence also called repair grafting.

B. Detach method of grafting:

1. Whip or splice grafting: This method is particularly useful for grafting relatively small plants of 0.5 to 1.5 cm in diameter. This method is highly successful if properly done because there is considerable cambial contact.

For example: Apple, Peach, Mango

Procedure

a) Select stock plant whose stem is about 0.5 to 1.5 cm in diameter at 30 cm from the soil surface.
b) Select a scion stick (5-10 cm long) of the same diameter and containing 2 or 3 buds.
c) Behead the stock plant at a height of about 30 cm from soil level.
d) Give a long (2.5 to 5 cm), sloping cut in the internodal region near the cut ends of the stock and scion. This should be made preferably with one single stroke of the knife so as to leave a very smooth surface.
e) Bring the cut surfaces of the stock and the scion together and tie them firmly with string or polyethylene strips or nurseryman's adhesive tape.

2. Whip and Tongue Grafting: This method is similar to that of whip grafting except for the difference that a tongue is opened on the cuts given to the stock and scion. The stock and scion are then united with the tongues interlocking and are tied together firmly.

For example: Apple, Peach, Plum

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Procedure

a) Prepare the stock and scion as in the case of whip grafting.
b) On the first cuts given on the stock and scion, give a second reverse cut starting from about one-third of the distance from the tip and extend to a length of about half the first cut. This cut should preferably run parallel to the first cut.
c) Slip the stock and scion together at the cut surface in such a way that the tongues of the stock and the scion are interlocked. Care should be taken to see that lower tip of the scion does not overhang the stock.
d) Tie the graft firmly and wax, if necessary.

3. Side Grafting: This method is useful in grafting branches of trees that are too large for whip of approach grafting but not so large for the cleft or bark grafting. This method may be used to provide a new branch at a position in a tree where it is particularly required (top working). In this method, the scion is inserted into the side of the stock which is generally larger in diameter than scion. There are many variations of side grafting.

For example: Mango, Apple

Procedure

a) Select a shoot of 2.5 cm in diameter on the stock plant.
b) Select relatively thin scion of about 8 cm long and containing two or three dormant buds.
c) On the stock at the desired position and in the internodal region give an oblique cut about 2.5 cm long at an angle of 20^{O} to 30^{O}.
d) At the basal end of the scion, make a wedge of about 2.5 cm long by giving two sloping cuts on either side. The cuts should be very smooth and should be given by single stroke of the knife.
e) Insert the wedge part of the scion into the cut made on the stock. The scion should be inserted at an angle rather than in a straight position so as to obtain the best cambial contact.
f) Tie the stock and scion together firmly and wax the grafted region.
g) After the graft union is completed cut off the stock just above the union either in gradual steps or all at once.

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4. Veneer Grafting

This is also a kind of side grafting with slight modification. It is used widely for grafting small potted plants and *in situ* grafting.

For example: Avocado, Mango

Procedure

a) On the stock plant, at the desirable height, in the internodal region give a shallow, inward cut running to a length of about 2.5 to 5 cm.

b) At the base of the first cut, make another short inward and downward cut intersecting the first cut and removing a piece of wood and bark.

c) On the scion, towards the base, give a long (2.5 to 5 cm), slanting cut towards one side and another short, inward and downward cut on the opposite side. The cut given on stock and scion should be of same dimensions so that the combium layers can be matched as closely as possible.

d) Insert the scion on to the stock such that a good contact of the cambium is established at least on one side, and tie them firmly.

e) Wax the graft region, if necessary.

f) After the union has healed, cut back the stock above the graft union either in gradual steps or all at once.

5. Cleft grafting: Cleft grafting is one of the oldest grafting methods and is mainly useful for top working trees, either in the trunks of small trees or scaffold branches of big trees depending upon their thickness. Cleft grafting is useful also for smaller plants. In top working trees, this method is limited to stock branches about 2.5 to 10 cm in diameter and to species with fairly straight grained wood that will split evenly.

Although cleft grafting can be done at any time during the dormant season, healing of the graft union is successful if it is done when the buds of the stock are about to swell but before active growth has started.

For example: Mango

Procedure

a) After selecting the stock plant, cut the branch or trunk to be cleft

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grafted at the desired position. The cut given should be smooth and perpendicular to the main axis of the trunk or branch. The part below this cut should be smooth for at least 15 cm without any knots.

b) Using a heavy knife make a split to a length of 5 to 8 cm down the centre of the stub to be grafted. After the split is made, drive a screwdriver or chisel into the top of the split to hold it open for the insertion of the scion.
c) Select one year (season) old scion, 8 to 10 cm long, about 1 to 1.5 cm thick and containing 3 to 4 buds.
d) Cut the basal end of the scion into a long, gently sloping wedges about 5 cm long by giving two cuts opposite to each other.
e) While giving these two cuts care should be taken to see that one side of the wedge is slightly wider than the other so as to keep the wider side towards the outer side of the stock and to get proper fit for the stock and scion. The two cuts given on the scion should be smooth and be made with a single stroke of the knife.
f) Insert the scion in the cleft of the stock keeping the wider side of the wedge towards the outer side. Two scions are usually inserted in a single cleft.
g) While inserting the scion, care should be taken to see that the cambial layers of stock and scion are in good contact. For this purpose the outer surface of the scion should be set slightly in from the outer surface of the stock to the extent equal to the difference in thickness of the bark of layers of the stock and scion.
h) Withdraw the tool inserted to keep the cleft open without disturbing the scions. Now the scions should be held in position by the pressure of the stock,
i) Cover all cut surfaces completely with grafting wax.

If the stock plant is comparatively larger or thicker, 2 clefts can be made perpendicular to each other and accordingly 4 scions can be inserted.

6. Epicotyl (Stone) Grafting: This method of grafting is done on the epicotyl region of the young seedlings: hence the name eipcotyl grafting.

For example: Cashew, Mango, Jack

Procedure

a) Select very young seedling about 10 days old raised in polyethylene bags (15 cm x 22 cm).
b) Cut off the top portion of the chosen seedling leaving 5 to 6 cm long shoot (epicotyl).
c) With a sharp knife make a vertical, downward slit (2 to 3 cm long) at the centre of the remaining portion of the epicotyl.
d) Select a dormant 3 to 4 month old terminal shoot of about 5 to 8 cm long from a proven mother plant as the scion stick.
e) Cut the lower end of the selected scion to a wedge shape by giving, slanting and inward cuts of 2 to 3 cm on opposite sides.
f) Insert the wedge shaped scion in the slit made on the seedling and secure firmly with polyethylene strips or tape.
g) Water the graft regularly without wetting the graft region. In about 3 weeks, the scion starts sprouting.

Note: 1. If the seedlings are raised in sand beds they are uprooted (with stones) 15 to 20 days after sowing (when seedlings attain 10 to 15 cm height) and grafting is done as described above. The grafted seedling is then planted in polyethylene bags or pots keeping the graft union above the soil level and without damaging the stone.

2. June to September is the best period for eipcotyl grafting

7. Softwood Grafting

It has been standardized recently in cashew and mango.

For example: Cashew, Mango, Jackfruit, Sapota, Jamun, Kokum, Aonla

Procedure

a) Raise the rootstock seedlings in suitable containers or preferably in the main field itself where the grafts are desired to be grown and allow them to grow for a year or more.
b) When the seedlings attain a height of 30 to 45 cm and the new shoot as well as leaves usually have bronze colour, decapitate the top portion of the fresh growth on the stock plant with a knife, retaining about 8 cm of the fresh stem.

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c) Make a longitudinal cut of 3 cm in the retained fresh stem.
d) Select a scion stick of about 10 cm long and about the same thickness as of the prepared stem on the stock.
e) Cut the basal end of the scion to a wedge shape of about 3 cm long by chopping the bark and a little wood on two opposite sides.
f) Insert the prepared wedge part of the scion stick into the slit made on the stock and secure firmly with polyethylene strips.
g) Water the grafted plant regularly. The scion sprouts in about 3 weeks.

Maintenance of grafts or budding

a) Any sprouts on the rootstock should be discouraged allowing only the bud(s) on grafted scion or bud patch to grow.
b) Staking of grafted or budded plants is needed for up to 2 years to withstand against wind damage.
c) Bearing of fruits may be discouraged for 2 to 3 years to encourage vegetative growth or frame work of the plant.

8. Micrografting / Shoot tip grafting (STG):

This is a special grafting technique preferred under aseptic conditions for production of grafts free from viral infection. Ex. Citrus.

Procedure:

1. The stock of Rangpur lime/rough lemon are raised from seeds which are surface sterilized and raised in test tube in laboratory.
2. Micro size shoot tip containing apical bud is collected from mother plant maintained disease free in green house/mother block.
3. Shoot tip is surface sterilized.
4. Tooth pick size seedling (rootstock) is grafted with micro shoot tip (wedge /placing of scion on decapitated stock) under microscope in aseptic condition.
5. Grafted plants are hardened before planting.

Methods of propagation by budding

Budding is also a method of grafting wherein only one bud with a piece of bark and with or without wood is used as the scion material. It is also

called as bud grafting. The plant that grows after successful union of the stock and bud is known as buddling.

Methods of budding

1. T- budding (Shield budding)

This method is known as T-budding as the cuts given on the stock are of the shape of the letter. T and 'shield budding' as the bud piece appears like a shield. This method is widely used for propagating fruit trees and many ornamental plants. This method is generally limited to the stocks that are about 0.75 to 2.50 cm in diameter and are actively growing so that the bark separate readily from the wood. **For example:** Citrus, Rose

Procedure

a) After selecting the stock plant, select an internodal region with smooth bark preferably at a height of 15 to 25 cm from ground level.
b) Give a vertical cut through the bark to a length of about 2.5 to 3.75 cm.
c) At the top of this vertical cut, give another horizontal cut (1 cm or 1/3rd the circumference of the stem) in such a way that the two cuts given resemble the letter T.
d) Lift the bark piece on either side of the vertical cut for the insertion of the bud.
e) Select the required bud stick.
f) Start a slicing cut about 1.5 cm below the bud continue it upward and under the bud to about 2.5 cm above the bud.
g) Give another horizontal cut about 1 cm above the bud.
h) Remove the shield of bark containing bud. The traces of wood, if attached, may be removed.
i) Insert the bud between the flaps of bark on the stock with the help of budding knife in such a way that the horizontal cut of the shield matches the horizontal cut on the stock.
j) Wrap the bud and stock tightly with polyethylene strip exposing only

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the bud.

2. Inverted T-budding

In heavy rainfall areas, water running down the stem of the stock may enter the T-cut, soak under the bark, and prevent healing of the bud piece. Under such conditions an inverted T-budding may give better results as it is more likely to shed excess water. The inverted T-budding procedure is same as that of T-budding except that the horizontal cut on the stock is made at the bottom of the vertical cut rather than at the top.

For example: Citrus, Rose

Procedure

a) On the selected stock plant give a horizontal cut at the bottom of the given vertical cut representing inverted T (⊥).
b) Select the required bud stick.
c) Start a slicing cut 1.5 cm above the bud and continue it downward and under the bud to about 2.5 cm below the bud.
d) Give another horizontal cut about 1 cm below the bud and remove the bud piece.
e) Insert the bud between the flaps of bark on the stock and push upwards till the horizontal cut of the shield matches the horizontal cut on the stock.
f) Wrap the bud piece and stock completely and tightly exposing only the bud proper.

3. Patch budding

In this method a rectangular patch of bark is completely removed from the stock plant and is replaced with a patch of bark of the same size containing a bud from the desired mother plant. For this method to be successful, the bark of stock and bud stick should be easily slipping. The diameter of the stock and bud stick should, preferably, be about the same (1.5 to 2.75 cm).

For example: Ber, Citrus, Cocoa and Rubber

Procedure

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a) On the selected stock plant at the desired place (10 to 15 cm above the ground level) give two transverse parallel cuts through the bark and about 1 to 1.5 cm long or one-third the distance around the stock. The distance between the cuts may be 2 to 3 cm.
b) Join the two transverse cuts at their ends by two vertical cuts.
c) Remove the patch of bark and keep it in place again until the bark patch with the bud from the selected mother plant is ready.
d) On the bud stick give two transverse cuts – one above and one below the bud and two vertical cuts on each side of the bud. The dimensions of the transverse and vertical cuts should correspond to those given on the stock.
e) Remove the bark patch with bud by sliding sideways.
f) Insert the bud patch immediately on the stock in such a way that the horizontal cuts of the bark patch and those on the stock plant match together perfectly.
g) Wrap the inserted bud patch with polyethylene strips covering all the cut surfaces but exposing the bud proper.

Note: If the bark of the stock plant is thicker than the bark of the bud patch then it is necessary to trim the corners of the bark of the stock plant so that the wrapping material will hold the bud patch tightly in place.

4. Flute budding

This is modification of patch budding. The bark removed from the stock almost completely encircles it leaving only a narrow connection of about 1/8th of its circumference between the upper and lower parts of the bark. The bark of the stock and bud stick should be slipping easily.

For example: Ber, Cherry

Procedure

a) On the selected stock plant at the desired place give 2 vertical and parallel cuts of 2.5 to 3.5 am long with a distance of 1/8th the circumference of the stock plant between them.
b) Join the ends of these two vertical cuts by two parallel horizontal cuts.

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c) Remove the bark piece and keep it in place again until the bark piece with a bud from the selected mother plant is ready.
d) Similar cuts are given on the bud stick to facilitate removal of a ring of bark with the bud.
e) Remove the patch of bark with bud from the bud stick.
f) Insert this patch on the stock plant. If the circumference of the bud patch is more than the width of the cut given on the stock, trim the sides of the bark to the required width so that the patch fits well to the stock.
g) Wrap the inserted bud patch with polyethylene strip covering the entire surface and exposing the bud proper.

5. Ring or annular budding

This method is similar to flute budding, but the bark encircling the wood has to be slipped off completely without leaving the narrow connection as in flute budding. The bark of the stock and the bud stick should be slipping easily. **For example:** Temperate fruit crops

Procedure

a) On the selected stock plant give a vertical cut of 2 to 2.5 cm long in the internodal region.
b) Join the ends of this cut by two parallel horizontal cuts at the top and the bottom.
c) Remove the bark piece and keep it in place again until the bark piece containing a good bud is obtained from the selected mother plant.
d) Similar cuts are also given on the scion stick and the bark with a good bud is loosened from the scion wood and slipped off from the scion.
e) Insert this patch (scion) at the cut given on the stock plant after taking out the replaced bark piece.
f) If the scion bark piece with the node does not suit the patch on the stock trim the sides so that it fits well to the stock.
g) Wrap the inserted bud patch with polyethylene strip exposing only the bud.

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6. Chip budding

This is the only method of budding that can be done even when the bark is not slipping easily. This method can be used with fairly small material 1 to 2.5 cm in diameter. A chip of bark and wood is removed from a smooth place between nodes near the base of the stock and replaced by another chip of the same size and shape removed from the bud stick which contains a bud of the desired cultivar. **For example:** Grapes, Rubber

Procedure

a) On the selected stock plant, at 15 to 20 cm above the ground level, in a smooth internodal region, give a cut at an angle of about 45^{O} and about $1/4^{th}$ deep into the stock.
b) About 2.5 cm above the first cut make a second cut going downward and inward until it intersects the first cut.
c) Remove the chip of bark and keep it in place again till the chip of the bud from the selected mother plant is ready for insertion.
d) On the selected bud stick at 0.5 cm below the selected bud give an inward and downward cut at an angle of 45^{O} and deep into the wood.
e) Start the second cut above the bud at a distance of 2.5 cm from the first cut and extend the cut downward and inward behind the bud until it intersects the first cut.
f) Remove the chip of bark and wood with the bud.
g) Place the chip in the cut given on the stock and tie it in place with budding tape.

Note: The length, width and thickness of the chip taken from the stock should be exactly the same as the chip of bud removed from the bud stick so as to get good fit.

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Course Name	**Fundamentals of Horticulture**
Lesson 4	**Plant propagation by specialized structures**
Content Creator Name	**Dr. Kirtimala Balaji Naik**
University/College Name	**University of Horticultural Science,Bagalkot**
Course Reviewer Name	**Jitendra Singh**
University/college Name	**Agriculture University Kota, Kota**

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Propagation by specialized structures is indicative of multiplication of plants by specialized structures like bulbs, corms, rhizomes, tubers and tuberous roots. The primary function of these modified plant parts is food storage for the plant's survival during adversity. However, they also function in vegetative reproduction.

The propagation procedure that utilizes the production of naturally detachable structures, such as the bulb and corm, is generally called as 'Separation'. In case in which the plant or plant part is cut into sections, as is done with rhizome, tuber and tuberous root, the process is known as 'Division'.

1. BULB

A bulb is a specialized underground organ consisting of a short, fleshy, usually vertical stem axis (basal plate) bearing at its apex a growing point or a flower primordium enclosed by thick, fleshy scales. Bulbs are produced by monocotyledonous plants in which the usual plant structure is modified for storage and reproduction.

Most part of the bulb consists of bulb scales, which are the continuous, sheathing leaf bases. The outer bulb scales are generally fleshy and contain reserve food materials, whereas the bulb scales toward the centre function less as storage organs and is more leaf like. In the centre of the bulb, there is either a vegetative meristem or an unexpanded flowering shoot. Meristems develop in the axils of these scales to produce miniature bulbs known as bulb lets, which when grown to full size are known as offsets. Bulb lets may form in leaf axils either on the underground portion or on the aerial portion of the stem. The aerial bulb lets are called stem bulb lets.

There are two types of bulbs

a) Tunicate (Laminate) bulbs

These bulbs have outer bulb scales that are dry and membranous. This covering called tunic, provide protection from drying and mechanical injury to the bulb. The fleshy scales are in continuous, concentric layers, called lamina, so that the structure is more or less solid.

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e.g.: Onion, Daffodil, Tulip

b) Non-tunicate (Scaly) bulbs

These bulbs do not possess the enveloping dry covering. The scales are separate and attached to the basal plate. In general, the Non-tunicate bulbs are easily damaged and must be handled more carefully than the tunicate bulbs.

Entire bulb or a mature bulb cut into several vertical sections each containing a part of the basal plate is used in propagating bulb crops.

e.g.: Lily

2. CORM

A corm is the swollen base of a stem axis enclosed by the dry, scale-like leaves in contrast to the bulb, which is predominantly leaf scales, a corm is a solid stem structure with distinct nodes and internodes. The bulk of the corn consists of storage tissue composed of parenchyma cells. In the mature corm, the dry leaf bases persist and enclose the corm. This covering is known as the tunic and gives protection against injury and water loss. At the apex of the corm is a terminal shoot that will develop into the leaves and flowering shoot. Propagation is by new corms or cormels which develop on the old corm. **e.g.:** Crocus, Gladiolus.

3. CROWN

The term crown is generally used to designate that part of a plant at or below the surface of the ground or on top of the fruit from which news shoots are produced. Crown division is an important method of propagation for herbaceous perennials and to some extent for woody shrubs, because of its simplicity and reliability. Division may be necessary to maintain the variegated form in some plants usually propagated by leaf cuttings such as *Sansevieria*.

In crown division, plants are dug and cut into sections with a knife. In herbaceous perennials, where an abundance of new rooted offshoots are produced from the crown, each may be removed from the old crown and planted separately.

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e.g.: African violet, Day lily (*Hemerocallis*), Pineapple, Shasta daisy (*Chrysanthemum superbum*), Strawberry.

4. RHIZOME

A rhizome is a specialized stem structure in which the main axis of the plant grows horizontally at or just below the ground surface. Typically, it is the main axis of the plant producing roots on its lower surface and extending the leaves and flowering shoots above the ground. The stem appears segmented because it is composed of nodes and internodes. A leaf like sheath is attached at each node. Adventitious roots and lateral growing points develop in the vicinity of the node.

There are two types of rhizomes

a) Pachymorph: This type of rhizome is thick, fleshy and shortened in relation to length. It appears as a many-branched clump made up of short individual sections. It is determinate *i.e.* each clump terminate in a flowering stalk, growth continuing only from lateral branches.

e.g.: Ginger, rhizomatous Iris

b) Leptomorph:

This rhizome is slender with long internodes. It is indeterminate *i.e.,* it grows continuously in length from the terminal apex and from lateral branch rhizomes. The stem is symmetrical and has lateral buds at most nodes and nearly all remaining dormant. This type does not produce a clump but spreads extensively over an area. Intermediate forms between the two types also exist. These are called Mesomorphs.

Propagation by rhizomes consists of cutting or dividing the rhizome in to sections (containing nodes) each of which is capable of producing new shoots from nodes and new roots from the adventitious buds on lower surface.

e.g.: Lily-of-the Valley, Canna and Cardamom.

5. RUNNER

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A runner is a specialized stem that develops from the axils of a leaf at the crown of a plant, grows horizontally along the ground and forms a new plant at one of the nodes. In most strawberry cultivars, runner formation is related to day length and temperature. Long days (12 to 14 hours) and high temperatures favour runner formation.

In propagating plants by runners, the rooted daughter plants are dug when they have become well rooted, and transplanted to the desired locations. **e.g.**: Strawberry, *Oxalis*

6. STOLON

Stolon is a term used to describe various types of horizontally growing stems that produce adventitious roots when it comes in contact with the soil. These may be prostrate or sprawling stems growing above ground. The underground stem of the potato that terminates in the tuber is a stolon.

In propagating plants by stolon, the stolon can be treated as a naturally occurring rooted layer and can be cut from the parent plant and planted separately.

e.g.: Bermuda grass (*Cynodon dactylon*), Mint (*Mentha*), Potato.

7. SUCKER

A sucker is a shoot which arises on a plant from below ground. The most precise use of this term is to designate a shoot which arises from an adventitious bud on a root. However, in practice, shoots which arise from the vicinity of the crown are also referred to as suckers even though originating from stem tissues. The tendency to sucker is a characteristic possessed by some plants and not by others. To propagate, suckers are dug out and cut from the parent plant.

e.g.: Banana, Chrysanthemum, Pineapple, Red raspberry

8. TUBER

A tuber is a special kind of swollen, modified stem structure that functions as an underground storage organ. A tuber has all the parts of a

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typical stem but is very much swollen. Extremely, the eyes, present in regular order over the surface, represent nodes each consisting of one or more small buds subtended by a leaf scar.

Propagation by tubers can be done either by planting the whole tubers, or by cutting them into sections (commonly referred to as seed) each containing one or more buds or eyes.

e.g.: Caladium, Jerusalem artichoke (*Helianthus tuberous*), Potato

a) Tuberous Root and Stem: Various herbaceous perennials are known for the massive enlargement of their secondary roots. Internal and external structures of these tuberous roots resemble those of true roots. Nodes and internodes are absent and the buds are produced only on the crown or stem (proximal) end while the fibrous roots are produced on the distal end.

The usual method of propagating tuberous roots is by dividing the crown so that each section bears a shoot bud. They can also be propagated by inducing adventitious shoots on the fleshy roots as in sweet potato.

e.g.: Dahlia, Sweet Potato

b) Tuberous stem: Tuberous stems are produced by the enlargement of the hypocotyl section of the seedling plant, but may include the first nodes of the epicotyl and the upper section of the primary root. These structures have a vertical orientation with one or more vegetative buds produced on the upper end or crown. Fibrous roots are produced on the basal part of the structure.

Tuberous stems can be divided, shortly after growth starts, into long sections containing a bud each as in tuberous begonia or they may be multiplied by cutting off the upper one-third of the tuberous stem and notching the surface into 1 cm squares. The cut surface should be dusted with a fungicide and each section dried for several days after cutting and before placing in a moist medium.

e.g.: Cyclamen, Tuberous begonia

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9. OFFSETS:

The term offset is generally applied to a shortened, thickened stem of rosette like appearance. It is also applied to lateral shoots arising on the stems of monocotyledonous fruit plants, e.g: date palm, pineapple, banana etc.

10. BULBILS

In some species, bulblets may develop in the leaf axils either on the underground portion or on the aerial portion of the bulb (stem). These aerial bulblets are called bulbils

e.g.: *Lilium bulbiflorum, L. sulphureum,* Agave, Garlic.

11. PSEUDOBULBS

A pseudobulb is an enlarged fleshy stem with several nodes. The pseudo bulb is cut into different sections by a sharp knife during dormant season. Each section is sown and new growth begins at nodes **e.g. :** *Cattleya, Laelia, Miltonia, Cymbidium.*

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Course Name	**Fundamentals of Horticulture**
Lesson 5	**Propagation structures**
Content Creator Name	**Dr. Kirtimala Balaji Naik**
University/College Name	**University of Horticultural Science,Bagalkot**
Course Reviewer Name	**Jitendra Singh**
University/college Name	**Agriculture University Kota, Kota**

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Propagation structures are the important components of nursery. There are several kinds of propagation structures.

The most important ones are:

a) Green house
b) Mist house
c) Hot beds

These structures are mainly used to provide control of environmental conditions either for promoting seed germination or inducing rooting in cuttings. They can also be used for hardening.

a) Cold frames
b) Shade house
c) Lath house

These structures are primarily used for hardening of young tender plants before they are planted to outdoor conditions. Even though, construction of these structure is expensive but it is advisable to construct as these structures are very useful in providing favorable conditions for proper growth and development of plants and useful in protection from adverse conditions.

A. Greenhouse: Greenhouses are the framed or inflated structures covered with transparent or translucent material large enough to grow crops under partial or fully controlled environmental conditions to get optimum growth and productivity. The existing greenhouses could be broadly grouped into three categories based on the extent of environmental control viz., high cost (fully controlled), medium cost (partially controlled) and low cost which are naturally ventilated. The high cost greenhouses are ideal from the point of view of their efficiency in monitoring the climatic conditions. In prevailing economic conditions, however, where capital is a scarce input, the choice of a majority of the nurserymen and entrepreneurs is in favors of low cost and medium cost greenhouses, which though have partial control over the environmental factors but are cost effective. Hence, details of only low and medium cost greenhouses using polyethylene as cladding material have been furnished in this practical.

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General classification:

Greenhouse structures normally of two types

a) **Detached or single span greenhouses**; which could be of different shapes like Quonset, gothic, globe, dome shaped etc. A single unit may cover an area of about 100m^2 to 500 m^2 and

b) **Ridge and furrow or multispan** or gutter connected greenhouses are large greenhouses which are economical, provided they are used for crops requiring similar cultural and environmental conditions.

Planning and design: A greenhouse should be designed to withstand the load of the covering material, intensity of rain and wind velocity. A greenhouse in addition to being strong should admit adequate quantity of sunlight for crop production. At the same time, the structure should require minimum energy for maintaining the desired crop microclimate. Local climatic conditions and locally available materials must be taken into account to arrive at the mist appropriate greenhouse design.

a) Site selection: A greenhouse needs sources of good quality water and energy in the form of electricity especially in medium cost greenhouses where gadgets are used to control the environmental factors. Greenhouses should be away from the buildings and trees to avoid obstruction to sunlight. Adequate provision should be made to divert surface water away from the greenhouse.

b) Orientation: Orientation of the greenhouses could be in any direction when they are in single spans but multi-span greenhouses should be oriented in north-south direction only to avoid continuous shading of certain portions of the greenhouse by its structural members.

c) Components of a greenhouse: While a low cost greenhouse has normally two segments *viz*., the frame and the cladding material, the medium cost greenhouse has in addition environmental control gadgets/equipments. While a greenhouse frame is generally designed for a service period of 15to 25 years, glazing material has a life span of 3-10 years and the equipments normally wear out in 5 -10 year.

Construction of greenhouse

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a) Fabrication of frame : In order to reduce the cost of construction, use of mild steel (MS) or galvanized iron (GI) pipes (of 0.5 to 2.5 inch diameter) as structural frame is desirable. These are less expensive than aluminum angles or GI pipes of large dimensions.

The size of a greenhouse varies from 100 to 500 m^2 or even more (single to Multispan) depending on the purpose for which it is established. While a polyhouse of 100 m^2 area would be an economical unit for propagation and production of plant material, a polyhouse of 300 to 500 m^2 area would be desirable for growing commercial flower/vegetable.

The length, breadth and height of the structure could be varied depending on the local situation and the purpose for which it is utilized. In low cost naturally ventilated greenhouses for growing crops, as a thumb rule, increasing the central height at least to 3.5 m is desirable and if the size of structure is 500m^2 and more providing a central height of 5-7 m with top ventilation would be ideal to manage the temperature.

b) Covering / cladding of frame: The cladding material to be used should be UV stabilized and it can be of glass, fibre or polythene sheet. Polythene sheet is cheapest and easily available, the sheet should be 200 micron (800 gauge) thickness and UV stabilized (Domestic / Imported).

Some other important points to be considered in the construction are:

1. The structural frame should not have any sharp edges as otherwise it would damage the cladding material.
2. The film must be stretched and secured to the frame rightly by rise of clamps / poly grip assembly /nut and bolts or any other similar devices.
3. The film must be secured inside the ground in a trench of 0.5 m depth all along the periphery to reduce the cost of fixing devices. The structural parts which come in contact with the film should be insulated by wrapping them with separate plastic film.
4. MS pipes if used in the structure, need painting at least once a year to avoid rusting.
5. In heavy rainfall areas (especially in the coastal region), it is desirable to reduce the angle of curvature of the arched or to have a gable shaped roof to avoid sagging of poly film due to heavy down pours.

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6. In a medium cost greenhouse where evaporative cooling gadgets are used, on ventilation should be provided.

Management of greenhouse

a) Temperature / Light /Humidity:

Generally, the temperature in a greenhouse will be higher (3-10^{0}C) than ambient conditions
depending on the location, season and the extent of ventilation provided. Hence, reducing the
temperature especially during the summer months is of prime importance in the management
of a greenhouse under our conditions.

In a naturally ventilated / low cost greenhouse gadgets are provided to reduce the temperature. Sufficient ventilation should be provided with 40 to 50 mesh net all around.

The sides of the structure are provided with roll up mechanism. The accumulation of heat caused by solar radiation can also be reduced by providing shade nets on the top either outside or inside the structure. Reduction in the temperature especially during the summer month would also be achieved by providing frequent irrigation and / by providing fogging or misting in combination with natural ventilation. This will also help in increasing the humidity in the greenhouse. However, in a medium cost structure where gadgets like cool cell pad and exhaust fans (evaporative cooling system) are used instead of natural ventilation. Therefore, management of temperature and humidity becomes relatively easy and can be regulated by controlling the working of cool cell pads and exhaust fans speed. Providing shade net (25-50%) inside the structure on the top will also improve the efficiency of cooling it is also possible to reduce the temperature to a certain extent by increasing the humidity by providing additional gadgets like misting nozzles.

b) Irrigation and nutrition

Normally the water requirement of a crop in a greenhouse is relatively less as compared to open conditions due to reduced evaporation losses.

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Providing irrigation through micro-irrigation system like drip or micro sprinkler or fanjets is desirable as compared to conventional methods of furrow irrigation. These methods of irrigation will not only economize the quantum of water required but will also help in getting better growth, yield and quality of the produce by maintaining optimum water regime in the soil.

In a green house, maximum productivity could be obtained by providing optimum level of nutrients through fertigation as requirements are generally high in comparison with conventional method of cultivation. Fertigation also helps in saving the quantity of fertilizer applied. Fertigation can be accomplished with the help of pressurized fertilizer tank.

c) Pest and diseases.

Normally the incidence of pests and diseases in green house is less as the structure is covered either with 40-60 mesh (naturally ventilated) or completely covered with cladding material. However, due to high density of plant material and congenial micro- climate in the structure, spread of pests and diseases will be faster once there is an incidence due to entry of diseased plant material or improper management of the greenhouse. Effective prophylactic and control measures to manage various pests and disease are necessary to get high returns.

C. Misthouse

It is a propagation structure in the nursery where in leafy and soft wood cutting can be rooted with great success. Many plants and shrubs of difficult to root can also be rooted under mist chamber with a higher success. In mist chamber, cutting can be raised in any season of year.

Basic principle involved in mist propagation is to provide optimum climatic conditions for propagation throughout the year. This is achieved by providing intermittent mist spray regulated by automatic timer device which forms a thin film of water over the propagules (cutting) and the rooting media. This reduces the temperature and increases the RH consequently the transpiration losses and respiratory activity are minimized and also there is greater mobilization of reserved/ stored food

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material such as sugar, starch, phenols etc to the site of root regeneration and these food materials are efficiently utilized in rooting.

Management of mist house

1. During summer, mist house should be provided with good ventilation facility and shade net (25-50 %) must be covered. Misting duration should be increased and misting interval should be reduced depending upon the outside temperature.

2.During winter (in temperate and cool subtropical regions), bottom heating of the beds / containers should be practiced, which can be achieved by supplying hot water through pipes either below the floor or in the floor. Misting period should be reduced and interval increased.

3.In mist house, rooting medium should be well drained and there should be adequate drainage facility.

4.Hardening: Mist propagated cuttings have thick, fleshy and delicate roots which are not ideal for outdoor growing. Therefore they must be acclimatized by exposing gradually to outdoor conditions. Hardening can be done by any one or all of the following means.

a. After ensuring complete rooting, misting period reduced by lessening the on period and increasing the off period.

b. Gradual removal of cover/ shade of house, if the polythene tent is used.

c. Shifting the containers / pots to shade house, lath house cold frames etc.

d. By transplanting cuttings during dormant season. During this 'period, as metabolic activity are reduced and the transplantation shocks are minimized.

D. Shade house and Lath House:

Shade houses are made with straight sides and flat top. The frame is generally made with MS, GI pipes or bamboo (Low cost). The frame is covered with shade net (25, 35, 50, 70, 90 % shade intensity). Shade houses cut down the light intensity and slightly increases the RH inside the structure. The structure is mainly used in nursery for propagation, hardening and general maintenance of plants before selling. Lath house is same as that

of shade i.e. side is straight and cover is flat. But cover of the lath house is a movable lath sash (wooden frame with cloth / plastic with movement).

E. Hot beds:

Hot beds are heating structures mainly used for geminating seeds or for rooting of cuttings during cold winter (in temperate and subtropical regions). Hot beds are heated by hot air, hot water by using electricity are easy to operate and temperature can be regulated according to the need. Hot bed consists of following parts:

1. **Frame:** It is made with concrete blocks / plastics or even with wood. Hot beds prepared with concrete blocks are permanent structure those made with plastic and wood are temporarily one. Concrete blocs acts as effective insulator. Plastics ate lighter in weight, easy to handle, but has a short life.
2. **Cover:** Cover of the hot bed made with glass, plastic / cloth. Glass panes are fitted into wooden frame. Plastics and cloth are used as continuous sheet. Cloth frame is slipping on either side at top and standard width is 2 m
3. **Heating cables:** Hot beds are heated with hot air / hot water / electricity. These beds are mist convenient to operate when compared with conventional type of hot beds. The cover of hot bed should be opened during hours and evening so as to allow fresh air into beds and to wipe out the moisture from inside the bed.
4. **Rooting media:** About 10-15 cm thick layer of rooting media is placed upon the heating cables for sowing seeds / rooting of the cuttings.

F. Cold frames:

These structures mainly used to protect herbaceous plants during winter period. Cold frames can also be used to protect young and tender plant from heavy rain, heavy wind and frost. These structures are basically similar as that of hot beds. They are also made with frame, cover, growing media, but they are not provided with heating system.

The covering of cold frame kept open in summer period. The heat of the sun is used to maintain required temperature as the cover transmit and retains the sun's heat.

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Course Name	**Fundamentals of Horticulture**
Lesson 6	**Seed dormancy and Seed germination**
Content Creator Name	**Dr. Kirtimala Balaji Naik**
University/College Name	**University of Horticultural Science,Bagalkot**
Course Reviewer Name	**Jitendra Singh**
University/college Name	**Agriculture University Kota, Kota**

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Seed is the most common means of propagation for self-pollinated and cross- pollinated plants. Most of the vegetables, ornamental annuals, flowering trees and many fruits are usually propagated by seeds. Horticultural crops are grown from seeds for three main reasons *viz*., (i) to grow crops commercially (ii) to develop new varieties and (iii) to grow rootstocks for grafting and budding.

The seed is a mature ovule enclosed within the ovary or fruit. The seed basically contains three essential parts. (i) embryo, the end product of the sexual cycle which develops into a new plant, (ii) food storage tissues, like endosperm, cotyledon or perisperm which supply the embryo and young seedlings with necessary food materials during their early stages of growth, and (iii) seed coverings, which provide mechanical protection for the embryo and play an important role in seed germination.

Seed germination

Germination can be defined as the process whereby the dormant embryo resumes growth and the radical and plumule break through the seed coat. By definition, germination incorporates those events that commence with the uptake of water by the quiescent dry seed and terminate with the elongation of the embryonic axis. The visible sign that germination is complete is usually the penetration of the structures surrounding the embryo by the radicle; the result is often called visible germination. Subsequent events, including the mobilization of the major storage reserves, are associated with growth of the seedling. Germination process involves complex sequence of biochemical, physiological and morphological changes. Three conditions must be fulfilled before the resumption of germination. First, the seed must be viable, that is, the embryo must be alive and capable of germination. Second, the dormancy inducing internal conditions, the physical or chemical barriers to germination must have disappeared. Third, the seed must be subjected to appropriate environmental conditions. Not all seeds germinate readily although the environmental conditions are favorable.

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Selection of seeds: For successful cultivation, selection of good seed is very important. The qualities of good seeds are

1. Seeds must be healthy
2. Seeds should be of improved type
3. They should have higher percentage of germination
4. Seeds must be free from diseases, weed seeds, seeds of other crops, inert material etc.
5. Seeds should be vigorous and have optimum moisture content
6. Seeds should be obtained from reliable sources.

Many horticultural research stations, institutions, agricultural universities and reputed nurseries are supplying good quality seeds.

Seed Dormancy

Seed dormancy has been defined as the incapacity of a viable seed to germinate under favourable conditions. For the sake of simplicity, seed dormancy is regarded here as the failure of an intact viable seed to complete germination under favorable conditions. The seeds of some species are prevented from completing germination because the embryo is constrained by its surrounding structures. This phenomenon is known as coat enhanced dormancy; embryos isolated from these seeds are not dormant. In other species, a second category of dormancy is found in which the embryos themselves are dormant (embryo dormancy).This difficulty arises because all dormancy assays are based on seed germination, which is the result of the balance between the degree of dormancy and the capacity of the embryo to overcome dormancy. Mechanistically one can distinguish factors that influence dormancy and germination on the basis of their effect on germination, being either inhibiting or promoting.

Many seeds may have protective mechanisms (embryo dormancy), protective chemicals (inhibitor dormancy), water repellent or very thick seed coats (seed coat dormancy) in nature, this prevents seed from germinating at the wrong time of the year, insuring subsequent successful growth.

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Types of Dormancy

1. Exogenous Dormancy

1. This type of dormancy is imposed by factors outside the embryo.

2. In exogenous dormancy, the tissues enclosing the embryo can affect germination by inhibiting water uptake, providing mechanical resistance to embryo expansion and radicle emergence, modifying gaseous exchange (limit oxygen to embryo), preventing leaching of inhibitor from the embryo and supplying inhibitor to the embryo.

It is of three types:

a) Physical dormancy (seed coat dormancy):

Seed coat or seed covering may become hard, fibrous or mucilaginous (adhesives gum) during dehydration and ripening as a result they become impermeable to water and gases, which prevents the physiological processes initiating germination This type of dormancy is very common in drupe fruits i.e. olive, peach, plum, apricot, cherry etc. (hardened endocarp), walnut and pecan nut (surrounding shell). In various plant families, such as Leguminosae, the outer seed coat gets hardened and becomes suberized and impervious to water.

b) Mechanical dormancy:

In some fruits seed covering restricts radicle growth, resulting in dormancy of seeds. Some seed covering structures, such as shells of walnut, pits of stone fruits and stones of olive are too strong to allow the dormant embryo to expand during germination. The water may be absorbed but the difficulty arises in the cementing material as in walnut. Germination in such seeds does not occur until and unless the seed coats are softened either by creating moist and warm conditions during storage or by microbial activity.

c) Chemical dormancy:

In seeds of some fruits chemicals that accumulate in fruit and seed covering tissues during development and remain with the seed after harvest. It is quite common in fleshy fruits or fruits whose seeds remain in juice as in citrus, cucurbits, stone fruits, pear, grapes and tomatoes. Some of the

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substances associated with inhibition are various phenols, coumarin and abscisic acid. These substances can strongly inhibit seed germination.

2. Endogenous dormancy: This type of dormancy is imposed by rudimentary or undeveloped embryo at the time of ripening or maturity. This can be of different types such as morphological, physiological, double dormancy and secondary dormancy.

A. Morphological dormancy (Rudimentary and linear embryo): Dormancy occurs in some seeds in which the embryo is not fully developed at the time of seed dissemination. Such seeds do not germinate, if planted immediately after harvesting. Plants with rudimentary embryos produce seeds with little more than a pro-embryo embedded in a massive endosperm at the time of fruit maturation. Enlargement of the embryo occurs after the seeds have imbibed water but, before germination begins. Formation of rudimentary embryo is common in various plant families such as Ranunculaceae (Ranunculus), Papavaraceae (poppy). Some plants of temperate zone like holly and snowberry have also rudimentary embryos.

B. Physiological dormancy

a) Non-deep physiological dormancy: After ripening time is required for seeds in dry storage to lose dormancy. This type of dormancy is often transitory and disappears during dry storage. Temperate fruits such as apple, pear, cherry, peach, plum and apricot, cultivated cereals, vegetables and flower crops, have this type of physiological dormancy which may last for one to six months and disappears with dry storage.

b) Photo dormancy: Seeds that either require light or dark condition to germinate are termed as photo-dormant seeds. It is due to photo-chemically reactive pigment called phytochrome widely present in some plants. When imbibed seeds are exposed to red

Seed treatments to break dormancy of seeds light (660-760 nm), the phytochrome changes to red form (Pfr), thereby substituting the germination process. However, when seeds are exposed to far-red light (760-800), Pfr is changed to Pf which inhibits germination process.

c) Thermo dormancy: Some seeds have specific temperature requirement for their germination, otherwise they remain dormant. Such seeds are

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called as thermo dormant .For example seeds of lettuce, celery and pansy do not germinate if the temperature is below 25°C.

Physiological dormancy is of 3 types:

I) Intermediate physiological dormancy: The seeds of some species require a specific period of one-to-three months of chilling, while in an imbibed and aerated state, commonly called as moist chilling. For example, most of temperate fruit seeds require moist chilling to overcome seed dormancy. This requirement led to the standardization of world famous, horticultural practice of stratification. In this process, the seeds are placed between layers of moist sand in boxes and exposed to chilling temperatures (2 to 70C) for the period varying from 3-6 months to overcome dormancy.

II) Deep physiological dormancy: Seeds, which usually require a relatively long (>8 weeks) period of moist chilling stratification to relieve dormancy as in peach.

III) Epicotyl dormancy: Seeds having separate dormancy conditions for the radicle hypocotyl and epicotyl, is called as epicotyl dormancy e.g. Lilium, Hepatica antiloba and trillium.

C. Double dormancy

In some species, seeds have dormancy due to hard seed coats and dormant embryos.

For instance, some tree legumes seed coats are impervious and at the same time their embryo are also dormant. Such seeds require two years for breaking of dormancy in nature. In the first spring, the microorganisms act upon the seed making it weak and soft and then embryo dormancy is broken by chilling temperature in the winter next year.

Combination of two or more types of dormancy is known as double dormancy. It can be morpho-physiological i.e. combination of under developed embryo and physiological dormancy or exo-endodormancy *i.e.* combination of exogenous and endogenous dormancy conditions i.e. hard seed coat (physical plus intermediate physiological dormancy).

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D. Secondary dormancy Secondary dormancy is due to germination conditions. It is a further adaptation to prevent germination of an imbibed seed.

I. Scarification

Scarification is a process to modify the hard or impervious seed coat. Scarification can be done mechanically or by using acid.

1. Mechanical scarification

It is a process of mechanically altering the seed coat by breaking or scratching the seed coat to make it permeable to water and gases. This is possible by rubbing the seeds on sand paper or with a file and also by cracking the seed with a hammer. Care must be taken not to injure the embryo. Mechanical scarification is useful for large sized seeds in small quantities. Eg. : ber, gulmohar, sapota.

2. Acid scarification

This is done to modify the hard or impervious seed coat by using concentrated sulphuric acid which is strongly corrosive. The seeds are soaked in concentrated sulphuric acid for duration of 10 minutes to 6 hours, depending upon the temperature and nature of the seed coat. Eg. : ber, gulmohar, sapota.

II. Stratification (moist chilling)

This is a process of exposing the seeds to low temperature and moisture. This treatment is necessary to induce prompt and uniform germination in certain seeds as it permits physiological changes known as after ripening to occur within the embryo of the seed. The seeds are exposed to low temperature (0 to 10^{O}C) in the presence of moisture and air for certain period of time. The time may vary from one to four months depending upon the kind of seeds. e.g.: Apple, pear, peach, plum, rose etc.

III. Soaking seeds in water

Soaking seeds in water may modify hard seed coat, remove inhibitors, soften seeds and reduce the time of germination. Some impermeable seed coats can be softened by placing the seeds in 4 to 5 times their volumes of

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hot water (77^{O} to 100^{O}C) for 5 to 10 minutes. Inhibitors present in seeds may be leached out by soaking or washing the seeds in cold water for 12 to 24 hours.

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Course Name	**Fundamentals of Horticulture**
Lesson 7	**Principles of Orchard Establishment**
Content Creator Name	**Dr. Kirtimala Balaji Naik**
University/College Name	**University of Horticultural Science,Bagalkot**
Course Reviewer Name	**Jitendra Singh**
University/college Name	**Agriculture University Kota, Kota**

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Orchard

Orchard refers to an area where intensive cultivation of fruit crops is done **or** it is an enclosed area where a fruit /group or fruit trees are grown.

Some related terminologies are described as under

Orcharding: refers to growing of fruit plants in an orderly manner and maintain them for successive economic returns

Plantation: refers to a fairly large area where cultivation is done with a particular type of fruit crop. e.g. Mango plantaion, apple plantaion,, coconut plantation etc.

Estate: refers to large area (more than 1000 acres)/tracts of sole crop cultivation. This terminology was used in earlier days during the era of British empire

e.g. Coffee estate, Tea estate.

Types of Orchards.

There are various types of orcharding

1. Orcharding with single variety of a particular fruit crop
2. Orcharding with different variety of a fruit crops
3. Mixed orchard with different fruit crops of almost equal life span.
4. Orcharding with intercrops/intercropping
5. Multistoried orchard
6. High density orchard
7. Dry land orchard
8. Clonal orchards
9. Nutrition /Kitchen garden

Orcharding with single variety of a particular fruit crop:

e.g. Mango orchard exclusively alphonso variety

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Pomegranate orchard of Bhagwa variety

Guava orchard of Sardar variety

Advantages;

1. Purity of the variety can be maintained
2. Convenient for planning and management
3. All the trees come to harvest at a time

Disadvantages:

1. The variety may be imcompatable (which leads to poor fruit set)
2. The variety may be susceptible to pests and diseses
3. The variety may be irregular like Alphonso variety
4. The variety may not satisfy all consumers

2. Orcharding with different variety of fruit crop:

e.g. Mango orchard - Alphonso+ Kesar+Pairi

Sapota orchard- Cricket Ball+ Kalipatti

Grape- Thomson Seedless+ Sonaka +Sharad Seedless

Advantages:

1. If one variety fails for some reasons other variety will give some returns/income
2. Problem of self incompatability can be overcome
3. It can help in supply variety of fruits during different periods and to cater the needs of different customers

Disadvantages:

1. Purity of variety may be affected
2. Management and harvesting varies

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3. Mixed orchards with different fruits of equal life span

e.g. Mango+Sapota+Guava

Tamarind+Ber+Annona+Aonla

Fig+Pomegranate+Ber+Lime

Papaya+Banana+Pineapple

Advantages:

1. More than one crop may be available on the same piece of land
2. If one crop fails other crop will come to rescue and maintains continuity of income
3. Year round income

Disadvantages:

1. Management becomes very difficult
2. Problems of pest and diseases

Orcharding with intercrop: This system involves incorporation of another species (fruit /vegetable) in between the interspaces of main crop. This system uses the open space available during pre-bearing period of main crop. The intercropping is discontinued once the main crop completely covers the canopy. The intercrop selected should have the following characters.

1. Should be compatible with main crop in their water, nutrient and soil requirement
2. Compact stature and should not compete with main crop
3. Short duration when compared to other perennial crops
4. Should not act as a alternate host for pest and diseases

Advantages:

1. Helps in getting additional income from the orchard during pre-bearing stage of main crop

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2. It also acts as a cover crop and prevents soil erosion
3. Suppress the weed growth in open space
4. Efficient land utilization

   e.g. Banana, papaya, pineapple, guava, Phalsa, fig, beans, cowpea, dolichos, marigold, gaillardia, aster etc.

Multistoried orchard;

e.g Coconut+Black pepper+cocoa+pineapple

Arecanut+Vanilla+Banana+Pineapple

The principle involved in multi-storeyed orchard is harvesting light at different height/storey. The planting should be such that sunlight is harvested by different crops at different stories/levels/height and there won't be competition for soil nutrients, moisture and sunlight because the spread and distribution of roots at different crop component is distributed in different layers of the soil profile.

High density orchard: High density aims at increasing the productivity per unit area by increasing plant population/unit area by closer spacing. This has been successfully done in several temperate fruit crops like apple, pear, peach etc. where there is availability of dwarfing rootstocks and plant responds for training and pruning and chemical regulation of size

e.g: Apple 3m x 3m = 1111 plants

3m x 2m=1666 plants.

Limited success of high density is noticed in tropical and subtropical fruit crops because of

1. Non availability of dwarfing rootstocks
2. Vigorous growth throughout the year
3. Poor response for training and pruning

   High density orchard was tried in mango with dwarfing variety like Amrapali and with the use of dwarfing rootstock like Olour, Vellaikollamban.

   Different types of high density planting followed in fruit crops.

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Bush orchard, Pyramid orchard, Tatura trellies, Meadow orchard, Hedge row system etc.

Advantages:

1. High returns per unit area
2. Maximum use of resources
3. Possibility of adopting mechanization

Disadvantages:

1. Competition in later years
2. Pest and disease problems
3. Cultural operation is difficult

Dryland orchard: Growing of fruit plants in drylands like arid and semi-arid zones as rainfed crop. This concept is gaining importance as several fruit crops have been identified for cultivation in arid and semi arid regions.

e.g. Ber, aonla, datepalm tamarind, fig, phalsa etc.

With the advancement of irrigation technology and efficient water harvesting and conservation some of high value fruit crops are also being grown in arid and semiarid/rainfed re.gions.

e.g. Mango, grape, pome.granate, etc.

Clonal orchard. Orchard established from plants derived from single individual mother plants through vegetative means.

e.g. Clonal orchard of mango var. Alphonso

Advantages: Plants will be uniform in growth, bearing habit and management practices.

Digging and filling of pits:

Marking of pits and planting should always be done with the help of planting board. The guide pegs are installed at both the ends. One metre deep pits of one metre diameter should be dug. Top 30 cm soil should be kept on one side, which is used for refilling the pits as it is considered the fertile soil. Bottom 70 cm soil should be kept on other side, which is discarded. The pits should be left exposed for a few days before actual planting. These pits should be refilled with mixture of topsoil, 2-3 baskets of silt and 2-3 baskets of well-rotten farmyard manure. The refilled pits

should be watered a few days before planting the tree. To each pit add carbafuron for control of white ants.

Method of planting

Make hole of suitable size in the centre of the filled pits with the help of planting board. Place the earth ball of a plant in it in such a way that the upper surface has the same level as ground. Fill loose earth around the ball and press it firmly with the handle of a spade or khurpi. Apply water soon after setting the plants in the pits.

Planting distance of fruit plants

The spacing given to the fruit trees is generally governed by the different factors like climate and soil, choice of varieties, growth habit of tree, rootstock used, nature of irrigation and pruning technique followed. The spacing may vary according to different systems of planting. Provision of optimum spacing to fruit trees is one of the most important aspects of successful fruit culture. Optimum spacing regulates the proper utilization of sunlight, avoids competition in the uptake of nutrients caused by the collision of root systems and facilitates proper irrigation. The latest technology on high-density plantation system where trees are planted at critical spacing for maximum utilization of space is becoming popular. It will be very difficult to suggest exact spacing for fruit trees, which will suit every locality or soil.

Given below is the spacing of some important fruit plants, which serve the basic guideline for establishing a new orchard.

Name of fruit tree	Planting distance (m	Number of plants/ha (square system)
Mango	10	100
Citrus, Pome.granate	6	275
Grape i) Head system	2.0 x 1.5 4.00 x 3.00	3300 1100

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ii) Kniffin system iii) Bower system	3.1 x 6.0	550
Guava, Peach, Loquat	6.5	225
Lithi, Sapota	7.5-9.0	180-123
Ber, pear	7.5	180
Date-palm, almond	6-7	275-202
Jamun	10-12	105-75
Phalsa, Papaya	1.5	4400
Banana i) Tall varieties ii) Dwarf varieties	2.7 x 3.0 1.8 x 1.8	1210 3052
Pineapple	30 x 60 x 90 cm	43500
Custard apple	5	390
Jack fruit	10	100

Planting season: The planting season of different fruit crops vary on the basis of their evergreen or deciduous nature.

Evergreen fruit plants: There are two planting times for evergreen fruits viz., February-March (spring) and August-September (rainy season). The fruit plants such as citrus, mango and litchi should preferably be planted during September or in the beginning of October when the weather becomes mild and more favourable and there is enough moisture in the soil. Guava can also be planted bare-rooted during February-March or August-September. The plant should be defoliated and the roots covered with moist material.

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Most of the sub-tropical and tropical evergreen fruit plants are suitably transplanted during the rainy season when the atmospheric humidity is high and sufficient supply of soil moisture is obtained. During this active period of growth, the plants easily penetrate their roots in the soil and get established. High atmospheric humidity during the rainy season helps them to minimize the transpiration loss.

The evergreen plants can also be transplanted during the onset of spring with equal success provided an ample quantity of irrigation water is available. Early regeneration of rootlets due to high temperature and available moisture during this period helps in early establishment of the plants in most of the cases.

Deciduous fruit plants: The deciduous fruit plants are planted during winter when they are dormant. Their planting must be completed before the start of new growth i.e., up to middle January in case of peach and plum and up to middle of February in case of pear and grapes. The bare rooted Ber can also be planted during January and up to middle of February.

It would be wise, if the planting operation in deciduous fruit plants could be done well before the dormancy is broken and the plants start their growth afresh during subsequent period.

Planting should be avoided during hot and dry spells of weather. The fruit trees should preferably be planted in the afternoon and on cloudy and humid days rather than in bright sunshine and dry weather.

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Course Name	**Fundamentals of Horticulture**
Lesson 8	**Orchard Management**
Content Creator Name	**Dr. Kirtimala Balaji Naik**
University/College Name	**University of Horticultural Science,Bagalkot**
Course Reviewer Name	**Jitendra Singh**
University/college Name	**Agriculture University Kota, Kota**

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Orchard is an area, often enclosed, devoted to the cultivation of fruit trees. It depends on various resources like land, water, trees, external inputs for production. All these resources have to be well utilized to the best advantage for higher production per unit area on sustainable basis without adversely affecting the quality of environment. We should also understand that a good manager is one who gets maximum out of various inputs consistently without any loss of fertilizers and manure, plant itself, plant protection chemicals, produce etc. Therefore, one should understand the management of the qualities of both resource and output. Various resources are soil, water, resources for better comprehension of orchard management.

(I) Soil management
(ii) Water management
(iii) Nutrition management
(iv) Pruning and training (plant management)
(v) Weed management
(vi) Plant protection against insect pests and diseases.
(vii) Bearing, fruitfulness and causes of unfruitfulness.
(viii) Maturity and harvest.
(ix) Post harvest handling, utilization and marketing.

Soil management/Floor management

Soil management aims at maintaining soil in good condition, or improving the condition if necessary. This includes protection from direct sunlight and from the impact of rainfall and wind erosion. In annual crops like vegetables and flowers which do not leave vacant space. there is no such problem except that one has to replenish nutrients harvested by crops and leached out but in tree crops, wherein, it is usually several years after planting before a tree with lorm such an extensive canopy that it can provide adequate protection to the soil, the vacant space needs to be productively utilized and protected through different management practices like intercropping, cover cropping, cultivation, sod culture, mulching, rotation, high density plantation etc.

Objectives of soil management:

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(i) To create favourable conditions for moisture supply and proper drainage.
(ii) To maintain high fertility level and replenishment against losses.
(iv) To provide proper soil conditions for gasc us exchange and microbial activities through addition of organic matter.
(iii) To check or reduce soil erosion.
(v) To ensure supply of nutrients for growth and development of plants.
(vi) To utilize vacant land for additional income because such a loss is inconceivable for
small holders.
(viii) To reduce the cost of cultivation with high economic returns.
(vii) To suppress weed population.

Definitions of terms to be used in management of soil

Intercrop: Any crop other than main crop grown between the rows of perennial tree crops is
known as intercrop and the cultivation thereof is intercropping.

Green manure crop: The crop other than main crop grown for the purpose of enriching the
soil for organic matter is called green manure crop. These crops are usually ploughed down in the field when tender. It must be incorporated in the soil before flowering stage. Besides it, the foliage and greens of shrubs and trees are useful green manure.

Cover crop: The crop grown to provide a cover to soil to protect it from erosion. It may be green manure crop also.

Methods of Soil Management:

Appropriate soil management method is important for the control of weeds, incorporation of organic and inorganic fertilizers and to facilitate absorption of water in soil. Common soil management practices are **(1) clean cultivation (2) sod culture (3) sod mulching and (4) rotation.** Choice of the system is determined by many factors as mentioned below

(i) Crop

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(ii) Rooting depth of the crop
(iii) Slope of the soil
(iv) Rainfall of the area
(v) Climatic condition of the place (vi) Economic condition of the farmer

Cultivation: Cultivation in context with soil management refers to working of the soil by ploughing, harrowing, disking, or hoeing. It is essential for removal of weeds, incorporation of manures and fertilizers, green manuring, and to facilitate water and nutrient absorption through better aeration. Depth of tillage and areas are determined by root depth and spread of the canopy of the tree. In cultivation different modifications are made under specific conditions.

(i) Clean cultivation: In this method of soil management the space between plants is kept clean by tillage and removal of weeds.

Advantages:

(a) Removes competition of weeds for light, water and nutrients from crop and avoidance of alternate host for pests and diseases.
(b) Improves soil physical condition through better aeration by breaking clods.
(c) Helps in breaking hard top and obstructions in the infiltration of water.
(d) Improves soil biological activities through better aeration.

Disadvantages:

(a) Loss of organic matter
(b) Loss of soil through erosion even on flat lands through water and wind.
(c) Loss of nutrient through excessive leaching.
(ci) Injury to roots and creation of entry points for pathogens.

Looking to several such disadvantages, clean cultivation is not advisable in fruit farming, perhaps just before planting. Even so, it will seem inconceivable to most small holders not to use good land whenever possible and interorops involving short duration crops and nitrogen fixing annual crops are preferred. If it should be, cultivation should be shallow and infrequent and should be stopped at flowering time.

(ii) Cultivation and cover crops: In areas where soil is eroded during rains and drainage is poor, soil is cultivated and cover crops are grown between

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the rows during rains. The crop may and may not be turned into soil. These crops not only increase water retaining capacity of soil and biological complex of the soil but also add organic matter when ploughed in besides checking erosion. As cover crops, legumes should be preferred because they add extra N in soil through fixation of atmospheric—N in their nodules. They also suppress weeds during rainy season. Crops like greengram, blackgram, cowpea, cluster— bean, soybean should be preferred during karif season while pea, fenugreek, broad bean and lentil can be preferred in winter season as cover crops.

Advantages:

(a) Adds organic matter in soil
(b) Improves soil condition
(c) Improves soil fertility
(d) Increases water retention capacity of soil
(e) Increases biological complexes of soil
(f) Checks soil erosion
(g) Checks nutrient losses through soil erosion.

(ii) Cultivation and intercropping

In this case of orchard soil management cultivation is done for the purpose of raising intercrops. Intercropping is growing of two or more crops simultaneously on the same field so that crop intensification occurs in both time and space dimensions, and there is intercrop competition during all or part of crop growth. This can be mixed strip or relay cropping.

In context of an orchard or a plantation of perennial fruit trees, however, the practices of growing annuals or relatively short duration crop in the interspace during their formative years is referred to as intercropping and the growing of perennial in the interspacing of perennials is called mixed cropping. The term multistory cropping refers to a multispecies crop combination involving both annuals and perennials with an existing stand of perennials.

Purpose of intercropping: intercropping is intended to maximize land and space use efficiency to generate supplement income, particularly during the initial unproductive phase of the orchard, to protect the inter space

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from losses through weeds, erosion, impact of radiation, temperature, wind and water, and enriching it by nitrogen fixing leguminous crops.

Disadvantage: If the main plantation is not given priority care, serious losses may occur as a result of root restriction, damage and infection, undue exhaustion of the soil, perpetuation of viral, fungal and nematode infection. Intercrops should therefore, receive secondary importance and fulfil following criteria.

(a) Should not be tall growing and spreading type

(b) They should not be exhaustive.

(c) Should not function as alternate host for common pests and diseases.

(d) The water requirement schedule should match or phenology of crop should match so that operation could be synchronized.

(e) Should be compatible with main crop

Besides, it is necessary that separate provision for nutrients should be made for intercrop to avoid competition. Normally if one selects intercrop on the basis of agroclimate, resource, market and compatibility of crop with perennial plantation it should be a successful choice.

Annual crops particularly legumes and shallow rooted vegetable crops like tomato, onion, beans, radish, spinach etc. are preferred.

Some perennials like pineapple, phalsa, banana, papaya are also taken as intercrops and popularly referred a filler crops. Based on experience and experimental evidences some recommendations for intercropping in young orchards exist. They are being presented in

Table: 1 Intercrops in different orchard crops

Sl.No.	Crop	Duration for Intercrop	Recommended intercrops
1	Apple	4 years	Tomato, cabbage, beans, strawberry, early potato, peach
2	Banana	5 months	Greengram, cowpea, cauliflower, cabbage, yam,

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			elephantfoot, onion, blackgram, turmeric, brinjal, colocasia, dioscorea, chillies, okra
3	Ber	2 years	Greengram, onth bean, clusterbean, cowpea, cumin, chillies
4	Citrus	4 years	Beans, carrots, tomatoes, berseem, senji, onion, potato, chillies, pulses, cucurbits, lady's finger, gram, peas, potato, cabbage
5	Date palm	5 years	Citrus medica, Guava, Sapota
6	Grape	1 year	Vegetables relevant to area
7	Guava	3 years	Cauliflower, peas, frenchbean, cowpea, clusterbean, blackgram, greengram, Ladys finger, onion, turmeric, garlic, cabbage, chillies, papaya
8	Litchi	7 years	Turmeric, ginger, pointed gourd, sweet potato, tomato, radish, cabbage, turnip, brinjal, cucurbits, greengram, blackgram, cowpea
9	Mango	5 years	Phalsa, papaya, guava, banana, peach, strawberry, pineapple Cowpea, cucurbits, okra, cabbage, knolkhol, beet,

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			onion, carrot, cauliflower, tomato, clusterbean
10	Papaya	6-9 months	Cabbage, cauliflower, chillies, radish, tomato
11	Peach	3-4 years	Soyabean, pineapple, cowpea, turmeric
12	Pomegranate	4 years	Berseem, Lucerne, cowpea, green gram, cucurbits, cabbage, cauliflower, bean, peas, tomato, carrot, onion, potato, brinjal
13	Sapota	7 years	Banana, papaya, pineapple, tomato, brinjal, cabbage, cauliflower

Minimum tillage

In this method inter space is maintained without any traditional soil working by ploughing, disking, harrowing etc. This is receiving widespread adaptation in uneven topography. Here sod, weeds, cover crops and other vegetation are killed by herbicides in springs which forms, a layer of dead plant material on soil surface. This provides excellent erosion control, moisture conservation, and nutrients are released from dead material.

Sod culture

In this system, in the space between trees, grasses are allowed to grow without tillage or mulching Sometimes clover is mixed with grasses to improve fertility Such grasses are simply mowed and the surface is kept neat and tidy This system is commonly followed in temperate region of Europe and America for apple and pear orchards and does not exist in tropical and subtropical region of India due to scarcity of available nutrients and soil moisture in most part of the year. It i the best system for the control of soil erosion and rfaintenance of soil organic matter and soil structure In this case manures and fertilizers are not applied individually to

trees but provided all over sod and the system is satisfactory for deep rooted crops

Modifications in Sod culture

(i) Grasses are allowed to grow without cutting — not desirable because organic matter is lost

(ii) Grasses are grown cut as required and removed for making hay not desirable because organic matter is lost here also

(iii) Grasses are grown cut and left behind to decompose

(iv) Grasses are grown and pastured *i.e.* animals are allowed to graze.

(v) Temporary sod. Sod is allowed for two years or so, then soil is ploughed, cultivated and sod is re-seeded.

Sod is not being followed in India due to lack of cool and moist weather. Lack of aeration, rat holes in sod prove harmful and trees die. Nutrient deficiency is also common especially of K.

Mulching

Mulching is the practice of covering the soil around the plants to make conditions more favorable for growth and conserve the available soil moisture. In this management system the open soil is put under loose cover of straw, hay, crop residue, leaves, saw dust and plastic. It is essentially a surface barrier against evaporation and checks weed growth reducing competition for nutrients. This is one of the important soil management practices adopted in certain countries in orchards. It offers a number of advantages at the same time suffers from disadvantages too.

Advantages

(a) Conserves moisture by suppressing weed growth, regulating soil temperature and protection from sun and wind.

(b) Improves soil structure.

(c) Reduces soil temperature fluctuations

(d) Increases soil organic matter level

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(e) Controls erosion
(f) Improves water infiltration rate
(g) Improves nutrient availability through better soil condition microflora
(h) Avoids competition for nutrient and moisture with main crop.
(i) Controls weed growth

Disadvantages

(i) High cost
(ii) Transportation
(iii) Disease and pest infestation through dead plant material
(iv) Fire hazards and
(v) Roots grow shallow due to the effect through soil temperature and moisture. Therefore, in first year mulching may not be advisable.

Among all the mulching materials, plastic mulches are becoming popular especially black polythene mulch, where weed control is desired. Mulching is common in tropics especially in crops like banana, citrus, pineapple. Some of the recommendations made for different and crops are being presented below in

Table 2

Table: 2 Recommended mulches for different fruit crops

Sl. No.	Crop	Mulching material
1	Banana	Polythene, straw mulch, Banana trash, sugarcane trash
2	Mango	Straw mulch especially for spongy tissue
3	Pomegranate	Sugarcane trash, paddy husk, groundnut husk
4	Ber	Sugarcane trash. Wheat straw, black polythene, local grasses
5	Sapota	200 gauge black polythene
6	Grape	Black Polythene
7	Acid Lime	Dry leaf mulch
8	Strawberry	Black polythene and cut grasses, pine needles
9	Guava	Organic mulches

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10	Lemon	Dry grasses,, Black polythene
11	Coorg Mandarin	Dry leaf mulch, weedscrape
12	Sweet lime	Dry grasses
13	Date Palm	Local weed
14	Pineapple	Black polythene, saw dust, dry leaves
15	Apple	Oak leaves, hay, conifer leaves, black alkathane

Rotation

Planting of different crops in a regular sequence on a given piece of land is referred as rotation. When this technique is used for soil management, it is necessary that sequence in the year or the rotation includes legume as one of the crops. Even in plantations of perennial fruit crops like papaya, banana, pineapple, after clearing of fields, these crops should be followed by leguminous green manuring crop before planting them again. Choice of the legumes can be decided on the basis of climatic region. Generally sesbania, crotolaria, cluster- bean and cowpea, are preferred as they add higher quantities of organic matter and nitrogen.

Advantages

(a) Helps in controlling insect pests and diseases

(b) Helps in equalization of available nutrients

(c) Avoids bad effects of continuous monoculture through elimination of build up of toxins, diseases and pests.

Some of the recommendations are as under:

Banana —-- Crotolaria or Sesbania or cowpea

Papaya — Crotolaria or cowpea

Pineapple — Sesbania or Glyricidia

Besides, in young orchards when intercrops are taken, some of the recommended rotations of intercrops are as under:

Citrus Orchard

Cowpea I moong / urd / moth — cucurbits / turnip / Cauliflower ,carrot / radish I pea

Mango Orchard

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(i) Brinjal — cowpea
(ii) Tomato — clusterbean
(iii) Tomato — cowpea—soybean—coriander
(iv) Soybean — pea — cowpea — Palak — Chillies Banana Orchard
(i) Moong — Toria
(ii) Cowpea — Radish
(iii) Moong —Turmeric
(iv) Ragi — Bean
(v) Groundnut — Bean

Guava Orchard

Cowpealcl usterbean/blackg ram/g reng ram French beans

Litchi Orchard

cauliflower/Peas!

Cucurbits / greengram / blackgram / cowpea—radish / beat / turnip / carrot

Pomegranate Orchards

Cowpea/g reen gram — beans/peas/tomato/carrotlon ion/radish

Legumes should be included in rotation and crops like papaya, banana, pineapple and vegetables should be preferred for higher returns.

Agro-forestry Systems

Agro-forestry system is especially useful in orchard management where land is not so much productive and supportive to crop cultivation. Therefore, agro forestry should become an important land use system, especially in degraded soils, so that we not only meet the food and wood requirement of the people, but also protect this good earth from environmental hazards.

In agro-forestry systems, many options are available combining horticulture like agri—horti, horti—silvi, horti—pasture which combine horticultural crops with trees, pasture and agricultural crops. Among these horti-silvipastoral system appears to be one of the most efficient system for soil management. This encompasses any and all techniques that attempt to establish or maintain forests, horticultural crops, forage trees and pasture grasses on the same piece of land. It aims at systematically

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developing land use systems and practices where the positive interaction between trees and crops is maximized and seeks to achieve a more productive, sustainable and diversified output from the land than is possible with the conventional mono cropping systems. In this system fruits and vegetable crops provide seasonal revenue, while forest trees are managed at 5 to 10 years rotation to give returns from timber, fuel wood and fodder. Horti-silvipastoral land use is considered to be an effective method of soil management satisfying multiple needs of farm families. It offers a
number of advantages

(i) This system has higher employment potential being labour intensive.

(ii) As a conservation farming system can help in the control of erosion in catchment.

(iii) It is an excellent substitution for shifting cultivation in vogue in north-east region.

(iv) Degraded lands can be renovated by this integrated management system.

(v) It has potential to increase productivity under rainfed condition and provides stability in income.

(vi) Inclusion of drought hardy fruit tree component can ensure regular income in drought prone area.

In this system ber, pomegranate, aonla, mango, annona, jamun, tamarind, gonda, mahua and karonda as fruit trees; Acacia tortalis, Albizia amara, Leucena leucocephala, Eucalyptus spp. as forest trees and Cenchrus ciliaris, Cenchrus setigerus and Stylosanthes hamata as grass component have been found highly useful under rainfed semi arid conditions. In this case plantation of ber, mango and guava using staggered contour trenches, with forest spp like Leucaena leucocephala and Eucalyptus in highly degraded soil with Cenchrus ciliaris on gully rim and vegetable crops like cowpea, okra, clusterbean and brinjal in interface between fruit trees have been quite successful under rainfed conditions of Panch Mahal district of central Gujarat.

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Some of the other successfully tested agro forestry systems including horticulture like peach with turmeric, Eureka' lemon with chillies, and mandarin with ginger in Doon Valley; Arable crops with mango, guava, cashewnut acid lime and sweet orange in Andhra Pradesh; Eucalyptus with aonla, ber and guava in Faizabad (U.P.); 'Coorg' mandarin with Casurina and paddy in Karnataka, pastoral system under apple, almond, pear and plum with Festuca pretense, Dactylia glomerata and red and white clover in J and K and pineapple with Alnus nepalensis and Stylosanthes hamata in Shillong have been found successful. All these systems need large scale testing for soil management strategy and value addition to degraded areas before adoption.

Multistorey Cropping System

In this system crops of different heights are grown on the same piece of land. This is most common in coconut based farming system in Kerala to meet the diversified needs of the farming community for fodder, food and fuel besides increasing net return from a unit area. This system involves growing of annuals and perennial in different tiers by exploiting soil and air space more efficiently. It has been demonstrated that intercropping and mix cropping with compatible component crops in coconut do not have any adverse effect on the yield of main crop while increasing net returns for the farmers. Some common systems in vogue are -

(i) Coconut/cocoa/pineapple/pepper

(ii) Coconut/hybrid napier and legume (Stylosanthes grad//is).

(iii) Coconut/arecanut/cocoa black pepper/pineapple.

This system is becoming most popular being efficient for effective utilization of solar energy and soil management.

High Density Plantation

Planting density in general depends on the kind of fruit tree and its growth habit, rootstock utilized, pruning and training needs, rainfall of the area and soil type. However, recommended planting densities in fruit crops results in underutilization of interspace during early stage of orchard's life.

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This makes orcharding unattractive, particularly on small holdings because of long gestation period before giving returns and soil management problematic for vacant space. Therefore, high density planting, planting more than optimum number of plants per unit area, is being-considered as soil management strategy for making maximum use of land to achieve high yields in the early periods of orchard life along with ease in its management. This has been successful in fruit crops like apple, pear, banana, pineapple, mango, guava, citrus, ber and pomegranate. This can be achieved through the use of one of the following factors like dwarf genotypes, dwarfing rootstock, interstock, pruning and training, use of retardants, adjustment of planting geometry and induction of viral infection.

Table: 3 Recommended densities of some fruit species

Fruit	Variety	Spacing	System of planting	Number of plants/ha
Mango	cv. Amrapalli Dashehari	2.5 x 2.5 m 3.0 x 2.5 m	Triangular Rectangular	1600 1333
Citrus	Kinnow mandarin	6 x 6 ft 8 x 8 ft 10 x 10 ft	Square system using Troyer citrange as rootstock Karna Khatta as rootstock Soy sarkar as rootstock	3025 1780 1111
Banana	Cavendish group	1.2 x 1.2 m 1.0 x 1.0 x 2.0 m 25 x 60 x 75 cm	Square system Paired row system Double row planting system	6944 6666 63000

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Apple	Variety spur type on rootstock MM 111, MM 109 Non spur type on MM106, M7 M9	4 x 4 m 3 x 3 m 2 x 2 m	Square system Square system Square system	400 1111 2500
Guava	Aneuploids Lucknow-49	3 x 3 m 6 x 2 m	Square system Square system	1111 833
Papaya	Pusa nanha	1.25 x1.25 m	Rectangular system	6400
Acid Lime	Kagzi	4.5 x 4.5 m	Square system	484

Soil is an important but finite natural resource on which agriculture based. It is necessary to maintain this in optimum state of productive capacity and put in appropriate use for sustainable crop production. Therefore, appropriate strategy of management should be adopted depending on crop, climate, topography, resource and socio-economic condition of the farmer. In any case management system should be such that quality of this resource is improved for which right decisions are necessary after proper evaluation of all the factors involved.

Establishment of orchard: Establishment of an orchard is a long term investment and deserves a very critical planning. The selection of proper location and site, planting system and planting distance, choosing the varieties and the nursery plants have to be considered carefully to ensure maximum production. While planning and planting a new orchard, one should give utmost attention and care to various aspects like selection of location and site, nature of soil and subsoil, planning of suitable kinds and varieties of fruits, proper planting distance and purchasing of plants from reliable nurseries.

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Preparation of land

- The land should be cleaned properly for free movement of men and machinery.
- The soil of the area designed for growing fruit plants needs thorough preparation.
- A virgin land requires a deep ploughing and harrowing.
    - The land should be repeatedly ploughed and bring the soil to a fine tilth.

Layout plan

- The marking of position of the plant in the field is referred as layout.
- The layout plan of the orchard should be prepared carefully, preferably in consultation with horticultural experts.
- The orchard layout plan includes the system of planning provision for orchard paths, roads, water channels and farm building.
- A sketch of the proposed orchard should be prepared before the actual planting is taken up.

PLANNING OF ORCHARDS

Orchard is a long-term investment and needs lot of planning and expertise. While planning and planting a new orchard, one should give utmost attention and care to various aspects like selection of location and site, nature of soil and subsoil, planning of suitable kinds and varieties of fruits, proper planting distance and purchasing of plants from reliable nurseries.

Preparation of land

The land should be cleaned properly for free movement of man and machinery. All the trees, bushes and creepers should be removed. The stubbles should be avoid regeneration of growth and obstruction for movement of machines. The soil of the area destined for growing fruit plants needs thorough preparation. A virgin land requires a deep ploughing and harrowing. The land should be repeatedly ploughed and bring the soil to a fine tilt.

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System of planting

The following are the important systems of planting generally followed on the basis of Agro-climatic conditions.

1. **Square system**: It is the most commonly used method and easy to layout in the field. In this system, plant to plant and row to row distance is the same. The plants are at the right angle to each other, every unit of four plants forming a square. This system facilitates the interculture in two directions after the orchard is planted.
2. **Rectangular system**: In this system, the plot is divided into rectangles instead of squares and trees are planted at the four corners of the rectangle in straight rows running at right angles. Like square system, this system also facilitates the interculture in two directions. The only difference is that in this system more plants can be accommodated in the row keeping more space between the rows.
3. **Hexagonal system**: In hexagonal system, the trees are planted in the corners of equilateral triangles. Six trees thus form a hexagon with another tree at its centre. This system, though a little difficult for execution but accommodates 15 percent more plants. Cultivation of land between the tree rows is possible in three directions with its system. This system is generally followed where the land is costly and very fertile with ample provision of irrigation water.
4. **Triangular or alternate system**: In this system, trees are planted as in the square system but the plants in the 2^{nd}, 4^{th}, 6^{th}, and such other alternate rows are planted midway between the 1^{st}, 3^{rd}, 5^{th}, and such other

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alternative rows. This system provides more open space for the trees and for intercrop.

5. **Quincunx or diagonal system**: This system is exactly like the square system but one additional tree is planted in the centre of each square. The number of plants per acre by its system is almost doubled than the square system. Fruit trees like papaya, kinnow, phalsa, guava, peach, plum etc. can be planted as fillers in the permanent trees provides an additional income to the grower in the early life of the orchard. The filler trees are uprooted when the main orchard trees start commercial fruiting.
6. **Contour system:** This system is usually followed in the hilly areas with high slopes but it is very much similar to the square/rectangular system. Under such circumstances, the trees may be well planted in lines following the contour of the soil with only a slight slope. Irrigation and cultivation are then practiced only across the slope of the land as this practice reduces the chances of soil erosion. In this system layout is done as in square/rectangular system, first by establishing the base line at the lowest level and then marking for the trees should be done from the base to the top. Bench terraces are used where the slope is greater than 10 per cent.

Method of layout

- For laying out an orchard, according to square system, a base line is first established and position of the trees is marked along this line by laying wooden stakes in the ground.
- Another base line at right angle to the first base line, is then marked along with the other edge of the field with the help of a carpenter square or a cross staff.
- The right angle can also be drawn with the help of measuring tape.
- One end of this tape is fixed at three metre distance from the corner along the first line and the tape is then stretched along the second base line for a distance of four metre.

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- The diagonal distance between these two points should be five metres.

The wooden stakes are put in the ground at the desired distance along the second line.

- All the four rows are thus established and staked.
- Three men, one putting the peg in the field and others correcting alignment while moving along the base line, can easily stake the whole field.
- The marking of position of the plant in the field is called “layout”.

- **Aims of layout**
  The marking of position of the plant in the field is called lay out.
- To provide adequate space to plants.
- To accommodate more number of plants.
- Easy intercultural operations.
- System of planting
- All the trees, bushes and creepers should be removed.

Square system

It is the most commonly used method and easy to layout in the field. In this system, plant to plant and row to row distance is the same. The plants are at the right angle to each other, every unit of four plants forming a square. This system facilitates the interculture in two directions after the orchard is planted.

Advantages:

1) Most easy and popular one.
2) In this row to row and plant to plant distance is kept similar.
3) Plants are exactly at right angle at each corner.
4) Inter culture operations can done in both the directions.

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5) Adequate space for inter-cultivation of remunerative crops like vegetables.

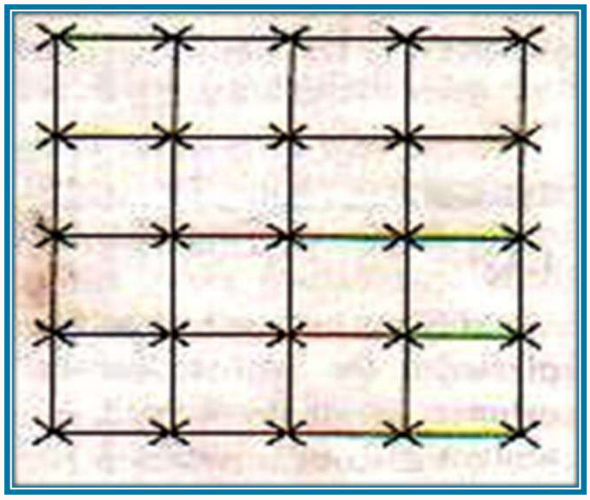

Fig 1: SQUARE SYSTEM OF PLANTING

Rectangular system

In this system, the plot is divided into rectangles instead of squares and trees are planted at the four corners of the rectangle in straight rows running at right angles. Like square system, this system also facilitates the interculture in two directions. The only difference is that in this system more plants can be accommodated in the row keeping more space between the rows.

Advantages :

1) Laid out in rectangular shape.
2) More space between row and row.
3) Inter-cultural operations in both the ways.
4) Plants get proper space and sunlight .

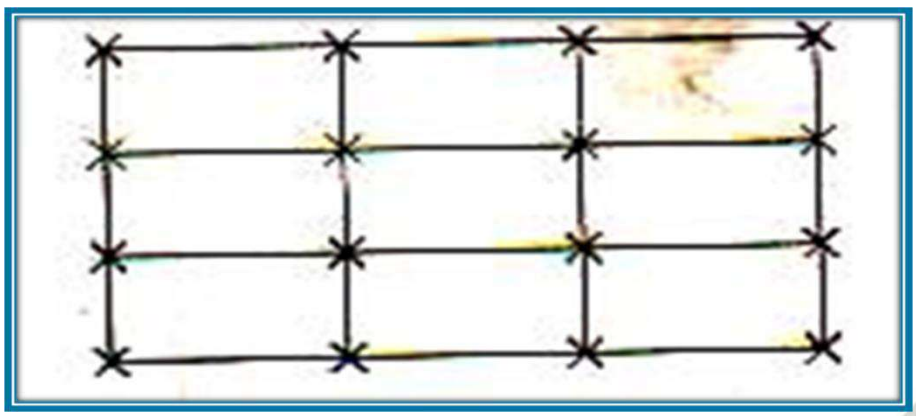

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Fig 2: Rectangular system of planting.

Hexagonal system

In hexagonal system, the trees are planted in the corners of equilateral triangles. Six trees thus form a hexagon with another tree at its centre. This system, though a little difficult for execution but accommodates 15 percent more plants. Cultivation of land between the tree rows is possible in three directions with its system. This system is generally followed where the land is costly and very fertile with ample provision of irrigation water.
Advantage:

1) Accommodates 15 % more plants than square system .
2) Plants are planted at the corner of equilateral triangle.
3) Six trees are planted making a hexagone.
4) If seventh tree is planted in the centre called septule.
5) This requires fertile land.
6) Lay out is difficult and cumbersome.

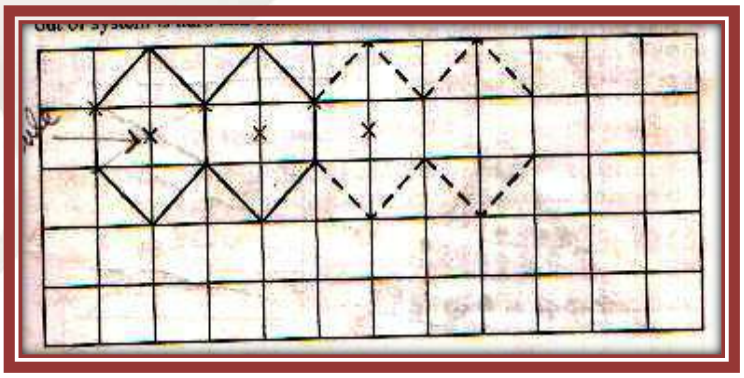

Fig 3 : Hexagonal system of planting.

Quincunx system

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permanent trees provides an additional income to the grower in the early life of the orchard. The filler trees are uprooted when the main orchard trees start commercial fruiting.

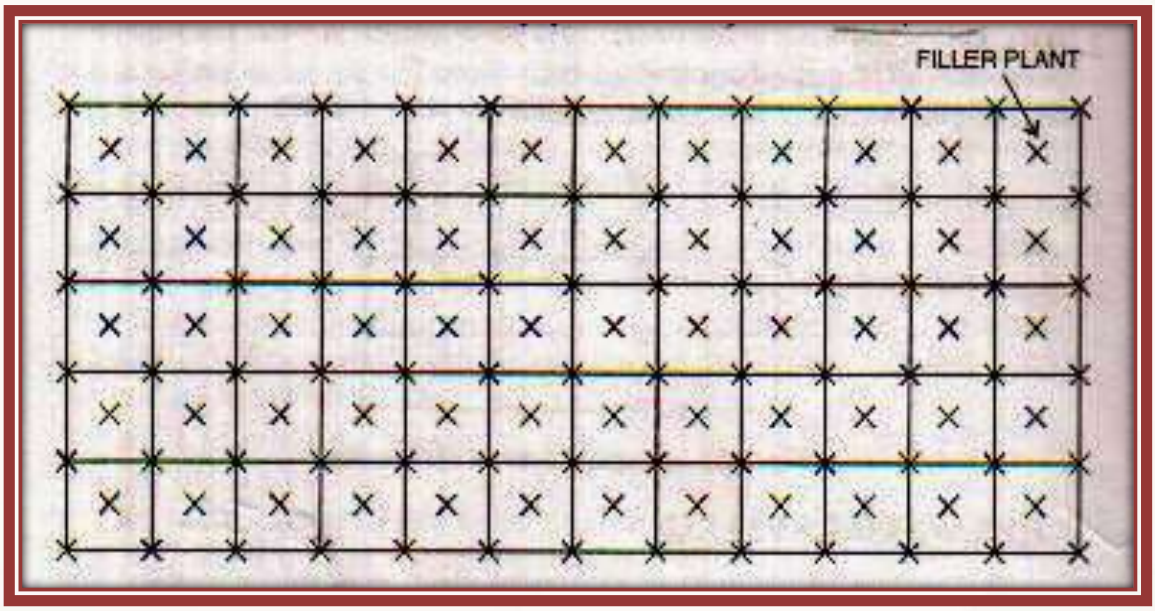

Fig 4: Quincunx system of planting.

Contour system

This system is usually followed in the hilly areas with high slopes but it is very much similar to the square/rectangular system. Under such circumstances, the trees may be well planted in lines following the contour of the soil with only a slight slope. Irrigation and cultivation are then practiced only across the slope of the land as this practice reduces the chances of soil erosion. In this system layout is done as in square/rectangular system, first by establishing the base line at the lowest level and then marking for the trees should be done from the base to the top. Bench terraces are used where the slope is greater than 10 per cent.

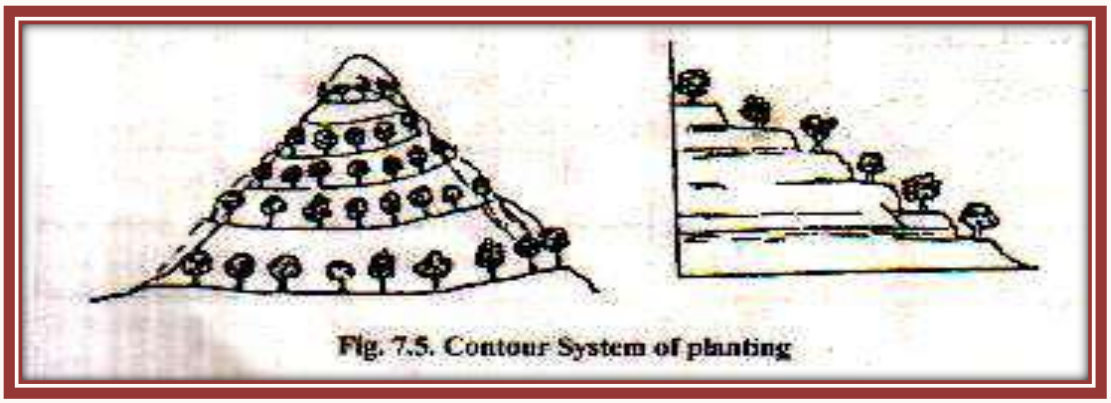

Fig 5: Contour system of planting.

Triangular system

In this system, trees are planted as in the square system but the plants in the 2nd, 4th, 6th, and such other alternate rows are planted midway between the 1st, 3rd, 5th, and such other alternative rows. This system provides more open space for the trees and for intercrop.

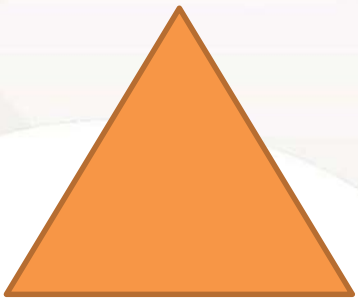

Fig 6: Triangular system of planting

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Course Name	**Fundamentals of Horticulture**
Lesson 9	**Training and Pruning**
Content Creator Name	**Dr. Kirtimala Balaji Naik**
University/College Name	**University of Horticultural Science,Bagalkot**
Course Reviewer Name	**Jitendra Singh**
University/college Name	**Agriculture University Kota, Kota**

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Training is a practice to get a desired shape and form of plant. 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. Training includes summer training and summer pruning as well as dormant pruning. The goal of tree training is to direct tree growth and minimize cutting.

Pruning is the judicious removal of plant parts such as shoots, spurs, leaves, roots or nipping away of terminal parts etc. for better yield and quality to correct or maintain tree structure and increase its usefulness.

It is mainly done to make the plant more productive and bear quality fruits

To increase longevity of the tree

To make it into manageable shape and

To get maximum returns from the orchard.

Pruning increases fruit size, nitrogen per growing point and stimulates growth near the cut. Excessive pruning reduces fruitfulness especially with young vigorous trees that may already be developing too much vegetative growth. Large cuts results in excessive stimulation of sprouts near the cut while well distributed small cuts spreads the stimulus better over the entire tree. The severity, kind and amount of pruning to be done on a tree depends on the age, existing framework, condition of bark and wood, growth characteristics and fruiting habit of the variety. Pruning is most often done during the winter, commonly referred to as dormant pruning.

Objectives of Training

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.

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Principle of Training

The principle objective of training a young tree is to develop strong framework of scaffold branches. All methods of training must stand or fall by their ability to achieve a tree capable of bearing high yielding fruits without undue breakage and hence secure a balanced distribution of fruit bearing parts on the main limbs of the plant.

Plant Management

Horticultural plants are grown for their produce like fruits, vegetable, flowers, medicinal components, spices (oleoresins), aromatic (essential oils) etc. Therefore, these plants should be managed in such a way that human desires for the purpose of growing them are fully satisfied in terms of quality and quantity of produce. This demands direct manipulation of plant growth itself or plant environment through various inputs. In manipulation of plant development, training and pruning are important for which our knowledge about plant development and its phenology has to be complete. These practices are important in fruit crops.

Methods of Training

Method of training of a plant is determined by the nature of plant, climate, purpose of growing, planting method, mechanization, etc. and therefore, intelligent choice is necessary.

Training in herbaceous annuals Biennials:

These plants are usually grown without any attempt to alter their growth patterns because even if useful not practical being in large number in field. However, for some of ornamental value and creeping nature following types of training is affected.

(i) Staking or supporting of vine like plants.

(ii) Training on pergola or trellis of vine type fruit plants or even indeterminate type tomatoes.

(iii) Nipping of apices far encouraging lateral growth to give bushy appearance or fullsome appearance in pot plants like aster, marigold, chrysanthemum.

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(iv) De-shooting or removal of lateral buds for making single stem for large flowers as in chrysanthemum, Dahlia.
(v) Staking with bamboo sticks and tying together various shoots in potted chrysanthemum.

Training of woody perennials:

The woody perennials, which are widely spaced and remain on a place for a long duration, are trained by developing strong framework for sustainable production of quality produce and for ornamental beauty in different shapes (topiary). In these plants following types of training affected.

(i) **Open centre system (Vase shaped):** In this system the main stem is allowed to grow to a certain height and the leader is cut to encourage lateral scaffold from near the ground giving a vase shaped plant. This is common is peaches, apricots and ber
(Fig. 9.1).

Fig. 9.1 **Open centre system**

(ii) **Central leader system (closed centre):** In this system the central axis of plant is allowed to grow unhindered permitting branches all around. This system is also known as closed centre system and common in use in apple, pear, mango, sapota (Fig.9.2).

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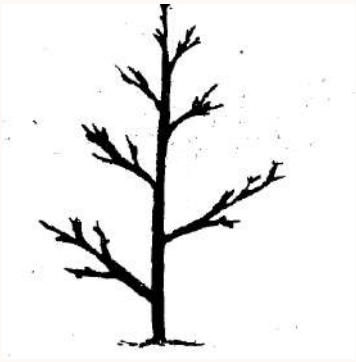

Fig. 9.2 **Central leader system**

(iii) **Modified leader system**

This system is in between open centre and central leader system wherein central axis is allowed to grow unhindered upto 4—5 years and then the central stem is headed back and laterals are permitted It is common in apple, pear, cherry, plum, guava (Fig.9.3).

Fig. 9.3 **Modified leader system**

iv**) Cordon system :** This is a system wherein espalier is allowed with the help of training on wires. This system is followed in vines incapable of standing on their stem. This can be trained in single cordon or double cordon and commonly followed in crops like grape, and passionfruit (Fig. 9.4).

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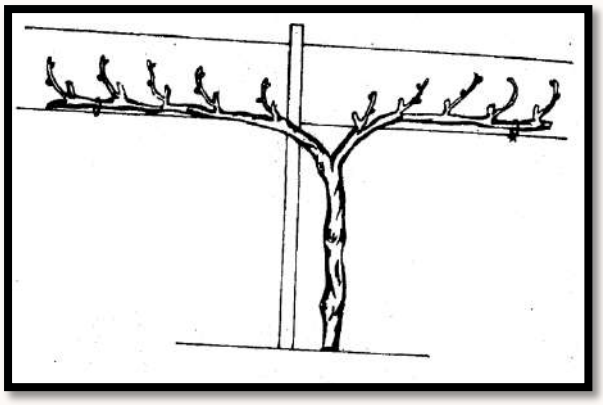

Fig. 9.4 **Cordon system**

(v) **Training on pergola:** To support perennial vine crops pergola is developed by a network of crisscross wires supported on RCC/angle iron poles on which vines are trained. This is common for crops like grape, passion fruit, small gourd, pointed gourd and even peaches.

(vi)**Training in different shapes**: Generally ornamental bushes are trained in different shapes for the purpose of enhancing beauty of places. These shapes could be vase, cone, cylindrical, rectangular box, flat and trapezoid. Presently for the convenience of mechanization these shapes are being utilized in fruit trees. Such shapes are given to adjust the geometry of plantation like hedge row system, box, unclipped natural in fruits like guava, mango, sapota and citrus.

Details of Training:

(i) **Height of the head** : This is the height from ground to first branching or scaffolding. Depending on this height the trees could be divided in three groups.

(a) **Low head** : 0.7—0.9 m. This is common in windy areas. Such plants are easy to maintain.

(b**) Medium head** : 0.9—1.2 m. This is the most common height which combines both effects, ability to stand against wind and easy management.

(c**) High head:** More than 1.2 rn. Common in tropics in wind free areas. Operations under the canopy are easy to perform.

(ii) **Number of scaffold branches:** It refers to allowing of number of scaffolds on the primary axis of the tree which vary from 2 to 15 but

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extremes are undesirable. In fruit trees 5 to 8 scaffolds are preferred to make the tree mechanically strong and open enough to facilitate cultural operations.

(iii) **Distribution of scaffolds**: Scaffolds should be distributed in all the directions spaced at 45—60 cm allowing strong crotches through wide angles of emergence.

A well trained tree is an asset to the farmer and therefore, efforts should be made for training trees appropriately in formative years for sustainable production. In fact the process should have begun from nursery itself.

Pruning

Definition:

It refers to removal of plant part like bud, shoot, root etc. to strike a balance between vegetative growth and production. This may also be done to adjust fruit load on the tree.

Objectives:

(i) To control fruiting

(ii) For better plant performance

Improvement in productivity and quality by regulating the load of the crop and extent of flowering.

Elimination of non-productive vegetative growth like water sprouts, suckers, dead and diseased wood.

In case of forest trees production of knot free lumber.

Types of pruning:

Basically there are three types of pruning with definite purposes.

(i) Frame pruning

(ii) Maintenance pruning

(iii) Renewal pruning

(i) **Frame pruning**: This pruning is done to provide shape and form to a plant in its formative years so that tree develops strong framework and a shape for ease of operations. This process begins from nursery itself and continues upto fruiting stage. This is done continuously irrespective of the season.

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(ii) **Maintenance pruning**: To maintain status—quo in production level and for uniform performance this pruning is done. In some plants like grapes, apple, pear, peach etc. (deciduous trees) it is an annual feature and in others (evergreen like mango, sapota) it
is rare confining to removal of water sprouts and unproductive
growth and opening of the tree.

(iii) **Renewal pruning**: This pruning is done in trees which decline their growth and production with age. So to bring back these trees into production like old mangoes, severe pruning is done to rejenuvate these trees.

Factors to be considered in pruning:

In some of the tree species pruning as a regular feature in bearing trees is done to strike a balance between vegetative growth and production so that farmers get sustained production uniformly with optimum quality of produce. To achieve this one should consider the following factors.

(i) Time at which buds are differentiated in relation to blooming

(ii) The age of the wood that produces the most abundant and highest quality of fruit buds.

In consideration of these factors our knowledge about bearing habit of the tree/plant should be complete. Bearing habit means relative position of a fruit with reference to its potential bud giving rise to flower or inflorescence in the shoot. This habit varies from plant to plant and we shoul know this to be intelligent and correct in pruning.

Kinds of flower bearing shoots:

Depending on the position of fruit bud and the kind of flower bearing shoots it produces, fruit trees can be classified into following eight groups. Basically there are two types of flowering: terminal and lateral and within each category there is variation depending on flower shoot: pure or mix, terminal or lateral (Fig. 9.5)

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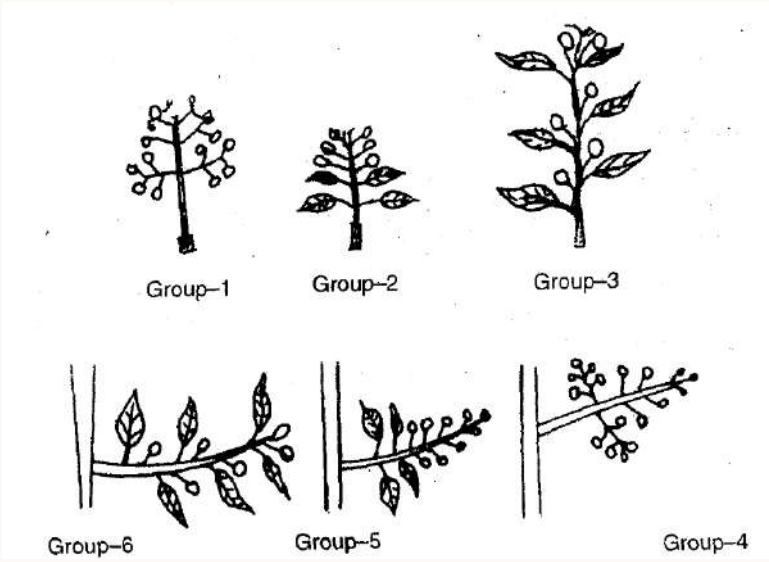

Fig. 9.5 **Flower bearing shoots**

Group—1 : Fruit buds borne terminally and unfold to produce inflorescence without leaves e.g. mango.

Group—2: Fruit buds borne terminally unfolding to produce leafy shoots hat terminate into flower clusters e.g. apple and unfolding to produce leafy shoot with flower cluster in the leaf axils e.g. fig, and avocado.

Group—3: Fruit buds borne terminally unfolding to produce leafy shoots with flowers or flower cluster in the axil of leaf e.g. Guava

Group—4: Fruit buds borne laterally unfolding to produce flowers without leafy parts e.g. citrus, coconut, papaya, coffee.

Group—5: Fruit buds borne laterally unfolding to produce leafy shoot terminating in flower clusters e.g. grapes.

Group—6: Fruit buds borne laterally

Group—7: Fruit buds borne both terminally and laterally but unfolding to produce inflorescence terminally e.g. walnut.

Group—8: Fruit buds always borne adventitiously in old trunk or shoots e.g. Jackfruit, cocos, Indian star goose berry.

Season of pruning

Generally pruning should be done in such a time that physiology of plant is disturbed to the minimum and it should not interfere with the principal function of the plant. Thus,

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(i) Fruit trees are pruned for fruiting when dormant i.e. late winter incase of temperate fruits and soon after harvest in evergreen if required. Sometimes the trees are subjected to stress to induce dormancy before pruning as in bahar treatment.

(ii) Pruning for structural adjustment is done when plant in making growth i.e. summer pruning.

Generally pruning is regularly done in temperate fruit crops like apple, pear, peach, plum, cherry, walnut, apricot, grape and subtropical crops like pomegranate, lemon, ber, guava.

Evergreens like mango, sapota, litchi are rarely pruned except thinning of branches to avoid over crowding and removal of deadwood. However, now this concept is under change.

Pruning Technique:

Basically there are two techniques which could be utilized individually or in combination depending on the need of the crop.

(i**) Heading back**: It is cutting back of terminal portion of a branch to a bud. This encourages spreading of growth, bushiness and compact plant. It is also called pinching.

(ii) **Thinning out**: It means complete removal of a branch to a lateral or main trunk. This makes the plant open, large tree or plant. Thinning out of growing wood is also called deshooting.

Table: 1 Pruning time and technique in important fruit crops

Sl. No.	Crop	Time	Technique
1	Apple	Late Winter	Light thinning coupled with heading back
2	Peach	Late winter (Dec-Jan)	A combination of thinning out and heading back
3	Plum	Late winter (Dec-Jan)	A combination of thinning out and heading back
4	Grape	Late winter (Jan.)	Heading back of cane

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	North India South India	Summer pruning (Aug.) Winter pruning (Sept-Oct)	Heading back to one or two buds which is almost thinning out Heading back to cane
5	Mango	After harvest	Thinning
6	Phalsa North India South India	Late winter early spring Dec-Jan	Heading back Heading back
7	Ber	Summer (April-May)	Heading back and thinning out of old branches

Other important considerations:

(I) Use good and sharp equipment

(ii) Cut should be small, smooth, and slanting so that water does not accumulate on cut end.

(iii) Large wounds should be treated with antifungal chemicals like Bordeaux paste.

(iv) Shoots from rootstock should be removed regularly.

(v) Removal of deadwood, parasites (loranthus), epiphytes (Ferns), climbing vines, and nests of bees, wasps, ants, termites should also become part of pruning.

Besides pruning and training plants can also be managed through biological and chemical methods.

(I) Biological control: In this method following techniques could be utilized.

(a) Use of rootstock: Use of dwarf, vigorous and semi vigorous rootstocks can alter plant size eg. MIX for dwarfing of apple, trifoliate for dwarfing of citrus.

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(b) Phloem disruption (Ringing) can be utilized for regulating flowering and fruiting.

(c) Hardening: By subjecting plants to low temperature, high heat or stress plant size can be altered.

(ii) Chemical control : There are a number of plant growth regulators like inhibitors, retardants, gibberellin, auxins and ethylene when applied to plant modify plant growth and development and they can also be utilized for managing plant, and its performance. Some of the useful responses are being mentioned below:

Rooting — Auxins enhance rooting e.g. IBA, NAA Bolting GA enhances while MH reduces bolting.

Modification of flower sex — Ethylene for the induction of femaleness and gibberellins for maleness

Flower induction — Auxin and ethylene in pineapple Cultar in mango have positive role, gibberellin may help delaying flowering. Fruit set — Auxins and gibberellins in seedless fruits have positive role.

Control of fruit drop: Auxins check fruit drop

Thinning — Auxins in higher concentration and phenols can be utilized to thin crop.

Regulation of ripening — Ethylene enhances whereas auxins, kinetin and gibberelins delay ripening.

Pinching — Methyl ester

Disbudding — NAA

Sprout control — NAA

Abscission — Enhanced by ethylene and check by gibberellins and auxins.

Storage disorder —prophenyl amine reduces storage disorders.

All these techniques individually or in combination can be utilized for the management of tree and its productive functions. However, they need to be utilized after proper testing for their concentration, timings, and combinations.

Top Working : It is a technique or method of rejuvenation where in the objective is to upgrade seedling plantations of inferior varieties with superior commercial cultivars or hybrids suitable for domestic or export

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market or the desired variety of the grower. The technique involves grafting with procured scions of desired variety on shoots emerged on pruned branches by adopting softwood grafting during monsoon season (Season of top working slightly varies from species as it also depends on availability of good shot and scions). The scion shoots and the emerged shoots should be of same thickness.

Advantages of top working:

1. Increase the tree productivity /orchard productivity
2. conversion of old and senile orchards into productive orhard
3. Conversion of seedling or inferior variety plantaion /orchard into new orhard with desirable variety or varieties through top working
4. Possibility of grafting several varieties on the same plant
5. Increasing the fruit set of orchard by grafting few shoots with polliniser varieties.
6. Additional income by selling the pruned wood during non bearing season or period

Disadvantages:

1. Chances of death of plant if not done properly or on severe pruning
2. Need good management post pruning periond
3. Loss of crop for 2-3 years
4, Chances of pest and disease occurrence (stem borer, anthracnose etc)
5. Needs skilled labour for thinning of shoots, removal of side shoots etc.

Top working technique can be successfully followed in crops like mango, sapota, aonla, cashew, guava, tamarind, jackfruit etc.

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Course Name	**Fundamentals of Horticulture**
Lesson 10	**Importance of Plant Bio-Regulators in Horticulture**
Content Creator Name	**Dr. Kirtimala Balaji Naik**
University/College Name	**University of Horticultural Science,Bagalkot**
Course Reviewer Name	**Jitendra Singh**
University/college Name	**Agriculture University Kota, Kota**

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Since 1930, PGRs have been a systematic use in different agriculture practices. Plant bio-regulators, both natural and synthetic affect growth and development processes in plants. Plant growth regulators refer to organic compounds other than nutrients which in small quantities promote, inhibit or otherwise modify any plant physiological process. Plant hormones refer to bio-regulators produced by the plant which usually move within the plant from the site of production to the site of action and regulate plant physiological process at very low concentration.

Uses

Propagation: Gibberellins are used for seed germination and substitution of chilling requirement.

Rooting of cuttings: 100-500 ppm IBA is very suitable for softwood cuttings
500-1500 ppm for semi hard wood
2000-5000 ppm for hard wood

Use in Tissue culture: In banana, low concentration of IAA and high level of BA is essential for rapid growth of explant.
In grapes, BA and NAA is essential for establishment of explants
IBA helps in rapid multiplication.

Breaking of seed and bud dormancy:

GA is used for accelerated seed germination in citrus, aonla, grapes, ber, Annona, apple, peach etc.
In pecanut, GA significantly reduces the period of seed stratification.
GA is sprayed for termination of rest period of buds in peach and apple
Dormax is used for substitution of chilling in Kiwi and pecan.

Control of Vigour:

SADH/ paclobutrazol is beneficial in reducing the growth of pear, peach, lemon, apple, litchi, apricot, plum and mango.
Ethrel treatment is beneficial in mango, grapes and avocado.

Flowering:

Ethylene is responsible for flowering in pineapple. – Acetylene, calcium carbide, ethephon and NAA (10-15 ppm) used to induce flowering in pineapple.

Soil application of paclobutrazol (cultar) @ 5 g per tree is effective in regulating fruiting in mango.

In litchi, NAA replaces girdling for improved flowering.

SADH promotes flowering in apple, pear, peach and blueberry.

Grapes and lemon respond to CCC with increased flowering.

Inhibition or delay of flowering:

In fruits like apple, pear, fig, grapes etc. GA application produces parthenocarpic fruits.

Cytokinin in grapes is used for parthenocarpic fruit set.

Application of GA increases fruit set in strawberry, peach, plum and cherry.

Fruit Thinning:

NAA application at post bloom is useful for thinning in apple.

DNOC (sodium 4, 6-dinitro-o-cresol) in stone fruits.

Pre-bloom application of GA provides optimum fruit set and loosens and provides attractive clusters in grapes.

Fruit growth and maturity:

Post bloom application of CPPU, a derivative of cytokinins is used to increase the berry size in kiwi.

Prevention of Fruit drop:

NAA, 2,4-D and 2.4.5-T is used for controlling fruit drop in mango and citrus.

Harvesting: Ethrel sprays induces early harvesting in walnut, pecan, olive, cherry and grapes.

Improvement of fruit quality:

GA_3 is used for loosening clusters, decrease fruit set, reducing number of berries per cluster and increasing size of remaining berries and improvement of berry size in grapes.

GA_3 (50-100 ppm), NAA (25-50 ppm). – Dipping bunches in GA_3 (75 ppm) for 10 seconds is useful for size improvement in grapes.

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Fruit Ripening:

Ethrel application is useful for apple for uniform ripening and early fruit maturity.

Ethephon in citrus prior to storing ensures postharvest degreening.

In lemons, dipping in 1000 ppm ethephon is useful for attachment of marketable yellow colour.

For ripening of banana, mango ethrel is useful.

Course Name	**Fundamentals of Horticulture**
Lesson 11	**Irrigation and Fertilizer Application in Horticultural Crops**
Content Creator Name	**Dr. Kirtimala Balaji Naik**
University/College Name	**University of Horticultural Science,Bagalkot**
Course Reviewer Name	**Jitendra Singh**
University/college Name	**Agriculture University Kota, Kota**

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Irrigation

Irrigation is defined as the artificial application of water to the soil in order to ensure an adequate supply of water to the plants. In crop production it is mainly used to replace missing rainfall in periods of drought, but also to protect plants against frost. Additionally irrigation helps to suppress weed growing in rice fields. In contrast, agriculture that relies only on direct rainfall is sometimes referred to as dryland farming or as rain fed farming.

Irrigation is an ancient practice, with archaeological evidence of irrigation in Mesopotamia and Egypt as far back as the 6th millennium BC.

Various types of irrigation techniques differ in how the water obtained from the source is distributed within the field. In general, the goal is to supply the entire field uniformly with water, so that each plant has the amount of water it needs, neither too much nor too little.

Surface irrigation

In surface irrigation systems water moves over and across the land by simple gravity flow in order to wet it and to infiltrate into the soil. Surface irrigation can be subdivided into furrow, borderstrip or basin irrigation. It is often called flood irrigation when the irrigation results in flooding or near flooding of the cultivated land. Historically, this has been the most common method of irrigating agricultural land. Where water levels from the irrigation source permit, the levels are controlled by dikes, usually plugged by soil. This is often seen in terraced rice fields (rice paddies), where the method is used to flood or control the level of water in each distinct field. In some cases, the water is pumped, or lifted by human or animal power to the level of the land.

Localized irrigation

Localized irrigation is a system where water is distributed under low pressure through a piped network, in a pre-determined pattern, and applied as a small discharge to each plant or adjacent to it. Drip irrigation, spray or micro-sprinkler irrigation and bubbler irrigation belong to this category of irrigation methods.

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Drip or trickle irrigation

Water is delivered at or near the root zone of plants, drop by drop. This type of system can be the most water-efficient method of irrigation, if managed properly, since evaporation and runoff are minimized. In modern agriculture, drip irrigation is often combined with plastic mulch, further reducing evaporation, and is also the means of delivery of fertilizer. The process is known as fertigation.

Deep percolation, where water moves below the root zone, can occur if a drip system is operated for too long of a duration or if the delivery rate is too high. Drip irrigation methods range from very high-tech and computerized to low-tech and relatively labor-intensive. Lower water pressures are usually needed than for most other types of systems, with the exception of low energy Centre pivot systems and surface irrigation systems, and the system can be designed for uniformity throughout a field or for precise water delivery to individual plants in a landscape containing a mix of plant species. Although it is difficult to regulate pressure on steep slopes, pressure compensating emitters are available, so the field does not have to be level. High-tech solutions involve precisely calibrated emitters located along lines of tubing that extend from a computerized set of valves. Both pressure regulation and filtration to remove particles are important. The tubes are usually black (or buried under soil or mulch) to prevent the growth of algae and to protect the polyethylene from degradation due to ultraviolet light. But drip irrigation can also be as low-tech as a porous clay vessel sunk into the soil and occasionally filled from a hose or bucket. Subsurface drip irrigation has been used successfully on lawns, but it is more expensive than a more traditional sprinkler system. Surface drip systems are not cost-effective (or aesthetically pleasing) for lawns and golf courses. In the past one of the main disadvantages of the subsurface drip irrigation (SDI) systems, when used for turf, was the fact of having to install the plastic lines very close to each other in the ground, therefore disrupting the turfgrass area.

Sprinkler irrigation

In sprinkler or overhead irrigation, water is piped to one or more central locations within the field and distributed by overhead high-pressure sprinklers or guns. A system utilizing sprinklers, sprays, or guns mounted overhead on permanently installed risers is often referred to as a *solid-set* irrigation system. Higher pressure sprinklers that rotate are called *rotors* and are driven by a ball drive, gear drive, or impact mechanism. Rotors can be designed to rotate in a full or partial circle. Guns are similar to rotors, except that they generally operate at very high pressures of 40 to 130 lbf/in² (275 to 900 kPa) and flows of 50 to 1200 US gal/min (3 to 76 L/s), usually with nozzle diameters in the range of 0.5 to 1.9 inches (10 to 50 mm). Guns are used not only for irrigation, but also for industrial applications such as dust suppression and logging.

Centre pivot irrigation

Centre pivot irrigation is a form of sprinkler irrigation consisting of several segments of pipe (usually galvanized steel or aluminum) joined together and supported by trusses, mounted on wheeled towers with sprinklers positioned along its length. The system moves in a circular pattern and is fed with water from the pivot point at the centre of the arc. These systems are common in parts of the United States where terrain is flat.

Centre pivot with drop sprinklers. Most Centre pivot systems now have drops hanging from a u-shaped pipe called a *gooseneck* attached at the top of the pipe with sprinkler heads that are positioned a few feet (at most) above the crop, thus limiting evaporative losses. Drops can also be used with drag hoses or bubbler's that deposit the water directly on the ground between crops. The crops are planted in a circle to conform to the centre pivot. This type of system is known as LEPA (Low Energy Precision Application). Originally, most centre pivots were water powered. Most systems today are driven by an electric motor mounted low on each span. This drives a reduction gearbox and transverse driveshafts transmit power to another reduction gearbox mounted behind each wheel. Precision controls, some with GPS location and remote computer monitoring, are now available.

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Lateral move (side roll, wheel line) irrigation

A series of pipes, each with a wheel of about 1.5 m diameter permanently affixed to its midpoint and sprinklers along its length, are coupled together at one edge of a field. Water is supplied at one end using a large hose. After sufficient water has been applied, the hose is removed and the remaining assembly rotated either by hand or with a purpose-built mechanism, so that the sprinklers move 10 m across the field. The hose is reconnected. The process is repeated until the opposite edge of the field is reached. This system is less expensive to install than a Centre pivot, but much more labor intensive to operate, and it is limited in the amount of water it can carry. Most systems utilize 4 or 5 inch diameter aluminum pipe. One feature of a lateral move system is that it consists of sections that can be easily disconnected. They are most often used for small or oddly-shaped fields, such as those found in hilly or mountainous regions, or in regions where labor is inexpensive.

Sub-irrigation

Sub-irrigation also sometimes called *seepage irrigation* has been used for many years in field crops in areas with high water tables. It is a method of artificially raising the water table to allow the soil to be moistened from below the plants' root zone. Often those systems are located on permanent grasslands in lowlands or river valleys and combined with drainage infrastructure. A system of pumping stations, canals, weirs and gates allows it to increase or decrease the water level in a network of ditches and the control the water table thereby.

Sub-irrigation is also used in commercial greenhouse production, usually for potted plants. Water is delivered from below, absorbed upwards, and the excess collected for recycling. Typically, a solution of water and nutrients floods a container or flows through a trough for a short period of time, 10–20 minutes, and is then pumped back into a holding tank for reuse. Sub-irrigation in greenhouses requires fairly sophisticated, expensive equipment and management. Advantages are water and nutrient conservation, and

labor-saving through lowered system maintenance and automation. It is similar in principle and action to subsurface drip irrigation.

Manual irrigation using buckets or watering cans

These systems have low requirements for infrastructure and technical equipment but need high labor inputs. Irrigation using watering cans is to be found for example in peri-urban agriculture around large.

Methods of fertilizer application

Broadcasting:

- Fertilizer in solid state or granular or dust are spread uniformly over the entire field.
- Leaching loss may be more

Disadvantages.

- Some of the elements like phosphorous and potash do not readily move in the soil therefore surface application may not be available to the trees especially in drier tracks.
- Leads to accumulation of potassium in surface soil beyond determental levels causing injury to plants
- Surface application always stimulates weed growth.

Band placement:

- Application of fertilizer on the sides of rows.
- Fertilizer in solid and liquid forms can be applied
- Quantity of fertilizer may be economised.

Ring placement

- Commonly followed in fruit trees.

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- Fertilizers are applied in a ring encircling the trunk of the trees extending the entire canopy.
- It is more labour intensive and costly.

Foliar application

- Fertilizers are applied in liquid form as foliar sprays.
- They are easily absorbed by leaves.
- Fertilizers are applied in a very low concentration tolerable to the leaves.
- Recommended when the nutrients are required in small quantity.

Starter solution

- Liquid form of fertilizer application.
- Seedlings and propagules are kept emerged upto their root system for varying durartion in starter solution.
- The starter solution is prepared either by dissolving high analysis fertilizer mixture at a concentration not exceeding 1%.

Fertigation

- Application of fertilizers in irrigation water in either open or closed systems.
- Nitrogen and sulphur are the principal nutrients applied.
- Phosphorous fertigation is less common because of formation of precipitates takes place with high Ca and Mg containing water.

Advantages

- Nutrients especially nitrogen can be applied in several split doses at the time of greatest need of the plant.
- Nutrient is mixed with water and applied directly near the root zone, as such higher use efficiency.

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- Cost on labour is saved.

  Best results of fertigation are noticed when the fertilizer is applied towards the middle of the irrigation period and applied towards the middle of the irrigation period and their application terminated shortly before completion of irrigation. Use of soluble fertilizer improves use efficiency.

  Note: The grower must consider the economics and advantages before deciding for using fertigation.

  Fertigation is used extensively in

  Cut flower production in green houses,

  Fruit crops – Grapes, Papaya, Banana and Pomegranate.

  Vegetables- Tomatoes and Capscicum under poly/green houses

Tree injection

- Direct injection of essential nutrients into the tree trunk.
- Iron salts are injected into chlorotic trees that are known to suffer from iron deficiency.

Feeding needles

- Several types of feeding needles or guns are available.
- With these, fertilizers, either in dry form or in water solution, are placed in holes.

Factors favouring nutrients absorption and transport

- High humidity, proper temperature and incident radiation.
- Good CHO supply and vigorous growth
- Chemical and physical properties of nutrient spray solution.
- Leaf characters like leaf thickness, hairyness,wax coating on the leaf.
- Generally more vigorous plant and young growing leaves have good capacity to absorb nutrients.
- Nitrogen- applied in the form of urea (1%) is readily absorbed.
- Sodium and potassium (Kcl) - readily absorbed by leaves and they are among most highly mobile.

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Note:

- Foliar application proves to be most effective where problems of nutrient fixation in soil exits. So far the most important use of foliar sprays are been in application of micronutrients.
- Foliar sprays should be applied either with pressure sprayer or with specially designed spray guns. The trees should be sprayed until the nutrient solution begins to drip from the leaves.
- Foliar application of urea has been found effective in many fruit crops like citrus, guava ,apple, etc
- Potassium spray (3-5g/lt)- Papaya, Pineapple, Citrus, Guava.

Precaution:

While applying foliar sprays care should be taken to ensure correct concentration of spray solution.
Apply in morning or evening hours on a clear sky day.

Fertilizer application in horticultural crops.

Fertilisers are necessary for most of the horticultural crop production systems. Plants require differing amounts of nutrients at differing phases of their growth cycles. The nutrients in soil may not be always available in adequate amounts for economical crop production. In todays horticulture additional nutrients play a major role in meeting the crop yield and quality. With regards to environmental issues, becomes necessary to maximize the benefits of fertiliser use and minimize the negative impacts associated with its pver or under use.

Different methods of fertilizer application are as follows:

1. Broadcasting method: It refers to the spreading of fertilizers in an uniform manner over the field. In this method large doses of fertilizers are applied and use of insoluble fertilizers like rock phosphate is done.
Broadcasting is of two types:

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i) Also known as basal application. It is done at the time of sowing or planting. It is mainly done for uniform distribution of fertilizers over the entire field and to let it mix well in the soil.

ii) Top dressing: It refers to the broadcasting of fertilizers particularly nitrogenous fertilizers in closely sown crops like paddy and wheat, with the objective of supplying nitrogen in readily available form to growing plants.

Disadvantages of broadcasting:

i) As the roots of plants grow they move over a long distance laterally as a result the nutrients are not fully utilized by plant.

ii) Weeds grow all over the field as nutrients are scattered.

iii) If the fertilizer comes in contact with large mass of soil the nutrients get fixed in the soil.

2. Placement method

1. When the fertilizers are placed in soil at a specific place it is referred as placement method.
2. It is very helpful to apply phosphatic and potassic fertilizers.

There are two methods of placement:

i) Plough sole placement

1. Fertilizer is placed in a continuous band at the bottom of the plough furrow during the process of ploughing.
2. Every band is covered as the next furrow is turned.
3. Very useful in clayey soils, where we get dry soil below the soil surface

ii) Deep placement

This method ensures better distribution of fertilizer in the root zone soil and prevents loss of nutrients by run-off.

By this method better distribution of fertilizer in the root zone of soil is possible which prevents loss of nutrients by run-off. This method ensures better distribution of fertilizers in the root zone soil and prevents loss of nutrients by run-off especially ammonical Nitrogen.

iii) Localized placement

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When the fertilizers are applied close to the seed or plant in the soil in order to supply the nutrients in adequate amounts to the roots of growing plants.

Methods followed to place fertilizers close to the seed or plant are :

a) Drilling

When seed-cum-fertilizer drill is used to apply fertilizers at the time of sowing its is referred to as drill method of fertilizer application. This places fertilizer and the seed in the same row but at different depths. Widely followed for the application of phosphatic and potassic fertilizers in cereal crops, but the drawback of this method is that, sometimes germination of seeds and young plants may get damaged due to higher concentration of soluble salts.

b) Side dressing

When the fertilizers are spread in between the rows and around the plants it is known as side dressing. The common methods of side-dressing are. Placement of nitrogenous fertilizers by hand in between the rows of crops like maize, sugarcane, cotton etc., to apply additional doses of nitrogen to the growing crops and placement of fertilizers around the trees like mango, apple, grapes, papaya etc.

c) Band placement: When the fertilizers are placed in the band it is known as band placement.

Band placement is of two types.

i) Hill placement

It is practised for the application of fertilizers in orchards. In this method, fertilizers are placed close to the plant in bands on one or both sides of the plant. The length and depth of the band varies with the nature of the crop.

ii) Row placement

When the crops like potato, maize, cereals etc., are grown close together in rows, the fertilizer is applied in continuous bands on one or both sides of the row, which is known as row placement.

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d) Pellet application

1. It refers to the placement of nitrogenous fertilizer in the form of pellets 2.5 to 5 cm deep between the rows of the paddy crop.
2. The fertilizer is mixed with the soil in the ratio of 1:10 and made small pellets of convenient size to deposit in the mud of paddy fields.

Advantages of placement of fertilizers

The main advantages are as follows:

i) When the fertilizer is placed, there is minimum contact between the soil and the fertilizer and thus fixation of nutrients is greatly reduced.
ii) The weeds all over the field cannot make use of the fertilizers.
iii) Residual response of fertilizers is usually higher.
iv) Utilization of fertilizers by the plants is higher.
v) Loss of nitrogen by leaching is reduced.
vi) Being immobile, phosphates are better utilized when placed.

The common methods of applying liquid fertilizers are:

a) Starter solutions

It refers to the application of solution of N, P_2O_5 and K_2O in the ratio of 1:2:1 and 1:1:2 to young plants at the time of transplanting, particularly for vegetables. Starter solution helps in rapid establishment and quick growth of seedlings. The disadvantage of starter solution is
(i)Extra labour is required, and
(ii) the fixation of phosphate is higher.

b) Foliar application

1. It refers to the spraying of fertilizer solutions containing one or more nutrients on the foliage of growing plants.
2. Several nutrient elements are readily absorbed by leaves when they are dissolved in water and sprayed on them.
3. The concentration of the spray solution has to be controlled otherwise serious damage may result due to scorching of the leaves.

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4. Foliar application is effective for the application of minor nutrients like iron, copper, boron, zinc and manganese. Sometimes insecticides are also applied along with fertilizers.

c) Application through irrigation water (Fertigation)

1. It refers to the application of water soluble fertilizers through irrigation water.
2. The nutrients are thus carried into the soil in solution.
3. Generally nitrogenous fertilizers are applied through irrigation water.

d) Injection into soil

1. Liquid fertilizers for injection into the soil may be of either pressure or non-pressure types.
2. Non-pressure solutions may be applied either on the surface or in furrows without appreciable loss of plant nutrients under most conditions.
3. Anhydrous ammonia must be placed in narrow furrows at a depth of 12-15 cm and covered immediately to prevent loss of ammonia.

e) Aerial application

In areas where ground application is not practicable, the fertilizer solutions are applied by aircraft particularly in hilly areas, in forest lands, in grass lands etc.

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