Fundamentals of Horticulture

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Lecture 1: DEFINITION, DIVISION OF HORTICULTURE

The term **Horticulture** is derived from two Latin words i.e. **Hortus** meaning garden or enclosure and **Cultra** meaning cultivation. So, horticulture literally means garden culture or culture of garden. Modern horticulture may be defined as a part of agricultural science, which deals with the production, utilization, and improvement of fruits, vegetables, flowers, ornamentals, plantation crops, medicinal and aromatic plants etc.

DIVISIONS OF HORTICULTURE

Horticulture crops include fruits, Vegetables, flowers, plantation crops, Spices, condiments, Medicinal and Aromatic crops etc. In addition to these, Horticulture also deals with raising of trees for shade, ornamental and avenue purposes, planning and raising of ornamental gardens, parks and raising of seed and planting material. Further, horticulture also deals with the utilization of horticulture produce and improvement of horticulture crops.

Hence, based upon the crops dealt and also their purpose and utilization, the branch of horticulture is sub-divided in to the following divisions for convenience.

- **Pomology:**It is derived from two words i.e. Pomum meaning fruit and Logos meaning discourse or study. So, pomology is study or cultivation of fruit crops. E.g. Mango, Sapota, Guava, Grape, Banana etc.
- **Fruit:** It is a developed and matured ovary with or without accessory parts and which is generally eaten as raw.
- **Olericulture**: It is derived from two words ie. Oleris meaning Potherb and Cultra meaning cultivation. So, Olericulture literally means potherb cultivation. In the present days it is broadly used to indicate the cultivation of vegetables. Eg. Brinjal, Okra, Tomato, Pumpkin etc.
- **Vegetable**: It is any part of the herbaceous plant that is generally used after cooking as a principal part of the meal.
- **Floriculture:** It is derived from two words i.e. Florus meaning flower and Cultra meaning cultivation. So floriculture means study of flower crops.
  In this there are again two sub-divisions. (1) Commercial Floriculture (2) Ornamental Floriculture.
  Commercial floriculture:Deals with the cultivation of flower crops grown on commercial scale for profit (Income). E.g.: Rose, Jasmine, Carnation, Aster, and Marigold etc.
  Ornamental floriculture:It deals with the raising of flower crops for ornamental, pleasure and fashion purposes. E.g.: Dahlia, Zinnia, Cosmos, Hibiscus, Balsam, Nerium, Poinsettia, Hollyhock, Gerbera, and Gaillardia etc.
- **Arboriculture:** This branch deals with the raising of perennial trees meant for shade, avenue or ornamental purposes. Eg.Polyalthia, Spathodea, Cassia, Gulmohar etc.

- **Plantation crops**: Are those crops, which are cultivated in an extensive scale in large contiguous areas, owned and managed by an individual or a company and whose produce is utilized only after processing.Eg. Coffee, Tea, Rubber, Coconut, Cocoa etc.
- **Spices and condiments:** This branch deals with the cultivation of crops whose produce is used mainly for seasoning and flavouring dishes.

  Spices:Are those plants the products of which are made use of as food adjuncts to add aroma and flavour. Eg. Pepper, Cardamom, Clove, Cinnamon, All spice etc.

  Condiments:Are those plants the products of which are made use of as food adjuncts to add taste only. Eg.Turmeric,Ginger,Red chillies,Onion,Garlic etc.

  Both spices and condiments contain essential oils, which provide aroma, flavour and taste and they are of little nutritive value.
- **Medicinal and aromatic plants**: It deals with the cultivation of medicinal plants, which provide drugs and aromatic crops which yields aromatic (essential) oils.
- ***Medicinal plants***- are those plants, which are rich in secondary metabolites and are potential sources of drugs. The secondary metabolites include alkaloids, glycosides, coumarins, flavonoides and steroids etc.

  Eg. Periwinkle, Opium, Menthi, Cinchona, Dioscorea Yam, Belladona, Senna, Sarpagandha, Aswagandha, Tulasi etc.
- ***Aromatic plants-*** are those plants, which possesses essential oils in them. The essential oils are the odoriferous steam volatile constituents of aromatic plants. Eg. Lemon grass, Citronella, Palmrosa, Vetiver, Geranium, Davanam, Lavendor etc.

Lecture 2: IMPORTANCE AND SCOPE OF HORTICULTURE

The horticulture sector contributes about 30.4 per cent of the agriculture GDP, besides providing employment for 19 per cent of the labour force. The demand for horticulture produce is expected to increase owing to increasing urbanization, income-lead higher standard of living, enhanced awareness of nutrition security and family welfare programmes.

A. IMPORTANCE OF HORTICULTURAL CROPS IN HUMAN NUTRITION

From human nutrition point of view horticulture is most important to our daily living. Many of the horticulture crops and their products find place in our meals and diet. Human body requires vitamins, minerals, proteins, energy etc. for its health. All these are supplied by horticultural crops. Fruits and vegetables are the chief sources of vitamins, minerals, carbohydrates, fats, proteins etc. Fruits and vegetables are recognized as protective foods as they are necessary for the maintenance of human health.

The Role of Horticulture in Alleviating Nutritional Deficiencies in the Developing World

Malnutrition is the condition that occurs when your body does not get enough nutrients.

Fruits: The Simple Solution

Vitamins: These are the important constituents of fruits and are indispensable part of human diet. Although required in very minute quantities, they are absolutely essential for the maintenance of health. The deficiency of any vitamin from the diet for considerable period may lead to diseased state or disorder conditions. Fruits supply several vitamins

- **Vitamin-A:** Sources-Mango, Papaya, Dates, Jackfruit, Walnut etc.
- **Vitamin B1 (Thiamine):**. Sources - Orange, pineapple, jack fruit, cashew nut, walnut, dry apricot, almond, banana etc,.
- **Vitamin B2 (Riboflavin):** Sources **-** Bael, papaya, litchi, banana, apricot, pomegranate, pear etc.
- **Vitamin -C (Ascorbic Acid):** Sources - Amla, guava, ber, citrus, strawberry, pineapple etc.
- **Calcium:** Sources **-** Acid lime, Orange, Fig, Dried apricots, wood apple etc.
- **Iron:** Sources **-** Custard apple, Guava, Pineapple, Straw berry, Grape, Black currents, dried dates etc.
- **Phosphorous:** Sources - Guava, Grape, Jackfruit, Passion fruit, Orange
- **Proteins:** Sources: Fruits- Guava and Banana. Nut fruits like Walnut, Cashew nut and almond etc supplies proteins besides energy.
- **Enzymes:** Sources: Papaya-Papain and Pineapple-Bromelin.

B. COMPARISON OF HORTICULTURE WITH OTHER AGRICULTURAL SECTORS

1. Per Unit Area Yield is High: As compared to the field crops per hectare yield of horticulture crops is very high. From an fruit area of land more yield is obtained e.g. paddy gives a maximum yield of only 30 q/ha, while Banana gives 300 to 500 q/ha, Pine apple 450 q/ha and Grapes 90 - 150 q/ha. In present shortage of food and scarcity of land by growing fruits more food can be produced.

2. High Returns per Unit Area: From one unit area of land more income will be obtained e.g. Well kept orchard of apple, grapes and sweet orange can give as much as Rs. 25,0000 per ha as net income.

3. A Free Grower/Labour Remains Engaged for the Whole: An opportunity for maintaining labours throughout the year like the cereals where one cannot keep himself and employ the labours during the slack season.

4. Best Utilization of Waste Land:

Some fruit crops can offer best utilization of waste land crops like wood apple, custard apple, karonda, litchi etc. can be grown in such areas.

5. Food energy: To meet the annual calories requirements of food per year one would have to cultivate about 0.44 ha of wheat or 0.03 ha of banana or 0.06 ha of mango for satisfying once need. Thus mango produces about 9 times more food energy than the wheat produced per unit area.

6. Raw Material for Industries: Fruit farming is the base for several industries like canning, essential oils etc which in turn provide work for more people.

7. Use of Undulating Lands: Fruit growing can be practiced in places where the gradient is uneven or where the land is undulating and agronomical crops cannot be cultivated. In Konkan region, mango and cashew are cultivated on large scales on hilly and hill back area.

C. **HORTICULTURE IS ALSO IMPORTANT FOR 3 REASONS**

- Economic
- Aesthetic
- Environment

a. Economic Importance

Horticulture puts over billions of rupees in a year into the Indian economy by

- Providing jobs.
- Producing food.
- Fruits.
- Vegetables.
- Nuts.
- Increasing home value through landscaping

b. Aesthetic Importance

- Aesthetic = Appearance
- Improves appearance of homes & buildings through landscaping.
- Improves appearance of land from fruit, vegetable, and ornamental crops grown

c. Environmental Appearance

- Provides health & comfort by
- Cleaning the air.
- Preventing erosion.

- Providing shade.
- Providing nutrition.

SCOPE OF HORTICULTURE

Like any other things, 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.

1. Incentive for the farmer:

- The biggest incentive for the farmer is money.
- Horticultural crops provide more returns in terms of per unit area of production, export value, value addition compared to agricultural crops.

2. Adaptability:

- 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 we have soils from loam, alluvial, laterite, medium black, rocky shallow, heavy black, sandy etc., and thus a large number of crops can be accommodated with very high level of adaptability. Thus, there is lot of scope for horticultural crops.

3. Necessity:

- After having achieved the self sufficiency in food, nutritional security for the people of the country has become the point of consideration/priority.
- To meet the nutritional requirement in terms of vitamins and minerals horticulture crops are to be grown in sufficient quantities to provide a bare minimum of 85 g of fruits and 200 g of vegetables per head per day with a population of above 120 crores.
- 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 percent of total trade. Moreover, these commodities (spices, coffee, tea etc.,) 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.

4. Export value:

- Among fresh fruits-mangoes and grapes; in vegetables- onion and potato; among flowers, roses; among plantation - cashewnut, tea , coffee, coconut, arecanut, and spice crops like black pepper, cardamom, ginger, turmeric, chillies, etc., constitute the bulk of the export basket.
- European and gulf countries are major importer of horticultural produce

- In the recent past communication and transport system have improved, investment in food industry has increased which will support growth of horticulture through quick deliverance and avoidance of waste.

LECTURE|: 3 HORTICULTURAL AND BOTANICAL CLASSIFICATION

From time to time, horticultural crops have been classified into various groups depending on their growth habits, cultivation requirements, climatic needs and uses. Horticultural crops are popularly classified into the 5 broad divisions of fruits, vegetables and flowers, plantation crops, aromatic and medicinal plants. The classification of horticultural crops are as follows-

1. Classification of Horticultural Crops Based on Growth Habit and Physiological Character

Herbs: Ageratum, Lawn Grasses.

Shrubs: Nerium, Hibiscus,

Trees: Mango, Tamarind, Rain tree

Climbers: Bougainvillea

Creepers: Bignonia, gracillis.

2. Classification of Horticultural Crop Based on Life Span of Plants

I) Annuals:

From the name it is clear that the plants live for one season or less. Annual plant is one which completed its life cycle from germination to seed formation within one season and then dies usually as a result of complete exhaustion of its food reserve in the process of reproduction. Mostly they complete their life history in 3 to 6 months. They comprise of several of most beautiful and easily grown plants, widely varying in from habit of growth and colour. Annuals are very effective, grown neither in pots nor in ground. Particular annuals thrive best in particular period of the year. The annuals are conveniently grouped according to season as follows.

1. Rainy Season Annuals:

They can stand more in rain than others and therefore grown to flower during rainy season. The time of sowing then would be from April to May in most places e.g. Mary gold, Aster, Salvia, Zinnia etc.

2. Winter or Cold Season Annuals:

They thrive and bloom best during winter. These are sown in September, October e.g. phlox, Antirrithium.

3. Hot weather or summer season Annuals:

They are sown in January - February and blooming period is April, May e.g. Sunflower, Gailardia, and Zinnia.

II) Biennials:

These plants usually requires two years or at least two growing seasons with more or less of a dormant season or lasting season between two completed life cycle. Seed sown in spring or summer, and vegetative growth is completed in first year and in the following spring, flowering and fruiting takes place. Generally the period of growth is 6 to 9 months e.g. Gladioli, Dahlia. No hard and fast line can be drawn between annuals and biennials crops like turnip, carrot, cabbage and onion are classified as biennials.

III) Perennials:

Any plant that lives more than two years is a perennial e.g. Mango, Citrus. These crops are classified in to two groups.

i) Herbaceous:

Herbaceous perennials are those with more or less soft succulent stems. In Temperate climates the tips die off after seasonal growth but root remains alive and produce new stem and tops on favorable conditions. In other words their tips are annual while ground parts are perennials lie many years and are classified as: a) Trees b) Shrubs c) Vines according to their habit of growth.

a) Trees:

Trees are upright in habit and stems take the form of central axis e.g. Mango, Sapota, guava, Mandarins etc.

b) Shrubs:

Shrubs have no main trunk but a number of erect or semi erect stems are seen but do not forms the main frame work e.g. Hibiscus, Rose, and Lantana Acalyphya etc.

c) Vine:

Both woody and herbaceous have stems which are flexible and not in position to keep their branches and leaves erect. They either spread on the ground or require some support whether alive or man made e.g. cucurbit vines, Grape vines, Passion fruit etc.

3. Classification of Horticultural Crops Based on Whether they shed Leaves during a Portion of Year

i) Deciduous: Fig., Guava, Apple, Ber, Sweet cherry, Pomegranate, Grape, Mulberry, Phalsa, Almond

ii) Evergreen: Aracanut, Dates, Coconut, Pineapple, Banana, Jackfruit, Avocado, Sweet orange, Mandarin orange, K. lime, Mango, Chicku, Papaya, Passion fruit, Cashew nut

4. Classification of Horticultural Crops Based on Climatic Requirements (Particularly Temperature)

Based on temperature requirements and response to different climatic conditions, horticultural crops have been classified in to three main groups and these are :

i) Temperate:

Temperate plants are commonly found in cold regions enjoying a mild and temperate climate. These plants endure cold and go to rest or dormancy by shedding of all their leaves during winter e.g. Apple, Plums cherry and almond etc.

ii) Tropical:

Tropical plants are those which do not tolerate severe cold but can tolerate warm temperatures of about 1000F. Those plants need strong sunshine, warms, humidity and a very mild winter. They cannot stand far against frost e.g. Papaya, Banana and Pineapple.

iii) Sub - Tropical:

Sub - tropical plants like Orange, Litchi, Fig, Mango and cashewnunt are intermediate in character. They need warmth and humidity and can tolerate mild winters.

The above classification, based on climatic preference of plants, is more or less arbitrary and no sharp line can be drawn between these several groups. It however, indicates the broad difference in climatic needs of various plants. This does not necessarily mean that a plant belonging to one zone does not grow in other zones. For instances, annual crops of the temperate region like potato, knolknol and cabbage grow in tropical and sub - tropical regions also, but they come up well only in the winter season than other climatic zones.

5. Classification of Horticultural Crops Based on Season

Horticultural crops are also classified according to the season in which they grow best. In our country we have three main season.

i) The Summer season, which starts from March and lasts upto May.

ii) The rainy season from June to October and

iii) The winter season from November to February.

Rainy season crops are known as "Kharif" crops. These crops come up best when sown with the onset of monsoon in May, June. Vegetables like Snake gourd, Lady's finger, Chilies and Beans comes under the category.

Lupines are known as "Rabi crops". They are generally sown October, November.

Only a few annual crops thrive in the warm summer months between March and June in the plains. Leafy vegetables, cluster beans, Brinjal, Cucumber, and Gourds are the common summer vegetables. The popular summer season Sunflowers, Cooks comb, Rose, Zinnia etc. There are some vegetables like tomato, brinjal, beans and flowers like which grow all the year count, but they come up best when there is optimum season.

The yield of a crop is also dependent upon the time of sowing. Crops which are sown under rain fed conditions are entirely dependent on rain fed conditions for their survival and growth and therefore, have to be sown just at the right time. Any delay in sowing causes great harm to rain fed crops. Even crops like sunhemp yield their best when sown in a particular optimum season and give even half the normal yield if sown in the strong season

6. Classification of Horticultural Crops based on Use of Horticultural Plants:

Vegetable:

a) Vegetables Grown for Aerial Portion:

1. Cole Crops: Cabbage, cauliflower
2. Legume Crops: Peas and Beans
3. Solanaceous Crops: Tomato Brinjal
4. Cucurbits: Cucumber, Red Pumpkin
5. Leafy Vegetables: Spinach, Methi
6. Salad Vegetables: Lettuce, Brocoli
7. Corn Vegetables: Sweet corn and Popcorn

b) Vegetable Grown for Underground Portion:

1. Root Crops: Beet. Carrot
2. Tuber Crops: Yam, potato.
3. Bulb Crops: Onion and Garlic

ii) Fruits

a) Temperate (Deciduous fruits):

1. Small Fruits: Grape, Strawberry
2. Tree Fruits: Apple, pear, Cherry
3. Nuts: Peach, Walnut

b) Tropical and Sub Tropical:

1. Herbaceous Perennials: Pineapple, Banana
2. Tree Fruits: Mango, Papaya
3. Nuts: Cashewnunt, Aracanut

II) Ornamental Plants

1. Flowering Trees: Gulmohar, Neelmobor, Cassua
2. Road Side Trees: Neem, Baniyan tree, Rain tree
3. Shade Giving Trees: Rain tree, Mahogany
4. Flowering Shrubs: Nerium, Hibiscus, Tagar
5. Foliage Shrubs: Thuja, Casurina
6. Climbers and Creepers: Petrea, Bignonia, Ipomea

7. Bulbous Plants: Canna, Caladium, Tuberose

8. Hedge and Edges: Duranta, Clearadendron, Ageratum

9. Annuals: Pitunia, Ainnia.

10. Perennials: Chrysanthemum, Roses.

CLASSIFICATION OF FRUITS

Classification is the system of grouping or placing of individuals according to nomenclature. It is very useful to the pomologist. It helps to:

- To identify and naming the crop.
- To study the close relationship.
- To know their hybrids and crossing behaviour.
- To know their compatibility & inter grafting ability.
- To know their adoptability to soil & climate.

POMOLOGY: Pomology is a branch of horticulture which deals with study of various aspects of fruits loke, rising of saplings, growing them properly and providing various intercultural operations.

- The term pomology is a combination of two Latin words **„Pome"** means **_Fruits"** and _Logos' means **_study"**.
- **"Poma"** in Greek also meaning *fruits* later subsequently **"Pome"** in Latin word means *fruits, logos*-study.
- **Basic Pomology:** Study of basic aspects of fruit production like training, water management, use of PGR's.
- **Commercial Pomology:** It is concerned with commercial production of fruits.
- **Systematic Pomology:** It may be concerned with classification and nomenclature like kingdom, order, class, genus and species.

A. Classification of fruits based on climate adaptability.

In this classification, the fruits trees are categorized into three recognized groups.

i. Temperate fruits:

- Temperate fruit plants are exacting in their climate requirement.
- They are grown only in place where winter is distinctly cold, require as exposure of specific chilling temperature for certain period without which they do not flower.

 These fruit plants are generally deciduous and stand frost. Eg. Apple, almond, peach, pear, plum, strawberry, apricot, persimmon, cherymoya, walnut, peanut, hassle nut, cherry, pistachios and kiwifruits etc.

ii. Tropical fruits:

 Tropical fruit plants are generally evergreen and are extremely sensitive to cold.

 They do well under lesser fluctuations of diurnal temperature, light and dark periods they require a moist warm climate but are capable of withstanding dry weather in some cases Eg; mango, banana, papaya, sapota, etc.,

iii. Sub-tropical fruits:

 The fruit crops grown under a climatic condition between temperate and the tropical are known as subtropical fruit crops.

 They may be either deciduous or evergreen and are usually able to withstand a low temperature but not the frost.

 They are also quite adoptive to fluctuations of light and dark period during day and night.

 Some subtropical fruit plants require chilling for flower bud differentiation.

 Example; grape, citrus, durian, jackfruit, etc.,

B. Classification based on bearing habit: On the basis of bearing habit, fruit trees are classified in to six categories to facilitate cultural operation like pruning, skiffing, heading back etc.

1. Fruit buds bore terminally and giving rise to inflorescence without leaves e.g. Mango, Cherry, etc.
2. Fruit buds borne terminally and unfolding to produce leafy shoots which terminate in flower clusters. e.g. Apple
3. Fruit buds borne terminally and unfolding to produce leafy shoots with flower or flower clusters e.g Guava
4. Fruit bud borne laterally containing flower parts only and giving rise to inflorescence without leaves or leaves present, they are reduced in size., e.g. Citrus
5. Fruit bud borne laterally and unfolding to produce leafy shoots terminally in flower clusters this type of flowering is noticed in grapes and cashewnut.
6. Fruit buds borne laterally and unfolding to produce leafy shoots with flower clusters in leafy axils. eg.Fig.

C. Fruit morphology: 1) Simple fruit - Berry: Banana, Papaya, Grape, Sapota, and Avocado

2) Modified berry-

i. **Balusta** : Pomegranate

ii. **Amphisarca** : Woodapple, Bael

iii. **Pepo** : Water melon

iv. **Pome** : Apple, Pear, Laquat

v. **Drupe (Stone**) : Mango, Pear, Plum

vi. **Hesperidium** : Citrus

vii. **Nut** : Cashew, Litchi, Walnut, Rambutan

viii. Capsule : Anola, Carambola

3) Aggregate fruits : Etario of berries –Custard apple, Raspberry

4) Multiple fruit : Syconus- Fig **: Sorosis-** Jackfruit, Pineapple, Mulberry

D. Based on rate of respiration:

Climacteric Fruits	Non-climacteric Fruits
Mango, Banana, Sapota, Guava, Papaya, Apple, Fig, Peach, Pear, Plum, Annona, Tomato	Citrus, Grape, Pomegranate Pineapple Litchi, Ber, Jamun, Cashew, Cucumber, Cherry, Strawberry.

E. Based on photoperiodic responses

Long day	Short day	Day neutral plant
Passion fruit, Banana, Apple	Strawberry, Pineapple, Coffee	Papaya, Guava

F. Based on relative salt tolerance

Highly tolerant	Medium tolerant	Highly sensitive
Datepalm, Ber, Amla, Guava, Coconut, Khirni	Pomegranate, Cashew, Fig, Jamun, Phalsa	Mango, Apple, Citrus, Pear, Straw berry

G. Based on relative acid Tolerance

Highly tolerant	Medium tolerant	Highly sensitive
Stawberry, Raspberry, Fig, Bael, Plum	Pineapple, Avocado, Litchi	-

H. Based on longevity:

a) Very Long longevity - >100yrs- Datepalm, Coconut, Arecanut

b) Long longevity - 50-100yrs - Mango, Tamarind

c) Medium - 10-50yrs - Litchi, Guava,Pomogranate

d) Short - Pineapple, Banana

I. Based on consumers preference or weight of fruits

a) Very light - 50-100gm Grape,Ber,Banana

b) Light - 100-150gm Sapota,Pomegranate

c) Light medium - 150-300gm Mango

d) Medium - 300-350gm Avocado

e) Medium to heavy - 800-1000gm Mango

f) Heavy - 1-5kg Bread fruit, Pineapple

g) Very heavy - >5kg Jack Fruit

2. Botanical classification based on botanical relationship with genomes:

Common name	Botanical name	family	origin	Fruit type	Edible part	Chromosome no.
Aonla	*Emblica officinalis/ Phyllanthus emblica*	Euphorbiaceae	Tropical-asia (indo-china)	Drupecious fruit (berry)	Meso & endocarp	X= 7 2n=4x=28

Atemoya	*Annona atemoya*	Annonacea e	Man made hybrid	Etaerio of berries	Pericarp of individual berries	X=7 2n=2x=14
Custard apple	*Annona squamosa*	Do	Tropical america	Do	Do	Do
Indian wild strawberry	*Fragaria vesca*	Rosaceae	India	Etaerio of achenes	Fleshy thalamus & numerous achenes	X=7 2n=2x=14
Strawberry	*Fragaria X ananassa*	Do	Man made hybrid	Do	Do	X=7 2n=8x=56
Almond	*Prunus amygdalus*	Do	Persia-afganistan	drupe	Kernel/cotyledon	X=8 2n=2x=16
Apricot	*Prunus armeniaca*	Do	china	Do	Meso & endocarpe	Do
European plum	*Prunus domestica*	Do	Europe/ East Asia	Do	Epi & mesocarpe	X=8 2n=6x= 48
Japanese plum	*Prunus salicina*	Do	China	Do	Do	X=8 2n=2x=16
Peach	*Prunus persica*	Do	Do	Do	Do	Do
Sour cherry	*Prunus cerasus*	Do	Europe/ West asia	Do	Do	Do
Sweet cherry	*Prunus avium*	Do	Do	Do	Do	Do, 2n=16,24,3 2
Pomegranat e	*Punica granatum*	Punicaceae	Iran	Balausta	Aril/juicy seed coat	X=8,9 2n=2x=16, 18
Bael	*Aegle marmelos*	Rutaceae	India	Amphisarica	Succulent placenta	X=9 2n=4x=36

Grape fruit	*Citrus paradisi*	Rutaceae	West Indies	Hesperidium	Juicy placental hairs	X=9 2n=2x=18
Indian sweet lime	*Citrus limmetoides*	Do	East Asia	Do	Do	Do
Kagzi lime	*Citrus aurantifolia*	Do	India	Do	Do	Do
Lemon	*Citrus limon*	Do	East Asia	Do	Do	Do
Mandarin	*Citrus reticulata*	Do	China	Do	Do	Do
Pummelo	*Citrus grandis*	Rutaceae	South east asia	Hesperidium	Juicy placental hairs	X=9 2n=2x=18
Sweet orange	*Citrus sinensis*	Do	China	Do	Do	Do
Woodapple	*Feronia limonia*	Do	India	Amphisarica	Succulant placentae	Do
Papaya	*Carica papaya*	Caricaceae	Tropical America	Berry	Mesocarp	X=9 2n=2x/4x= 18/36
Passion fruit	*Passiflora eduli*	Passifloracewae	Brazil(Tropical america)	Do	Do	X=9 2n=2x=18
Phalsa	*Grewia subinaequalis*	Tiliaceae	India	Drupe	Epi & mesicarpe	X=9 2n=4x=36
Mango	*Mangifera indica*	Anacardiaceae	Indi-Burma region	Do	Mesocarp	X=10 2n=4x=40
Banana	*Musa acuminata*	Musaceae	South east asia	Berry	Meso & endocarp	X=11 2n=3x=33 4x,2x
Guava	*Psidium*	Myrtaceae	Peru(T.ame	Do	Thalamus &	X=11

	guajava		rica)		pericarp	2n=2x/3x=22/33
Karonda	*Carissa carandas*	Apocynaceae	India	Do	Epicarp &mesocarp	X=11 2n=2x=22
Rumbutan	*Nephelium lappaceum*	Sapindaceae	Malaya	Nut	Aril	Do
Avocado	*Persea americana*	Lauraceae	Mexico & West indies	Do	Pericarp	X=12 2n=2x=24
Carambola	*Averrhoea carambola*	Oxalidaceae	India-China	Berry		X=12 2n=2x=24
Chinese jujube	*Ziziphus jujube*	Rhamnaceae	China	Drupe	Do	X=12 2n=24,48,96
Indian jujube/ ber	*Ziziphus mauritiana*	Do	India	Do	Do	Do
Tamarind	*Tamarindus indica*	Leguminosae	Tropical Africa-India	Pod/Lomentum	Pulp/Mespcarp	X=12 2n=2x=24
Fig	*Ficus carica*	Moraceae	West asia	Synconus	Fleshy receptacle	X=13 2n=2x=26
Sapota	*Achras sapota*	sapotaceae	Mexico(T. america)	Berry	Mesocarp	Do
Jackfruit	*Artocarpus heterophyllus*	Moraceae	India	sorosis	Bracts/perianth/seeds	X=14 2n=4x=56
Litchi	*Litchi chinensis*	sapindaceae	china	Nut	Aril	X=14,15,16,17 2n=2x=30
Persimmon	*Diospyros*	Ebanaceae	Do	Berry	Epi & mesocarp	X=15

	kaki					2n=6x=90
Coconut	*Cocos nusifera*	Arecaceae	South east asia (India)	Drupe	Endosperm	X=16 2n=2x=32
Walnut	*Juglans regia*	Juglandaceae	South west Europe	Nut	Lobed Cotyledon	Do
Apple	*Malus x domestica*	Rosaceae	Asia minor	Pome	Fleshy Thalamus	X=17 2n=2x/3x= 34/51
Loquat	*Eribotrya japonica*	Do	China	Do	Do	2n=2x=34
Quince	*Cydonia oblonga*	Do	Do	Do	Do	Do
Date plum	*Phoenix dactylifera*	Arecaceae	West Asia/Arabia	Berry	Pericarp	X=18 2n=2x=36
Pecan nut	*Carya illinoensis*	juglandaceae	Southern USA	Nut	Seed/Cotyledon	X=16 2n=2x=32
Grape	*Vitis vinifera*	Vitaceae	Black sea to Caspian sea	Berry	Pericarp& Placenta	X=19 2n=2x=38
Jamun	*Syzygium cumini*	Myrtaceae	India	Drupe	Epi & mesocarp	X=20 2n=2x=40
Cashew	*Anacardium occidentale*	Anacardiaceae	Brazil/T.america	Nut	Cotyledon & fleshy peduncle	X=21 2n=2x=42
Olive	*Olea europaea*	oleaceae	Mediterranean region	Drupe	Epi & Mesocarp	X=23 2n=2x=46
Pineapple	*Ananas comosus*	Bromeliaceae	Brazil	Sorosis	Bracts & Perianth	X=25 2n=50,75,100
Chinese gooseberry	*Actinidia chinensis*	Actinidiaceae	China	Berry		X=29

						2n=58,174
Mulberry	*Morus alba*	Moraceae	Do	Syncarpus/sorosis/aggregates of druplets	Mesocarp	2n=308
pistachionut	*Pistachio vera*	Anacardiaceae	West Asia	nut	Cotyledons	X=15 2n=30

Lecture 4: CLIMATIC ZONES OF HORTICULTURAL CROPS

Climate is one of the important complex factors which influence the fruit production. It includes several basic environmental conditions such as temperature, rain fall, humidity, and lights. Fruits growing zones are based on the climatic factors. These zones are tropical, sub- tropical, temperate and arid zone. However, there are certain exceptions to this, e.g. grape can be grown in temperate and sub-tropical regions, while papaya can be grown in tropical and sub- tropical condition.

- **Temperate Fruits:**

This class of fruits grown successfully in cold regions where temperature falls below freezing point during winters. During the cold season, the trees, sheds their leaves and goes into rest period. For breaking this rest period, a definite chilling period is required. This class of fruits includes fruits like apple, pear, walnut, almond, plum, peaches, strawberry etc.

- **Tropical Fruits:**

This class includes fruit crops which are unable to endure cool temperature. Some of them are being severally injured by even the temperature somewhat above the freezing point. This class of fruits required hot and humid climate in a summer and mild winter. This class includes only evergreens such as mango, Sapota, papaya, cashew, pineapple, banana etc.

- **Sub-Tropical Fruits:**

This class includes fruit crops intermediate in character to tropical and temperate. These fruits grown mostly in plains where the climate is hot, comparatively dry and winter less severe. This class of fruits includes fruits like citrus, phalsa, fig, pomegranate etc.

- **Arid Zones:**

Besides these zones, the arid region has extreme climatic conditions. In arid zones rain is very greatly low and its distribution is erratic leading to low plats stand and productivity. To make it worse, the water storage capacity of soils in these areas is very low, being mainly poor textured and shallow soils, and is compared with high evaporative losses. This class of fruits includes ber.

Lecture 5: SOIL AND ENVIRONMENT FOR HORTICCULTURE CROPS

SOIL:

- Soil is the upper most crust of earth surface which supports plant growth.
- It is defined as a three phase system in which plants grow. These phases are solid, liquid and gas and are essential. Solid part is frame which provides space for other two. This consists of minerals, clay minerals and organic matter.
- The soil is also a living system with millions of microbes that breakdown organic matter and builds it again.
- Microbes are essential and survive only when soil is well aerated and rich in organic matter and devoid of waterlogged conditions.
- Texture of soil depends on the size of solid particles and classified as gravel, coarse and fine sand, silt and clay.
- Soils are classified according to relative distribution of these particles and there are 12 textural classes.
- Likewise, arrangement of these particles is referred as structure, and both texture and structure lend soil physical properties like water holding capacity, aeration and bulk density.
- Generally loamy soils and crumb structure are most preferred for fruit crops.
- According to level of organic matter, soils are classified as mineral soil or organic soil and soil having more than 20% organic matter is organic soil like peat and muck.
- Minerals and salts lend chemical properties to the soil like pH, alkalinity, sodicity, salinity and cation exchange capacity which influence the availability of nutrients in soil.
- Therefore, for making choice for soil, soil analysis in terms of following criteria is essential to decide on land capability.

Criteria for land capability class:

i. Slope and erosion hazard.

ii. Soil depth.

iii. Drainage.

iv. Workability.

v. Stoniness and rockiness.

vi. Water holding capacity.

vii. Permeability.

viii. Nutrient availability.

ix. Fertility status.

x. Salinity, alkalinity and acidity hazards.

- Based on these criteria there are 8 capability classes, of which (i) to (iv) are suitable for cultivation and (v) to (viii) are not suitable for cultivation.
- The soil provides support for the plant and act as storehouse of nutrients and water as well as oxygen for root growth.
- The ability of the soil to support plant growth is often referred to as its productive capacity which depends on fertility and physical condition. Therefore, the soil has to be a good soil.
- A good soil is one which has the capacity to nourish and sustain plant growth by providing mineral particles (nutrients) in an available form to plants by their interaction with soil air, moisture, microbes and humus.

Generally a loam soil is considered to be a good soil.

- Generally fruit crops need porous, aerated, deep (2 m) uniformly textured soils and the pH of soil should be within range of 6-8.
- Soil with hardpan within 120 cm from surface, soil with high clay content at surface and very less at subsurface or vice-versa are not suitable for fruit crops.
- Fruit crops are susceptible to waterlogged condition and growth is adversely affected by salinity, sodicity and alkalinity.
- It is, therefore, important that soil be analyzed for its quality and then choice of the crop is made for sustainable production.
- If the soils are problematic like poor aeration or drainage, sodicity, alkalinity, acidity and salinity, they require improvement or reclamation before taking up crop production or the venture would fail.
- Alternatively tolerant or resistant crops can be choosen for different problems.

Salinity tolerant crops: Kair, Khirni, Woodapple, Date palm, Ber, Aonla, Fig, Sapota etc.

Sodicity tolerant crops: Ber, Tamarind, Woodapple, Date palm, Aonla, Karonda, Fig, Phalsa, Pomegranate, Guava, Bael and almond.

Drought tolerant crops: Ber, Aonla, Ahalsa, Lasoda, Kair, Custard apple, Karonda, Fig, Guava etc.

If we know the soil and the requirement of soil for the crops, then choice of the crop can easily be made.

Grouping of fruits according to their tolerance to salinity:

a. **High salt tolerance :** Date palm, Ber and Aonla.

b. **Medium salt tolerance :** Pomegranate, Fig and Grape.

c. **Low salt tolerance :** Apple, Orange, Almond, Lemon and Avocado.

- In making choice of soil for fruit crops physical properties should he emphasized, more as chemicals can be added from outside to improve nutrient status and chemical properties of the soil.
- Generally the depth and the drainage-ability are very important for crop production.
- To upkeep soils for sustainable production following things are to be done before and after planting a crop:

Soil analysis in terms of its physical and chemical attributes

- Bring the soil to its optimum potential by applying organic matter, chemical fertilizers, micronutrient and amendments depending on soil analysis report.
- Adoption of soil conservation technique like green manuring on regular basis.
- Use of improved water management techniques like drip irrigation and check basin or Furrows.
- Incorporation of large quantity of bulky organic matter each year.
- Creation of appropriate drainage around the plot.
- Scrapping of salts and reclamation of soil by application of gypsum, iron pyrites, press mud etc., on regular basis in case of salinity problem.

- Replenishment of nutrients harvested by the crop on regular basis by preparing a balance sheet for nutrients.
- Recycling of organic waste.
- ***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, understanding about soil and climate and their requirement for different crops for optimum production on sustainable basis is important for horticulturists.

Climate is defined as the whole of average atmospheric phenomena for a certain region calculated for a period of thirty years. These phenomena are light, heat, water and air. **LIGHT:**

- Electromagnetic radiation to which the organs of plant react ranging in wavelength from 4000 to 7700 angstrom units, and is propagated at a speed of about 540 kilometres per second.
- It is essential for the process of photosynthesis and therefore, for 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. Eg. Turmeric and ginger.
- There are others like young mangosteen, coffee, cocoa and tea need shade during part of their development.
- A third group requires permanent shade like salak palm, duku, and carambola.
- The duration of light for the time elapsing between dawn and dusk referred as **photoperiod or day length**. This exerts considerable influence on flowering.

Based on the response by plants the major classes are following. However, fruit crops for such categories are not known.

1. **Long day plants:** Cabbage, Cauliflower, Onion, Beetroot, Radish, Carrot, Spinach, Potato, Dill and Plantago.

2. **Short day plants:** Strawberry, Pineapple, Chrysanthemum, Poinsettia, Aster, Balsam, Salvia, Euphorbia and Xanthium.

3. **Day neutral plants:** Tomato, most fruit crops, Pepper, Cucumber, Snapdragon, Mirabilis and certain varieties of 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.
- The growth of the plants depends primarily on temperature.
- Availability of heat units decide the crop for a given place and the average temperature of a place gives an 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.
- Frost and chilling are harmful for tropical and subtropical 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 temperature variations on the surface of the earth we have the 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.

1. **Tropical :** Mango, Banana, Papaya, Sapota, Pineapple, Coconut, Cashew, Arecanut, Breadfruit, Jackfruit and Avocado.

2. **Subtropical:** Guava, Grape, Citrus, Date palm, Phalsa, Pomegranate, Litchi and Loquat.

3. **Temperate:** Apple, Pear, Peach, Plum, Quince, Apricot, Walnut, Almond, Strawberry and Cherry.

Classification of vegetable and flower crops according to seasons

Crops	Warm Season	Cool Season
Vegetables	Bottle gourd, Water melon, Brinjal, Tomato, Cluster bean, Okra, sweet Potato, Radish	Cabbage, Caulifloweer, Pea, Radish, Tomato, Beans, Potato, Onion, Carrot
Flowers	Marigold, Zinnia, Chrysanthemum, Sunflower, Gomphrena, Gaillardia, Portulaca, Kochia, Amaranthus, Celosia, Coreopsis, Calendula	Aster, Poppy, Dianthus, Dahlia, Salvia, Petunia, Pansy, Phlox, Coreopsis, Verbena, Diamorphotheca

WATER

- Water is a transparent, odourless and tasteless liquid compound of hydrogen and oxygen (H20) with 11.91% hydrogen and 88.81% oxygen.
- It is 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, which reduces but again influenced by a number of factors like mountain ranges.

Water requirement of plant is dependent on soil type and evapo-transpiration 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 liking for high humidity and low humidity are there:
- **High humidity:** Sapota, Banana, Mangosteen, Jackfruit and Breadfruit.
- **Low humidity (Dry)**: Ber, Grape, Date palm, Pomegranate, Citrus, Aonla and Guava.

AIR

- 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 gasses like *hydrocarbons, SO2, CO2, CO, NO, ethylene and methane* the plant growth adversely affected but we are more concerned with the movement of air (wind) causing 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/hr whereas, hurricane has a wind speed of more than 100km/hr.

Lecture 6: PROPAGATION OF FRUIT CROPS

Objective of propagation: To produce individuals those are identical to the mother plant or original plant. Thus a successful propagation method is one which transmits all the desirable characteristics of a mother plant to the offspring.

In general field crops as well as almost all the vegetables and flower crops are commercially propagated by seeds but fruit crops are mainly propagated by vegetative means of propagation. Normally, field crops, most of the vegetables and flower crops are highly self pollinated in natures which are considered as homozygous. Hence when they undergo sexual reproduction, the resultant off springs will be homozygous in nature, similar to the mother plant. But in case of fruit crops, they are highly cross pollinated in nature, means highly heterozygous. Hence on sexual process they will produce off spring- not true to the type of mother plant. Therefore, in fruit crops in general vegetative means of propagation is more desirable to get true to the type of mother plant than sexual method of propagation.

Sexual propagation: Raisings of plant by means of seed. It has certain advantages over vegetative means of propagation-

- Seedis relatively a cheaper and simple way of obtaining large number of plants as compared to vegetative propagation.
- Seedlings have usually long life as compared to vegetatively propagated plants.
- Seedling plants have better root system and therefore provide better anchorage than vegetatively propagated plants.
- It is the only practical method of propagation of most of the vegetables, annual flowers and fruit plants like papaya, phalsa, mangosteen which cannot be propagated by vegetative means.
- Hybrids are 1st raised through seeds.
- Rootstocks for budding and grafting purpose are raised through seeds only.
- Sexual propagation may sometimes leads to the production of chance seedlings which may be superior to the mother plant.
- Seedling plants are comparatively more resistant to insect-pest and diseases than the vegetatively propagated plants.
- Seeds can be stored for a longer time and can be easily transported to distance market.

- Seedlings are usually hardy and can tolerate adverse climatic conditions in a better way than the vegetatively propagated plants.
- No special technical skill is required for raising plants through seeds.
- Majority of viruses are not transferred through seeds. Thus, seed propagation is useful in producing virus free plants.
- Nucellar seedlings can be utilized to raise uniform plants.
- In polyembryonic crops like mango, citrus seeds on sowing give rise to more than one seedling. Thus seed is the desirable means of propagation in such crop.
- Mangosteen fruit is developed through parthenogenesis. Seedlings obtained from seeds of such fruits are similar to its mother plant and thus propagated commercially through seed.

Disadvantages:

- Seedling plants are highly heterozygous in nature. Owing to segregation, the seedling trees are not uniform in growth, yield and fruit quality parameters.
- Seedling plants are usually tall and spreading types, thus the management cost involved in operation like harvesting, pruning and plant protection etc. is comparatively higher.
- Seedlings plants have usually long juvenile phase and take more time to come in bearing.
- In case of recalcitrant crop, seed loose viability very soon after extraction and thus very low germination rate.
- The beneficial effect of rootstock on scion variety cannot be taken in sexual propagation.
- Some fruit plants like pineapple, banana does not produce viable seeds and propagation through seeds is not possible in them.
- It is not possible to perpetuate the exact characters of any superior selection through seeds.

Classification of seed on the basis of storability: On the basis of storability of seeds in relation to moisture content, they are classified into two groups*viz.* Orthodox seeds and recalcitrant seeds.

a. **Orthodox seeds:** The seedswhich can be dried to low moisture level(5-8% of lower) and lose their viability with the increase of moisture, are called as orthodox seeds. The viability of these seeds can be maintained by drying the seeds and storing them at low temperature for longer period of time. Eg. Ber, custard apple, date palm, fig, grape, guava, mulberry, papaya, passion fruit, peach, pineapple, plum, phalsa, pomegranate *etc.*

b. Recalcitrant seeds: The seeds, which remain viable at relatively higher moisture level (8-15% or above) and if dried below certain moisture level, they start to lose their viability, are called as recalcitrant seeds. Eg. Avocado, Barbados cherry, carambola, bread fruit, jack fruit, litchi, mango, mangosteen, rambutan, citrus *etc*.

Vegetative propagation: Any plants are propagated commercially through asexual mean in which vegetative parts of the plant are used. It is possible because all the living cells of a plant have a capacity to regenerate into a full plant under favourable environmental condition. This tendency of plant cell is called as *totipotency*. The term given by Haberlandt in 1902. The plants produced by vegetative means are therefore genetically identical and similar to the mother plant.

Advantages:

- True to the type and uniform in growth, yield and fruit quality
- Ideal method of propagation for the plants which are more prone to seed dormancy (all the temperate fruits).
- Vegetatively propagated plants are less vigorous and thus can easily be maintained as compared to seedling plants.
- Some fruit crops like banana, pineapple, fig and varieties of grape, guava and lemon produce seedless fruit and have no viable seeds. Thus can only be perpetuated through vegetative means.
- Plants come in bearing earlier than seedling plants.
- Possible to regulate the tree size, fruit quality and precocity in bearing by exploiting the desirable effects of different rootstocks.
- It is possible to exploit the desirable abiotic effect of rootstocks on scion cultivar by budding and grafting.
- Helpful to overcome the problem of self incompatibility of different fruit crops by top working the desirable pollenizers on scattered trees throughout the orchards.
- Detection of virus in the plant system by using indicator plant is only possible through budding or grafting. Eg. Kagzi lime can be used as rootstock (indicator plant) for detecting the presence of tristeza virus in citrus.
- Helps in shortening in breeding cycle by grafting scion of new cultivar on to a large established tree or on certain dwarfing rootstock for early assessment.

- A clone can only perpetuated by vegetative means.
- Benefit of certain interstock can only be obtained through vegetative means.
- Damaged part of the tree trunk or root can only be repaired by bridge grafting or inarching.

Disadvantages:

- Have short life cycle and more prone to pest and disease attack.
- New variety cannot be evolved
- Specialized task and need technical skill
- Vegetatively propagated plants are usually prone to suckering
- More expensive than seed propagation
- Not applicable in some fruit crops like papaya.

Techniques for vegetative propagation:

- Propagation by apomictic seedling
- Propagation of plants on its own root system: Cutting, Layering
- Propagation of plants on the root system of other plants: Grafting, Budding
- Propagation by specialized structures: Bulbs, Tubers, Rhizomes, Corms, Suckers, Runners, Offsets, Bulbils, Pseudbulbs, Stolon, Slips, Crown *etc*.
- Micropropagation: propagation by using different explants (shoot tois, embryos, cell or protoplast culture) under aseptic condition.

Apomoxis

Defination: Development of embryo, not as a result of meiosis and fertilization but from diploid or haploid egg cells or from cells in embryo sac or surrounding nucellus or integument which does not undergo meiosis and emergence of off spring of same genetic makeup as of female parent is called as apomixes.

The seedlings which are produced through apomixis are known as apomictic seedlings.

- Plants that produce only apomictic embryos are called as **obligate apomicts** while other which produce both apomictic and sexual embryos are called as **facultative apomicts**.

Types of apomixes:

a. **Recurrent apomixis:** Embryo develops from the diploid egg mother cell or from some other diploid cells of the embryo sac without fertilization. It is quite common in

Parthenium, raspberry, apple, onion, *Poa* etc. In some species, this phenomenon occurs without the stimulus of pollination whereas in others, pollination appears to be necessary for the development of a viable embryo.

b. **Non-recurrent apomixis:** Embryo develops directly from the haploid egg cell or some other haploid cells of embryo sac without fertilization and as a result, the embryo developed is also haploid in nature. It is common in *Solanum nigrum* and *Lilium* species.

c. **Adventitious embryony:** It is also called as nucellar embryony. Here the embryo does not develop from the cells of the embryo sac but from a cell or a group of cells either of nucellus or integuments. Such embryos usually develop outside the embryo sac in addition to the regular embryo. This is quite common in citrus, where normal pollination and fertilization takes place in usual manner and apomictic embryos are develop outside the embryo sac.

d. **Vegetative apomixis:** In this type, vegetative buds or bulbils are produced in the inflorescence in place of flowers. These buds or bulbilis may sprouts into new plants while they are still attached to the mother plants. This is quite common in *Allium*, *Agave*, *Poa* and *Dioscorea*.

Apart from these, different scientists also included polyembryony as one type of apomixis. But it is not a separate type of apomixis. It is the phenomenon in which two or more embryos are produced in a single seed. The condition may results from many reasons. One of the most common reasons being the nucleus develops within the embryo sac, which may lead to the development of more than one embryo. Cleavage of pro-embryo during the early stages of development may the other reason for the development of multiple embryos.

Significane of apomixis:

- Produce homozygous line
- Useful for producing uniform rootstock. Eg. Rootstock of apple like *M. tiringoides*, *M. hupehensis*, *M. sikkimensisetc*.
- Apomictic seedling are quite healthy and highly uniform
- Effective for the production of virus free quality planting materials

<u>Cuttings</u>

Types of cuttings

A. Stem cutting: Next to seed, stem cuttings are the most convenient and popular method of plant propagation. Most the cutting techniques fall into this category. A stem cutting is any cutting taken from the main shoot of a plant or any side shoot growing from the same plant or stem. There are few general considerations which helps in selection of suitable cuttings. First of all it is essential for the cutting to have sufficient reserve food to keep tissues alive until root and shoots are produced. The shoots with high carbohydrate content usually root better. To maintain high carbohydrate content in a shoot, ringing or notching stem down to the wood are useful practices. As a general rule, cutting from young plants root better but if older shoots of the plants are cut back hard, very often they can be induced to produce suitable shoots for rooting. Broadly there are four types of stem cuttings which are as follows-

i. **Hardwood cuttings:** It is simple method of plant propagation in which cuttings are made from the mature and lignified stems of shrubs and trees. Such cuttings are easy to secure and can be easily handled, stored and transplanted. This type of cutting is prepared during dormant season. Usually from one year old immature shoots of previous season's growth. Only healthy shoots are selected and weak, fast growing shoots with long internodes should be avoided. The length of the cutting varies from 10-45 cm in length and 0.5-2.5 cm in diameter, depending on the species. usually the cutting of 25-30 cm length with pencil thickness are preferred. Each cutting should have at least 2 buds. While preparing the cutting, a straight cut is given at the base of shoot below the node while a slanting cut, 1-2 cm above the bud is given at the top of the cutting. This helps in maintaining the polarity of the shoot and if rain occurs, water does not accumulate on the tip of the cutting, which saves the cutting from fungal infection. It also helps in maintaining polarity of the cut sticks. It is often advantageous to take hardwood cutting with a heel (in temperate fruit crops), that is with a piece of old wood, attached to the base. Presence of Mallet (present in Quince) at the base of cutting should also be preferred. Similarly, stem cutting will more often root better if bases are etiolated, notched or girdled or ringed before being removed from the parent plant. After preparation of cutting, the basal portion of those cutting should be treated with root initiating hormone, especially Indole-3-butyric acid (IBA). For deciduous crop, the dose of IBA varies from 2500-5000 ppm (with maximum 10,000 ppm in difficult to root crops) while in evergreen plants it is 2000 ppm to slightly higher (5000-10000 ppm in difficult to root crops). It is generally practised in a number of deciduous fruit plants like grape, hazelnut, chestnut, fig, quince, pomegranate, mulberry, plum, olive are commonly propagated by hardwood cutting.

ii. **Semi-hardwood cutting**: The semi-hardwood cuttings are prepared from partially matured, slightly woody shoots. These are succulent and tender in nature and are usually prepared from growing wood of current season growth. Usually those shoot, which snap clean when broken, are considered ideal for preparation of semi-hardwood cutting. The length of the cutting varies from 7- 15 cm. The cuttings are prepared by trimming the branches with a straight cut below the node and removing a few lower leaves at the base and retaining 2-4 leaves at the top of the cutting. Treating the cutting with IBA @ 1000- 3000ppm (maximum 5000 ppm in difficult to root crops) before planting is beneficial for commencement of proper rooting. While planting one quarter of their length should be inserted in the soil. The best time for taking cutting is late spring to summer, when new shoots have emerged and their wood is partially matured.

It is normally practised in evergreen fruit plans like mango, guava, lemon, jackfruit, olive *etc.*

iii. **Softwood cutting:** Softwood cutting is the name given to any cutting prepared from soft, succulent and non-lignified shoots which have not become hard and woody. Usually, the cutting size is 7.5- 12.5 cm but it varies from species to species. Usually some leaves should be retained with this type of cutting. Before planting treatment with IBA (500-1250 ppm with maximum of 3000 ppm in difficult to root crops)is beneficial. The best time for the preparation of softwood cutting is spring to early summer.

It is normally practiced in different flowering annuals like Juniper, hollyhick, lilac. But some time it is also practised in apple, pear, peach, plum *etc.*

iv. **Herbaceous cutting:** The terminal leafy portion of the stem of a plant is used for preparing herbaceous stem cutting. These cuttings are soft and succulent with length varying from 7.5-12.5 cm. These cuttings are rooted under the same conditions as the softwood cuttings, requiring high relative humidity but are liable to wilt soon if proper humidity is not maintained. Therefore, much attention is required for working with herbaceous cuttings. Herbaceous cuttings of some plants exude a sticky sap that interferes with rooting process. In such cases basal end of the cutting should be allowed to dry for few hours before planting. For proper root initiation treatment of the basal portion of the cutting with IBA @ 500-1250.

It is generally practiced in flowering annuals like Geranium, poinsettia, dieffenbachia, chrysanthemum. In fruit crops it is followed in pineapple (slips and crown), and in persimmon.

B. Root cuttings: Propagation by means of root cuttings is also a simple and cheap methods of vegetative propagation in species which are difficult to propagate with other methods. In general the plants which produce suckers freely are easily propagated by root cuttings. For preparation of root cuttings, roots which are of 1 cm thick and 10-15 cm long are cut into pieces. The best time for taking root cuttings is late winter or early spring when the roots are well supplied with stored food materials but before the new growth starts. However in temperate fruits, root cuttings are prepared in the month of December and are kept in warm place in moss grass or wet sand for callusing and are then transplanted during February- march in open beds. While using root cuttings, it is important to maintain the correct polarity. Thus, to avoid their planting upside down, the proximal end of the cutting should have straight cut and distal end a slanting cut. The proximal end should always be kept up. While planting, insert the cuttings vertically so that the top is above the soil level. However, in some cases, horizontal planting gives satisfactory results as in sweet potato.

Balckberry and raspberry are commercially propagated by this method. However, kiwi fruit, bread fruit, fig, mulberry, apple, pear, peach, cherry and persimmon are also propagated by root cuttings.

Apart from theses different horticultural crops particularly different flowering annuals and vegetable crops also propagated by leaf cutting due to their herbaceous nature but fruit crops are rarely propagated by this particular means of propagation. However, leaf bud cutting technique is sometimes followed for the propagation of black berry, raspberry, lemon.

Budding

In grafting, the scion is a detached piece of shoot or stem with several buds. But in budding, scion consists of only one bud and small portion of wood. Thus, budding is a form of grafting and often called as bud grafting.

Advantages:

- Quick and efficient method of propagation as compared to grafting.
- Best propagation method if propagating material is scarce.
- Budding is useful in plants release excessive wound gum (stone fruit) from injury carried to xylem or wood portion of stem at the time of grafting.
- Budding results into stronger union compared to grafting thus injury to the budded plants due to storms and strong wind is less.

- It is comparatively simple method of plant propagation than grafting and can be done by common peoples.

Types of budding

i. **Shield or T budding:** as the name indicates shield is the shape of the bud and T is the shape of cut given on the rootstock for the budding operation. It is the most common method of budding practiced by nurserymen throughout the world. For T budding, one year old rootstock seedling of 25-35 cm height and 2-2.5 cm thickness is selected which is in actively growing stage, so that the bark will separate readily from the wood. In this budding, 1^{st} a vertical cut (2.5 cm length) to be made on the stock at 0.-2.5 cm above the soil level. Then the horizontal crosscut to be made at the top of the vertical cut to give T shape. As the horizontal cut is made, the knife is given a twist to open the flaps of bark for the insertion of the bud. Thereafter, scion bud is prepared by removing the bark shield with a bud. For this, an upward slicing cut is started at the point on the stem at 12-13 mm below the bud, continuing under the bud to an about 2.5 cm above. The shield piece should be thin, thick enough to have some rigidity. A 2^{nd} cut is then made at the upper portion of the 1^{st} cut which permitting the removal of the shield piece. After removal of the scion bud, it should be inserted into the T cut on the stock by pushing the shield downward under the two raised flaps of bark until its upper horizontal cut is matches the same cut on the stock. Then wrapping of the bud union must be done using budding tape.Eg. Apple, pear, peach, plum, apricot, cherry, rose and citrus are propagated by this method.

ii. **Inverted T budding:** In area that experiencing high rainfall during budding season, water running down the stem of the rootstock may enter the T-cut, soak under the bark of the stock and prevent into the shield piece from healing into place. In such condition, inverted T budding gives better results, since excess water is shed. For this, rootstock has the transverse /horizontal cut at the bottom rather than at the top of vertical cut. In removing the shield piece from the bud stick, the cut on bud stick should start above the bud and continuing downward below it. Then insertion of shield into rootstock should be done from lower part to upward direction.It is usually practiced in citrus.

iii. **Patch budding:** Widely successful in thick barked species such as walnut, pecan nut. In patch budding, bark of both stock and scion requires to slip easily. A special knife called double bladed knife is used in this budding technique which makes two transverse parallel cut 2.5-3.5 cm apart through the bark to the wood in a smooth area of the rootstock about 10 cm above the ground. Then two transverse cuts are connected at each side by vertical cuts made with a single bladed knife. The patch of bark containing a bud is cut from the budstick in the same manner as of rootstock. The size of the bark removed from the budstick should be same as of size of the bark removed from the rootstock. After the removal of bud patch from the budstick, it must be inserted immediately on the already prepared rootstock. The inserted patch is now ready to be wrapped.

iv. **I- Budding:** In this budding, two parallel cuts are made on the rootstock using the same parallel double bladed knife, used in patch budding. These two transverse cuts are then joined at their centres by a single vertical cut to produce the shape of the letter 'I'. The two flaps of bark can then be raised to insert the bud patch beneath them. A better fit may occurs if the side edges of the bud patch are slanted. It is mainly practiced in ber.

v. **Ring budding:** In ring budding, a complete ring of bark is removed from the stick and it is completely girdled. A similar ring of bark containing a bud is removed from the bud stick and it is inserted on to the rootstock. In ring budding, both stock and scion should be of same size. However, it is applicable in stocks having thickness below 2 cm. It has been utilized in ber, peach, mulberry because the newly emerged shoots from the heavily pruned plants are capable of giving such buds for budding, which can easily be separated. In this method, since the stock is completely girdled and if the bud fails to heal in, the stock above the ring may eventually die.

vi. **Flute budding:** In flute budding, the bark patch from the stock is removed in such a way that it must completely encircles the stock except with a narrow bark connection between the upper and lower cuts on the stock. A similar patch of bark is removed from budstick containing a healthy bud. The shield containing the bark is then inserted in the vacant area in the stock. After fitting it properly and tightly on the stock, it should be wrapped with suitable wrapping material, leaving the bud uncovered. Because of the presence of narrow connecting strip of bark on the stock, it remains alive even if the bud fails to sprout. It is mainly practiced in ber, mulberry, peach *etc.*

vii. **Chip budding:** it is a successful method of budding when the bark of the rootstock does not slip easily and plants are not in actively growing condition.In this technique, a chip of bark is removed from a smooth place between nodes near the base of the rootstock and replaced by another chip of the same size and shape from the budstick, which contains a bud of the desired cultivars. The chip in both budstick and rootstock are cut out in the same manner. In the budstick, the 1st cut is made just below the bud and down into the wood at an angle of 30-45 degree. The 2nd cut is started about 25 mm above the bud and goes inward and downward behind the bud until it intersects the 1st cut. The chip is removed from the stock in the same manner and replaced by the one from budstick. After proper fitting of bud piece on the stock wrapping should be done properly with suitable wrapping material, leaving the bud uncovered.Mainly followed in grape, apple and pear.

Lecture 7: GRAFTING

Detached scion grafting- Apical graftage

a. **Tongue grafting:** Useful for grafting relatively small material of about 6-13 mm in diameter. It is highly successful if done properly because there is considerable vascular cambium connection. It heals quickly and makes a strong union. Scion and rootstock of equal diameter is preferable for this technique for better graft union formation. The scion should contain 2 or more buds. It is done mainly during the dormant season of the plant.

For this, after heading back the stock, 1st a smooth cut is made at 2.5-6 cm long. Then a reverse cut is made downward from the point about one third of the distance from the tip and should be one half of the length of the 1st cut. Similar technique should be followed for the preparation of scion at its base. After that the rootstock and scion are inserted into each other, with the tongue interlocking. The lower tip of the scion should not overhang the stock as there is a likelihood of the formation of large callus knots. The use of scions larger than the rootstock should be avoided for the same.

It is commercially used in temperate fruits like apple, pear *etc*.

b. **Whip grafting (Splice grafting):** It is the same as the tongue grafting, except that the second or tongue cut is not made in either the stock or scion. A simple slanting cut of the same length and angle is made in both the stock and scion. These are placed together and wrapped or tied in such a way so that there should be no space in between stock and scion.

If the scion is smaller than the stock, it should be set at one side of the stock so that the vascular cambium layers will be certain to match along that side.

Mostly used in greenhouse production of vegetable crops for grafting on disease resistant rootstocks.

c. **Cleft grafting:** Although cleft grafting can be done during the dormant season, the chances for successful healing of the graft union are best if the work is done in the early spring just when the buds of the stock are beginning to swell but well before the active growth has started. The scion should be made from dormant one-year old wood.

In making cleft grafting, a heavy knife is used to make a vertical split on the stock for a length of 5-8 cm down the centre of the previously beheaded stock. After a good and straight split is made, a screwdriver, chisel or the wedge part of the cleft-grafting tool is driven into the top of the split to hold it open. Two scions are inserted, one at each side of the stock where the vascular cambium layer is located. The scion should be 8-10 cm long, about 10-13 mm in thickness and should have 2-3 buds. The basal end of the scion should be cut into a gently sloping wedge about 5 cm long and then inserted into the split portion of the stock. A common mistake in cutting scions for this type of grafting is to make the cut on the scion too short and the slope too abrupt, so that the point of contact is only at the top. Slightly shaving of the sides of the split in the stock will permit a smoother contact. After preparation of the scion, they are inserted into the stock properly and wrapped the stock tightly with poly grafting tape or adhesive tape at the point of graft union to hold the scions in place more securely. Thereafter, thorough waxing of the completed graft is essential.

Mostly used for rejuvenating the old orchards of the temperate fruits by top working. Apart from this, Walnut, hazelnut, pecan nut, grape are also propagated by this method.

d. **Wedge grafting:** A heavy, short bladed knife is used for making a V-wedge in the side of the stub, about 5 cm long. For this two cuts are made, coming together at the bottom and as far apart at the top according to the diameter of the scion. These cuts extend about 2 cm deep into the side of the stub towards the centre. The diameter of the stock to be grafted is the same as cleft grafting- 5-10 cm and the scions are also the same size- 10-13 cm long and 10-13 mm thick. After preparation of the stock, the scions are prepared by trimming the base to a wedge shape, exactly the same size and shape of the V- wedge on the stock..in a stock of 5 cm diameter, 2 scion should be inserted while in stock of 10 cm diameter, 3 scions should be inserted. After all the scions are firmly inserted into the place, all cut surfaces including the tip of the scion should be waxed thoroughly. Like cleft grafting, it can be made in late winter or in early spring before the bark begins to slip.

Mainly use to topwork the old orchards.

Detached scion grafting- Side graftage

Side-Stub grafting: It is useful for the trees that are too large for the whip or tongue grafting but not large enough for cleft or wedge grafting. The best rootstock for this type of grafting is about 2.5 cm in diameter. For this type of grafting, an oblique type of cut is made into the rootstock at an angle of about 20-30°. The cut should be 2.5 cm deep, so that when the branches are pulled back the cut will open slightly but will close when the pull is released.

The scion should be about 7.5 cm long and relatively thin and should contain 2-3 buds. At the base of the scion, a wedge of about 2.5 cm long is made.

Lecture 8. Micropropgation in fruit crops

It refers to the production of plants from very small plant parts, tissue or cells under aseptic (*in vitro*) condition. It is mainly based on the principal of *totipotency*. Strawberry was 1st commercially propagatedby micropropagation technique

Advantages:

1. large scale multiplication of virus free panting materials in limited time & space
2. Through out the year production
3. Beneficial in plants where vegetative propagation is not easy like papaya
4. Production of secondary metabolites
5. Long term storage in lesser space
6. Production of seedless variety through embryo rescue (Grape)
7. Shortening of breeding cycle
8. Homozygous plant production

Methods of micropropagations

- **Meristem tip culture:**Itconsist of 1 or 2 pairs of leaf primordia. Helpful for the elimination of virus from infected plant.
- **Callus culture:** Unorganised mass of parenchymatous cells. Organogenesis in two steps- 1st formation of meristem and 2nd active growth of stem bud and root
- **Anther culture:** produce homozygous plants. 1sy t time reported by Guha & Maheshawari (1959) in Datura. Stage- near microscopic mitosis, when pollen grain pass through uninucleate to binucleate condition.
- **Cell suspension culture:** Homogenizing a piece of callus into liquid medium and shaking with shaker until medium become cloudy with suspended cells.
- **Ovule culture:** Unfertilized or just fertilzed ovule excised and cultured. Helpful to obtained plant in self compatible species
- **Embryo culture:** Embryo excised at immature stage but before their degeneration

Different stages of micropropagation

- Shoot initiation
- Shoot multiplication
- Shoot elongation
- Rooting

- Acclimatization

Applications

- In India, the technique has been perfected in banana, grape and papaya
- Banana: Shoot tip excised from rhizomes of sword suckers
- Grape: Shoot tip with two nodal micro cutting, embryo rescue
- Papaya: Shoot tip

Limitations:

- Costly
- Require technical skill
- Chances of contamination
- Plants having high level of phenols (mango, datepalm, coconut) not responds properly

LECTURE 9: PROPAGATION STRUCTURE

1. Polyhouse: When the green houses are covered with plastic then it is called polyhouse.

Polyhouse

2. Net house: When the glazing material in greenhouse is net then it is called net house. Net house may be half shade net house or complete net house.

Net house

3. Plastic tunnel: It is tunnel like structure covered with plastic and smaller than playhouse. Its cost of construction is very lesser than Plastic tunnels; therefore small income group farmers easily may construct it. It is constructed on arch shaped steel or bamboo body. Small plants like vegetables, flowers can be cultivated inside it. Sometimes portable plastic tunnels are constructed. These portable tunnels can be kept at safer place when they are not in use.

Plastic tunnel

4. Mist chamber: It is nursery or plant propagating structure in which water is sprayed in the form of mist to maintain high humidity. The objective of misting is to retain a continuous film of water on the leaves to maintain turgidity by reducing transpirational loss. Mist chamber also prevents from disease infection in cuttings by washing off fungus spores before they attack the tissues.Generally fine sized nozzle is used to produce very fine mist. The water should have good pressure and it must be free from salts. The optimum pH of water to be used in mist unit is 5.5 to 6.5. Well-drained rooting medium is used for adequate removal of excess water.

Mist chamber

Plant growing structures / containers:

In nursery, seedlings or saplings are grown in containers. The containers are used for

1. Raising of seedlings
2. Raising rootstocks
3. Hybrid seed production
4. Growing potted plants

Advantages of containers in greenhouse production

1. Uniform production of planting materials

2. Quality production

3. Easy to maintain

4. Reduce production time

C. Store house: It is very necessary for storing of fertilizers, implements, tools, nursery stocks like seeds, bulbs, corms, tubers and other planting materials. A store house has generally two compartments, one is for storing of fertilizers, implements, tools and the other is for seeds, bulbs, corms, tubers and other planting materials which is well ventilated. Store house is made up of brick and mortar where seed compartment contain wooden or split bamboo shelves in several layers for storing bulbs, corms, tubers and other planting materials

Lecture 10: SEED DORMANCY

Seed dormancy refers in seeds to failure of a viable seed to germinate even when given favourable environmental conditions. In many species can get a clue about requirements for breaking dormancy by studying the natural environment of the plant.

Significance of Dormancy

1. From an ecological perspective, dormancy is an important survival mechanism that favours propagation and dissemination of seeds to establish plant populations.
2. Dormancy allows the seeds to remain in suspended animation without any harm during drought, cold or high summer temperature.
3. The dormant seeds can remain alive in the soil for several years. They provide a continuous source of new plants even when all the mature plants of the area have died down due to landslides, earth quake, floods, epidemics or continued drought.
4. It helps the seed to get dispersed over long distances through unfavourable environment or inhospitable area.
5. The small seeds with impermeable seed coat belonging to edible fruits come out of the alimentary canals of birds and other animals uninjured e.g., Guava.
6. Dormancy induced by the inhibitors present in the seed coats is highly useful to desert plants. The seeds germinate only after a good rainfall which dissolves away the inhibitors. The rainfall ensures the seed a proper supply of water during its germination.
7. It follows storage of seeds for later use by animals and man.

<u>**Dormancy Classification**</u>

Basically it is of two types-

A) Primary dormancy: It induced during seed development resulting in seeds that are dormant when dispersed from the mother plant.

B) Secondary dormancy: It induced by unfavourable environmental conditions following shedding of mature seeds from the parent plant. Secondary dormancy can be induced by conditions unfavourable for germination, such as adverse temperatures, illumination or oxygen. Types of secondary dormancy include:

i) Thermodormancy: It is caused by prolonged exposure of imbibed seeds to temperatures unfavourable for germination, generally high temperatures.

ii) Skotodormancy: It is induced in seeds that require light for germination when they are imbibed in the dark for extended periods of time.

iii)Photodormancy: It occurs in seeds that are inhibited by light when they are exposed to an excess of light.

Note, that secondary dormancy is not only induced in non-dormant seeds, but also in seeds that already have some form of primary dormancy. For example, a lettuce seed that requires light to germinate is said to be photosensitive and, when imbibed in the dark, it will not germinate until light is provided. However, if dark imbibition is extended for a period of time, skotodormancy can be induced and the seed will not germinate even if it is placed under optimum light conditions.

However, primary dormancy can again be classified into the following ways-

A. Seed coat dormancy

1. Physical dormancy – Here the seed coats are impermeable to water with low moisture level. Legumes are an example. Embryo is generally quiescent. The cause of physical dormancy is the structure of the outer cell layer which becomes impermeable to water. Macrosclereid cells, a mucilaginous outer cell layer, or a hardened endocarp are three reasons that seed coats become impermeable to water. Such seed coats develop during the last stages of seed development.

2. **Mechanical dormancy -** Seed coats are too hard to allow the embryo to expand during germination. Causes include: Structure of seed coats or remaining fruit. Occurs in olive.

3. **Chemical dormancy -** Presence of chemical inhibitors in the outer coverings of many fruits and seeds. This occurs in fleshy fruits, hulls, and capsules of many dry fruits. Examples are apples, citrus, grapes, desert plants. Very often this kind of dormancy disappears with dry storage. This kind of dormancy may also be present in other tissues surrounding the embryo such as the endosperm.

B. Morphological dormancy- Embryo is not fully developed at time of ripening. Need additional embryo growth after the seed is separated from the plant. This type of dormancy mainly observed in several herbaceous flower, seed such as Ranunculus, poppy; woody species such as holly; tropical plants such as date palms.

C. Endogenous dormancy: Here the dormancy is controlled internally within the living tissues of the seed. It may be exerted by semi-permiability of the seed cpvering and secondly due to dormancy present within the embryo. It may be of two types-

i. **Physiological dormancy:** Most of the temperate fruits (apple, pear, peach, plum, cherry), vegetables and flowering annuals have physiological seed dormancy lasting from 1-6 months, which disappear on storage. The seeds of these species have physiologically immature embryo and they do not germinate even under favourable conditions.

ii. **Embryo dormancy:** Here the dormancy is due to dormancy of the embryo which over winter in soil and germinate in spring under natural condition.

D. Epicotyl dormancy: Seeds of some species have different stratification requirement for their radicles, hypocotyls and epicotyls and this type of dormancy is called as epicotyls dormancy. On the basis of chilling requirement for epicotyls, different plant species are divided into two sub groups. In one group, seed germinate initially during warm period of 1-3 months and produce roots and hypocotyls but these require 1-3 months chilling for epicotyls to germinate as in lity and peony.

E. Double dormancy: In certain plant species, seeds have dormancy due to hard seed coats and dormant embryos. This is called as double dormancy. For proper germination, both the blocking conditions must be modified to allow water to penetrate the embryo and after ripening of the embryos. This type of dormancy is found in trees and shrubs producing seeds with hard seed coats, grown primarily in cold winter area. To overcome the problem of double dormancy, the seeds are first treated in a way to soften the seed coat and then cold stratification treatment is given to them.

<u>**Methods to Overcome Dormancy**</u>

The methods to overcome dormancy are better understood once the mechanisms of dormancy are known. For instance, if the cause of dormancy is an impermeable seed coat that impedes seed water uptake, removing the seed coat or reducing its permeability should break dormancy. When dormancy is caused by an underdeveloped embryo, additional time for embryo growth should overcome dormancy. Finally, when dormancy is imposed by a physiological mechanism, actions that decrease the amount of or sensitivity to dormancy-inducing compounds (e.g., ABA), along with actions that increase the amount of or sensitivity to dormancy-breaking compounds (e.g., GA) should break dormancy. This table shows effective methods in overcoming dormancy of different species.

Here are common methods to overcome dormancy:

• Scarification

• Afterripening

• Stratification (chilling)

• Use of chemical compounds

• Light

• Leaching

• Alternating temperatures

• Priming

Scarification is a treatment that removes or abrades the seed coat, allowing water uptake into the seed and promoting germination. There are two types of scarification treatments: mechanical and chemical.

Mechanical scarification includes a diversity of treatments that alter seed coat impermeability by mechanical means, such as grinding seeds with abrasives or sand, use of sand paper, piercing the coat with a needle, brief inmersion in boiling water, heating, cooling, drastic temperature shifts, etc.

- *Chemical scarification* involves the use of a chemical compound to degrade the seed coat. The most common compound used for chemical scarification is sulfuric acid.

Other alternatives are sodium hypochlorite and hydrogen peroxide.

It must be noted that, despite dormancy breaking and enhancement of germination, scarification treatments create damage to the seed due to the disruption of essential cells, favoring fungal invasion and mechanical injury. Precautions should be taken to minimize damage while maximizing dormancy relief. (108) For instance, optimal times for chemical scarification with sulfuric acid should be determined for each species. Longer periods will damage the seed, while shorter periods will be ineffective in dormancy breaking. In this example, 90 minutes in sulfuric acid were effective to overcome physical seed dormancy in *Acacia caven*. Note the improvement in seed germination of treated- versus non-treated seeds. (109) In this picture is the difference in volume of treated versus untreated seeds, showing the lack of water uptake in non-treated seeds.

While 90 minutes of scarification in sulfuric acid are required to overcome *Acacia caven* seed dormancy, in the case of *Prosopis chilensis* only 10 minutes was required. In this species more time would result in severe seed damage, while 10 minutes in *Acacia caven* would be ineffective in dormancy breaking.

Afterripening is defined as the progressive loss of dormancy in mature dry seeds. Afterripening rates may increase in response to environmental factors such as increased oxygen and temperatures and decrease with increasing seed water contents. (112) In this figure, the effects of afterripening in reducing seed dormancy of *Phleum arenarium* are presented. After 6 and 13 months of dry afterripening, the seeds achieved higher germination percentages under a wider range of temperatures.

Although the mechanisms explaining afterripening remain unknown, some possiblilities exist. For example, in seeds with morphological dormancy, afterripening may explain the progressive growth of the embryo during dry storage.

Afterripening in seeds with physiological dormancy could be associated with a reduction in the concentration of a inhibitory compound or a lower sensitivity to it. For example, this table shows how the seed ABA content from two tomato genotypes decreased after one year of dry storage.

Stratification is the exposure of the imbibed seed to low or warm temperatures. Because the most common approach is to expose seeds to cold temperatures, stratification is often used as a synonym for chilling or prechilling treatments. Use of warm stratification has been usually associated with release of morphological dormancy, while cold stratification has proven effective in overcoming physiological dormancy.

The temperature used for cold stratification usually ranges from 3 to 10°C, and the times of treatments vary depending on the species. While cold stratification is an absolute requirement for germination for some species; in others, it may only improve germination rates or uniformity. For some species, cold stratification may increase the range of temperatures under which germination occurs, or increase light sensitivity in species that require light for germination. (115) Effects of cold stratification in seeds with physiological dormancy are probably the result of changes in the balance of endogenous promoters and inhibitors. For instance, this figure shows the changes in ABA and GA concentrations in plum seeds during stratification. A drastic reduction in the ABA concentration and increase in GA concentration occurred that would explain dormancy breaking in this species after stratification.

In this example, germination rates of liquidambar seeds were improved by a stratification treatment of 15 days at 0°C, and this effect was similar to seed imbibition in a GA solution. Note that final germination percentage was similar in both treated and untreated seeds.

Chemical compounds. Imbibition of dormant seeds in a solution containing a compound that induces germination is another alternative to breaking physiological dormancy. An obvious and effective choice is imbibition of seeds in a GA solution. Other compounds that have been used to break dormancy are potassium nitrate, ethrel, butenolide (the active ingredient from smoke), hydrogen peroxide, and anaesthetic compounds (e.g., acetone, ethanol).

Light. Light quantity and quality can provide information about a seed's relative position in the soil or surrounding vegetation. Many seeds, especially small seeds, require light for germination. One of the most common and best studied examples is lettuce. This figure compares germination of lettuce seeds from a photosensitive genotype in dark vs. light. In lettuce and other species, the light mediated induction of germination in seeds is governed by phytochrome, which implies that red light induces germination and far-red light inhibits it. It has been determined that *Pfr*, the far-red absorbing or activated form of phytochrome, induces germination by promoting GA synthesis.

In some species, continuous light may inhibit germination. Onion and leek are examples of species where seed germination has been reported to be inhibited by continuous light. In these cases, seeds must be germinated in the dark.

Leaching. Physiological dormancy may be overcome by modifying the balance of compounds that inhibit and promote germination in the seed. In some cases such as beet seeds, dormancy may be alleviated by exposing seeds to running water that dilutes or removes the inhibitory compounds from the seeds. This treatment is known as *leaching*.

Alternating temperatures. In addition to light, temperature fluctuation is another signal for a seed regarding its relative position in the soil or surrounding vegetation. Deep in the soil and in the middle of abundant vegetation, temperature fluctuations during the day and night are lower than near the soil surface or in a gap without surrounding vegetation. This variation may explain, in part, why seed germination in some species is favored by alternating temperatures compared to a constant temperature; e.g., 30/20°C day/night versus a constant 25°C. Changes in hormone sensitivity have been suggested as a possible mechanism mediating induction of germination by alternating temperatures.

Priming treatments enhance germination percentage, uniformity and rate in several species. Additionally, in some species such as lettuce, priming treatments alleviate thermoinhibition and the light requirement for germination.

Lecture 11: PRINCIPLES OF ORCHARD ESTABLISHMENT

Orcharding is a long-term investment and deserves very careful planning so, no mistakes should be made initially on selection of site for fruit growing. Thus one should give atmost attention and care, while planning a new orchard.

(A) Site selection:

Selection of proper site for orchard is the most important aspect and number of factors considered during orchard establishment. Fruits are perishable in nature so needs to quick transport facilities for its marketing for getting decent returns. There production centres should be near to the market. Other factor, which have an important to success of an orchard in a particular locality are near to the market, railway station, transport facility, easy accessibility by road, storage facility, water supply, nearness to processing plant, etc. The following factors are to be considered before selecting a site for an orchard.

1. Climate: The climate of the locality should be suited to the fruits, or the fruit chosen should be suited to the climate. Enquires should be made on the following points to assess how climate affects the fruits intended to be grown.

a. Experience of the fruit growers and research stations in the locality regarding the acclimatization of the fruits under consideration.
b. The seasons of heavy rainfall, hail storms and hot winds.
c. The seasons and intervals of cyclones, heat waves and other catastrophic features

2. Soil: Few prospective sites should be examined for both physical and chemical properties. For this purpose profile pits of 2m depth should be dug in each representative part of the site as suggested by external appearance, samples should be collected and analyzed for deciding the choice. Soil samples must be analyzed to know the suitability of soil for growing fruit crops. Soil analysis gives information on the type of soil, its fertility; its pH value etc. As far as possible flat land should be selected. There should be no hard pan up to a depth of 2m.

3. Irrigation facilities: Most of the horticulture crops are raised under irrigation. So the water facilities should also be taken in to consideration (quantity and quality).Water table should be below 2 m depth.

4. Nearness to the market: Saves the over head charges in transport and gives close touch with market tastes (in the case of market gardens).In most cases a large percentage of the retail price of fruits is accounted for by transport charges.

5. Transport facilities: Fruits being perishable cannot be moved for long distances without quick and refrigerated transport. Bananas from the south are not reaching northern market in our own country owing to the absence of refrigerated transport. But under refrigerated conditions, they can be transported to longer distances. So; the orchards must be located where there is quick transport, preferably a refrigerated transport system.

6. Power (electricity) supply: It would be a great advantage if electric power lines are running in the proximity of the area as it can be tapped easily.

7. Proximity to established orchards: It is an added advantage if the site is in proximity to the already established orchards because of compactness of areas of production facilitates provision of transport and storage facilities. It also enables formation of co-operative societies and other associations which can collectively own grading and spraying machinery and other costly equipment including storage facilities. If there are compact blocks of single crop say citrus, banana, mango etc. the spread of diseases and pests are more.

In selecting a site close to other orchards, one must make sure that they are free from devastating pests and diseases like citrus scale, canker, panama disease of banana, the tristeza disease of citrus.

8. Availability of labour: Large orchards are started often in out of the way places and forest areas away from populated centres.It would therefore be necessary to ensure that adequate labour is available for orchard operatins.This point is of important in plantation crops particularly.

9. Social factors: These assume importance when large contingents of labour and managerial staff are to be employed as plantations or large orchards. They should be provided with medical and educational facilities, so that, they are content and stick on to the jobs.

(B) Fencing

Encroachment of trespassers, theft and animal grazing are the matter of common concern in fruit orchard. Live fencing is an age old and traditional practice. The fences act as wind break also if grown by using live plants particularly in the areas where cold and hot winds are the problem. The main purpose of fencing is to protect the plants from stray animals and harmful effects of cold and hot waves. Besides protection, the main function of live fences is to provide fuel wood, fodder and food, and enriches the soil. Therefore, fencing the orchard is an important aspect in fruit cultivation.

Traditional farmers have vast knowledge about the practice of live fencing and the species used. Planting live fence with tall growing trees as first row and small, bushy thorny plants in staggered manner as second row along the boundary of orchard is very much important. In sloppy lands, windbreaks should be planted along with contour in ascending and descending order to protect the plants even at higher points. At such places, the live fencing cannot be combined with wind break and must be planted along the boundary.

Fast growing hardy plants species can be grown as fence post at a spacing of 4-5m. These plants commonly grown by seeds or maintained from natural vegetations growing along the boundary to have strong root system. Farmers can also plant stakes of easy to root species such as Gliricidia sepium, Moringa, Flame tree etc. The live fence posts are more durable than traditional wooden poles as they are less prone to attack by termites and decay fungi. When grazing animals are part of the farming system, the only way to establish live fence posts and a living fence, is to start with a conventional wire fence supported by wooden pole and to gradually establish live fence plants to substitute for the decaying poles. Gliricidia live posts fence can be established by planting a few large (1.5-2.0 m) stakes in the existing conventional wire fence. These stakes normally take root within a month or so. After the first pruning, subsequent pruning can be carried out every 4 to 8 months. Shoot pruning at intervals of 6 to 8 months result in woody sprouts that are suitable for use as stakes. These pruned twigs can be used to multiply live stakes for fence posts within a year or two after establishing the first live fence posts. Palmyra palm, Babool, Simaruba, Jamun, Jangal jalebi, etc. can also be planted as fence posts.

Some hedge plants make a thicker and denser fence. Such plants include a number of species which do not require additional support of barbed wire. To minimize the initial cost of orchard establishment, it is advisable to establish dense and thorny hedges to protect the orchard. Another alternative often used by farmers is the combination of easy to establish live fence plants that are poisonous and unpalatable species. If well established, these natural barriers can deter both animal and human trespassers from entering into the orchard. A live fence should ideally be planted just before the monsoons and watered regularly after the rainy season is over to ensure optimum growth. Agave, Sisal, Boradi, Karonda and Mehandi etc. are the promising plant species which can be planted as live hedge along the orchard boundary.

(C) Windbreak

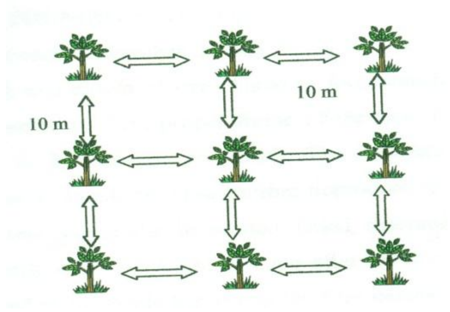
Tall trees are planted on the border of the orchard to reduce the impact of wind on the fruiting of the fruit trees. Windbreak is commonly tall trees having dense foliage and keeps the surrounding atmosphere humid. These trees help in minimizing the wind velocity, impact of high temperatures which adversely affect the young plants and cause excessive fruit drop. Trees, which are generally used as windbreak, are seedling mango, jamun, mulberry, moringa, jackfruit, carambola, shisham, teak, gamhar and bamboo. These can also be used as live fencing posts. These trees are usually planted close to each other to provide an effective shield. Tall growing trees like shisham and jamun are planted 6m apart while low headed trees like mulberry and carambola are planted at 7m distance. Normally, plants grown as wind break may extract nutrients from fruit plants. Therefore, a trench of one meter depth should be dug between fruit plant row and wind break.

(D) Planting system:

The following are the important system of planting generally followed on the basis of agro-climatic condition:

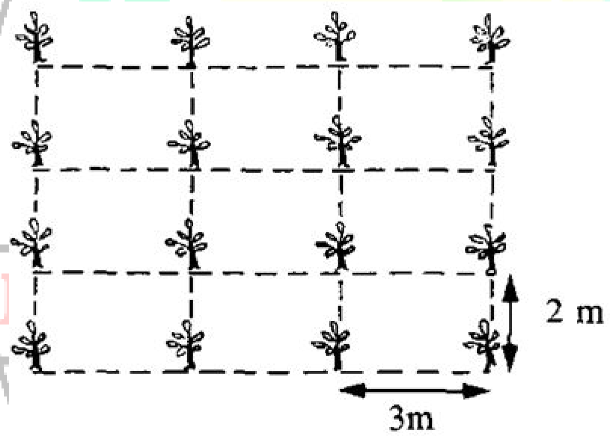
1. Square system:

In this system a tree is planted at each corner of a square whatever may the Planting distance. The distance between row to row and plant to plant is 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.



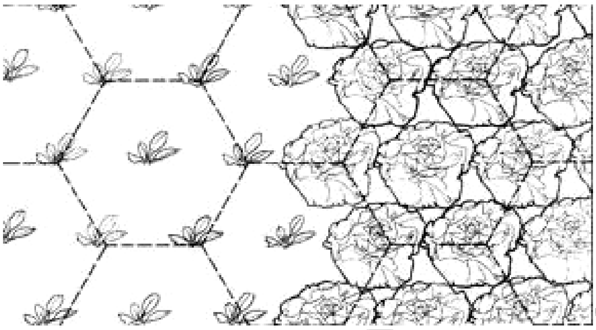
2. Rectangular system:

Similar to square system, except that the distance between plants in the row and distance between rows is not the same but different. 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. Row to row distance is more than that from plant to plant in the row.



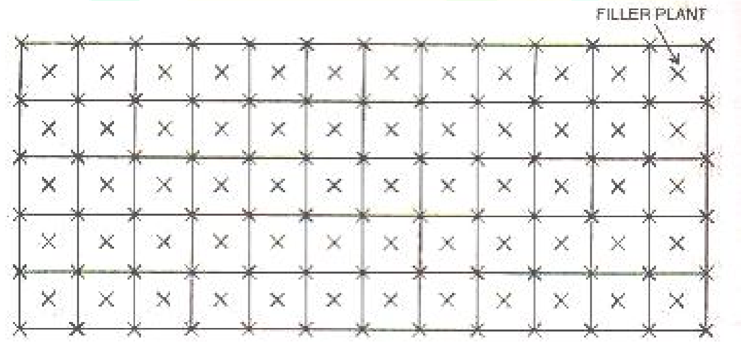
3. Hexagonal system:

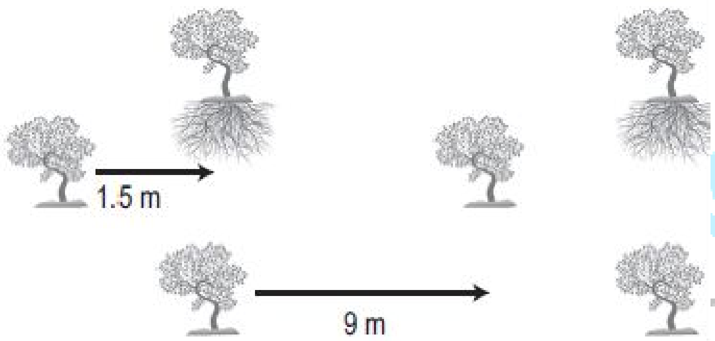
In hexagonal system, the trees are planted in the corners of equilateral triangles. Six trees thus form a hexagon with another tree at its centre. This system, though a little difficult for execution but accommodates 15 percent more plants. Cultivation of land between the tree rows is possible in three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



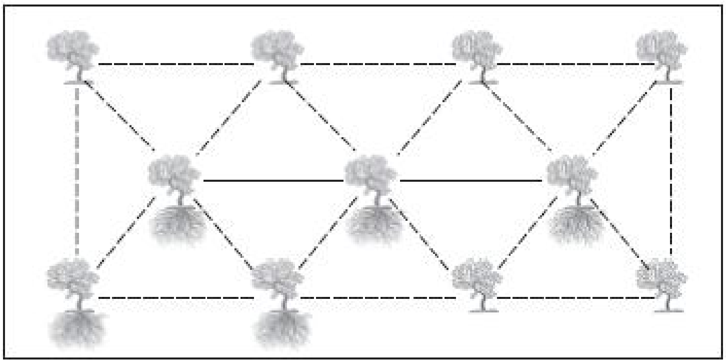
4. Quincunx system:

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 this 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.



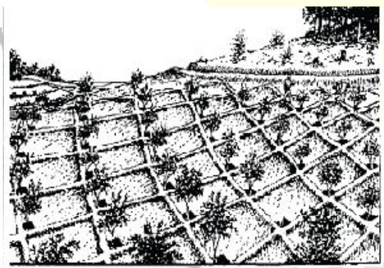


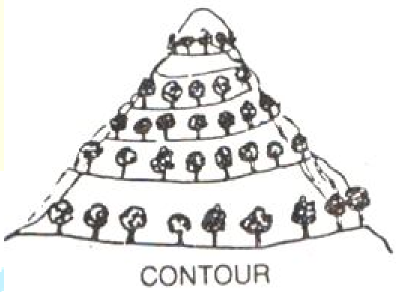
5. Triangular System; A pattern in which plants in alternate rows offset half the space between plants in a row. The distance between the rows is the same or more than that in a row. Thus a series of iso-scales triangles (two sides equal, instead of three as in an equilateral triangle) are formed. This is easier to layout than the hexagonal pattern but results in 9% fewer plants than the equivalent square or rectangle.



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.

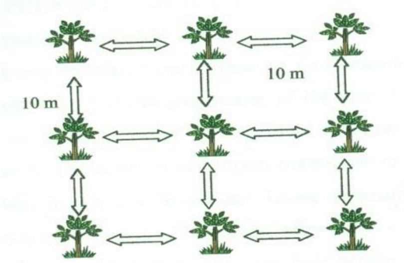




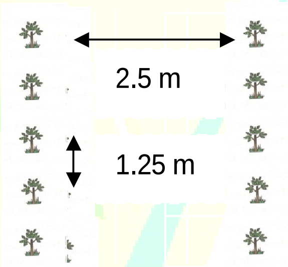
(6) Planting systems under high density planting (HDP):

High density planting is one of the important methods to achieve higher productivity per unit area both in short duration and perennial horticultural crops. Such system produces precocious cropping, high and regular yields of good quality fruits and low labour requirement to meet ever rising production costs.

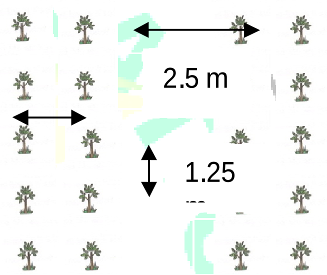
Planting systems	Spacing(m)	No. of Plant/ha
Square	2.5 x 2.5	1600
Hedge Row	1.5 x 2.5	2670
Double Hedge Row	(1.25 x 1.25) x 2.5	3556
Paired Planting	(1.25 x 2.5) x 2.5	2133
Cluster Planting	(1.25 x 1.25) x 2.5	2844



Square system



Single hedgerow



Double hedgerow

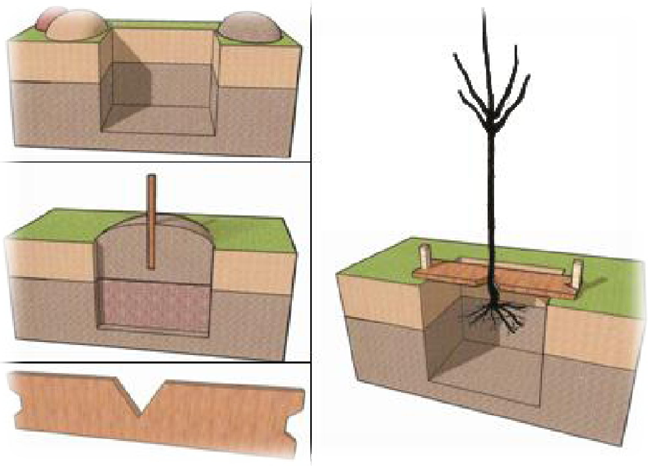
Paired Planting

Cluster Planting

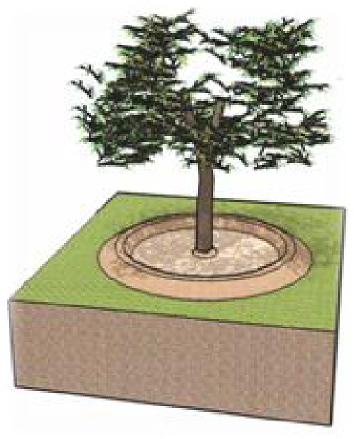
Planning and establishment:

Digging and filling of pits: Generally the pits are dug 2 to 3 months in advance of planting i.e. March to May. Allow the pits to weather. A planting board (a plank about 1.5m long or longer with two end notches and a center notch) is applied to the marking peg by its central notch and two pegs are driven at the end notches. Then the board and the marking pegs are removed and a pit of 1-meter cube is dug. The two pegs driven at the end notches remain in position on either side of the pit. All pits are dug similarly so that plant position is not altered at planting time. While digging, the top soil should be kept on one side and the bottom soil on another side separately as the topsoil is somewhat fertile than the bottom soil. While filling the pits, the topsoil is mixed with farmyard manure or compost, leaf mould or green leaf and a kilogram of super phosphate. Then the pits are filled with the bottom layer of soil first and then with the topsoil mixed with the manures. The soil after filling should rise about a foot over the orchard level so as to allow for shrinkage on setting.

Filling is done a fortnight or two after digging pits. The pits are filled with a mixture of Top soil; FYM, leaf mould and bone meal. Pits are filled a few inches above the ground level for shrinkage and settlement.



Planting method



Basin Around Tree

Lecture 12: HIGH DENSITY PLANTING

Accommodation of the maximum possible number of plants per unit area to get the maximum possible profit per unit of the tree volume without impairing the soil fertility status is called the **High Density Planting**. Basically the availability of a dwarf plant is the first and foremost pre requisite for establishing any high density orchard. It may be achieved by different approaches like use of dwarf cultivar, dwarfing rootstock/interstock and with the use of the growth retardants like daminozide, ethephon, chlormaquat and paclobutrazal. However closer spacing, growth regulation by the training and pruning, use of mechanical devices etc may also be tried either singly or coupled with other crop management practices for a successful adaptation of this concept. This concept has been successfully developed in a number of fruit crops by using various techniques in India.

High density planting is one of the improved production technologies to achieve the objective of enhanced productivity of Indian fruit industry. Yield and quality of the produce are two essential components of the productivity. High density planting aims to achieve the twin requisites of productivity by maintaining a balance between vegetative and reproductive load without impairing the plant health.

Based on plant population, HDP is termed as low HDP with less than 250 trees/ha, higher HDP with 500-1250 trees/ha and ultra HDP with more than 1250 trees/ha. Recently, super high density planting system has been also established in apple orchards with a plant population of 20,000 trees/ha. Still dense population of about 70,000 trees/ha is followed in certain orchards and this system of planting is referred as meadow orcharding as practiced in apple. The term **'meadow orchard'** which amounts to growing fruits without trees was coined by Hudson (1970) to describe an ultra high density apple orchard meant for mechanical harvesting by mowing the tress with their fruits as grass in a meadow. In the experimental meadow orchard of Luckwill (1978) the budded apple on clonal dwarfing rootstock were planted at a spacing of 30×45 cm (70,000 trees/ha).

Characteristics of HDP

- The trees of HDP should have maximum number of fruiting branches and minimum number of structural branches.
- These branches should be so arranged and trained in such a way that each branch casts a minimum amount of shade on other branches
- The height should be one and half its diameter at the base. A key to successful HDP depends upon the control of tree size

Advantages of High Density Planting:

- It induces precocity hence earlier production and higher return per hectare.
- Best utilization of land and resources.
- Increase in yield per unit area.
- Quality production of fruit crops.
- More efficient use of fertilizers and irrigation water due to greater root densities per ground area.
- Efficient pesticidal application due to better spray interception.
- Easy for other intercultural operation like training and pruning, harvesting since dwarf rootstocks are used.
- To obtain export quality of the harvest.

Disadvantages:

- Higher costs for planting and orchard care due to greater number of trees per hectare
- Lack of promising dwarfing rootstocks in mango, guava, sapota, peach, sweet cherry etc
- HDPresultsinovercrowding,over lapping not only in the tops,but also in the root system and heavy competition for space,nutrient sand water.
- More important is build up of high humidity, lack of cross ventilation in the orchard,which is more conducive for buildup of pests and diseases.
- Less life span of the fruit trees, reduction in yield in the long run after 15 years of age.
- Difficult to manage the tree canopy.
- Require high techniques for the maintenance of fruit trees.

Lecture 13: PRINCIPLES AND METHODS OF TRAINING IN FRUIT CROPS

Training is a practice in which tree growth is directed into a desired shape and form. Training young fruit trees is essential for developing a suitable structural framework that will last the tree's lifetime. Well trained trees are also much easier to prune than untrained tree.

Training is a broad term involves tying of branches to posts or tied or supported over a trellis or pergola in certain fashion or sum of its parts are removed or trimmed with a view to give the plant a particular desired shape.

Objectives of Training

- The main objective of training is to control and regulate shape of trees so that orchard cultural operations, harvesting can be done easily.
- To admit adequate sunlight and air to the centre of the tree and to expose maximum leaf area to the sun.
- To build the strong frame work of tree and arrangement of scaffold branches.
- To help to have a better crotch angle between scaffold branches of the tree.
- To build the structure of the tree in such heights at which trees are less exposed for sunscald and wind damage
- Training develops a balance between vegetative and reproductive growth of tree.
- To limit the growth and spread of the tree so that various cultural operations such as spraying and harvesting are performed at minimum cost.

System of Training for Fruit Crops

1. **Central Leader**:

This system of training is adopted in such types of trees which have a pronounced apical dominance. Here the main trunk grows undisturbed. On account of vigorous and rapid growth of the main trunk the tree develops a close center and grows to great heights. A central leader tree has one main, upright trunk, referred to as the leader. Branching begins on the leader 75 to 100cm above the soil surface to allow movement under the tree. In the first year, three to four branches, collectively called a scaffold whorl, are selected. The selected scaffolds should be uniformly spaced around the trunk, not directly across from or above another. Space scaffold whorls every 50 to 60 cm up the central leader, leaving alternate areas without any branches to allow light into the centre of the tree to the desired maximum tree height. The shape of a central leader tree is like that of a Christmas tree. The lowest scaffold whorl branches will be the longest and the higher scaffold whorl branches will be progressively shorter to allow maximum light penetration into the entire tree. Example, Pear

2. Open Center:

In this system, the main stem is allowed to grow only up to a certain height by heading within a year of planting and all the subsequent vegetative growth promoted by lateral branches. These results in a low head and as such the bulk of crop come closer to the ground. In contrast to the central leader system, all sunshine is equally distributed to all the branches in open center system. The open center trained trees are more fruitful resides greatly facilitate the operation like spraying, thinning and harvesting. However, the branches form weak crotches since the branches arise very close to one another almost from the same point. So there is a certain amount of risk of splitting of the branches when there are a heaver number of fruits on the trees. In areas of high light intensity, such trees suffer from severe sunscald injuries, e.g Peach, Apple etc.

3. Modified Leader System:

This system stands intermediate between the central leader and the open center, combining the advantages of both the system. It is developed first by training the tree to the leader type allowing the central stem to grow unsharpened for first two to five years. The main branches are allowed to arise on the main stem at reasonable intervals. After the required number of branches has arisen the main stem is cut off. The top laterals will take the place of the main stem. The result in a fairly strong and moderately spreading type of tress. E.g. Pear, Apple, Walnuts, etc.

Lecture 14: PRINCIPLES AND METHODS OF PRUNING IN FRUIT CROPS

Pruning is defined as the judicious removal of plant parts (Undesirable branches, shoots, roots or any other part of a plant) with an objective to obtain good and qualitative yield. The ultimate aim of pruning is to develop a canopy, which intercepts maximum Optimum light interception hence improves size, firmness, soluble solids, and other quality attributes. The extent and intensity of pruning on the same tree varies from year to year, depending on the growth of the tree, its bearing and season.

Methods of pruning

1. Thinning out: When a shoot is removed entirely from the inception (from the point of origin) so that, no new shoot arises from that place, it is referred as **thinning out**. This thinning is practiced in the removal of shoots arising in unwanted places, water shoots etc.

2. Heading back: When the branches grow tall and vigorously without producing flowers, these shoots are headed back. When only one-third to one-half terminal portions of the branches, having their basal portions intact, are removed, it is referred as **Heading Back.** When the branches having their basal portions intact are removed the apical dominance of the twig, shoot or branch is destroyed and the lateral buds are stimulated to growth. When a branch is cut almost to the base, leaving a few inches of stump, carrying few buds. These buds left on the stump will give rise to shoots which are important to the tree either being spur bearers or bearing flower buds or filling up of gaps in the tree or forming vegetative wood from which flowers may arise in the following year. The shoot from the bud nearest to the cut takes the place of the pruned shoot.

3. De-blossoming: Removal of surplus flowers to enable the tree to produce crops regularly year after year is called **deblossoming**.This is practiced in alternate bearers like mango. apple etc.

Objectives of Pruning

- To distribute the fruiting wood in all directions and to maintain a balance between vegetative and reproductive phases.
- To thin out branches so as to admit more light into the interior of the tree top so that the inner wood also becomes fruitful.
- To improve the quality of fruits in terms of shape, size and colour.
- To regulate the succession of crops and helps to obtain regular bearing.
- To remove diseased, damaged, insect infested and weak shoots.
- To regulate the size and quality of fruit by way of diverting the energy into those parts that is capable of bearing fruits.

Lecture 15: JUVENILTY AND FLOWER BUD DIFFERENTIATION

The non-flowering period after seed germination is called as Juvenility.

- Morphological differences

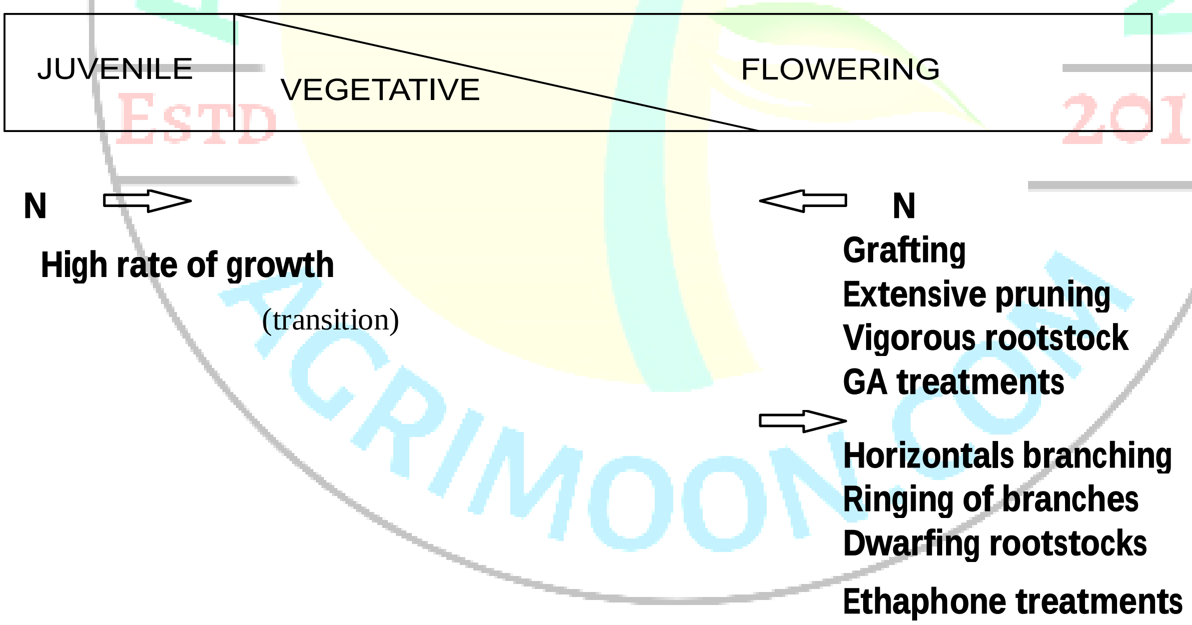
  Leaf shape and thickness

  Ability to form adventitious roots

- Seedling can not be induced to flower by any means

Transition to the adult phase occurs when the tissue reaches a certain stage. Grafting of mature tissues results in shoots that maintain their flowering. Increasing the growth rate by any means decreases the juvenile period

Factors affecting juvenility, vegetative grwoth and flowering



Flowering

3 major developmental processes occurring during two successive growing seasons

- Initiation:
- The time when the meristem is committed to form a flower.
- Usually occurs early during active vegetative growth.
- There are no visual clues to this development

Differentiation:

- Starts the time terminal growth on a tree stops.
- Actual flowering structures appear
- Before entering winter dormancy, flower buds have developed to 85% of their size

Anthesis: Flower opening and shedding of the pollen

Time of flower initiation and anthesis of some deciduous fruits

Kind	Beginning of induction or initiation	Flowers borne on	Season of anthesis relative to season of initiation
Peach	Late June-late July	Lateral buds, 1 yr. shoots	Next spring
Apricot	Early Aug	Lateral buds, 1 yr. Shoots + 2 yr. spurs	Next spring
Cherry, sweet	Early July	Lateral buds, 2 yr. spurs	Next spring
Cherry, sour	Mid-July	Lateral buds, 2 yr. spurs	Next spring
Apple	Mid-June-mid-July	Terminal buds. 2yr.spurs	Next spring
Pear	Early July– early Aug.	Terminal buds. 2yr.spurs	Next spring
Grape	Mid-summer	Compound bur “eye” on last year’s cane	Next spring

Strawberry	Fall	Terminal bud	Next spring
Blueberry	Late summer into fall	One year and older wood	Next spring
Raspberry	Late summer	Floricanes	Next spring

Factors influencing flower bud formation

- The vegetative needs to be at a certain stage. A critical node number is required I.e., 20 nodes for Cox's Orange Pippin and 16 nodes for Golden Delicious
- Hormonal balance
- Change in the distribution of nutrients inside the apical meristem
- Development of flower buds does not start unifromly throughout the tree. In apple the terminal bud of a spur begin their transformation 4-6 weeks earlier than lateral buds

Lecture 16: UNFRUITFULNESS

In an orchard all the fruit trees do not bear equally or regularly and sometimes fail to flower and fruit under similar conditions where another fruit tree bears heavily.

- This failure to set fruits may be attributed to unfruitfulness.
- To understand the problem of unfruitfulness in orchards a familiarity with following terms is necessary.

1. **Fruit setting:** It refers to initial growth of ovary and its associated parts after blossoming and taking it to maturity.
2. **Fruitfulness:** It is the state of plant when it is not only capable of flowering and fruit setting but also takes these fruits to maturity and inability to do so is unfruitfulness or barrenness.
3. **Infertility:** Ability of a plant not only to produce fruits but develop viable seeds and the inability to do so is referred as sterility or infertility. All fertile plants are fruitful but all fruitful plants are not fertile (Seedless fruits).
4. **Self fruitfulness:** Ability of a plant to mature fruits after self pollination.
5. **Self fertility:** Capacity of a plant for the production of viable seeds after self pollination.

- The ability of a plant to produce optimum crop is **Fruitfulness**. Where as,
- The inability to achieve this is referred to as **Unfruitfulness**.

o This unfruitfulness is one of the serious problems of many orchards and its causes need to be understood properly for effective control and obtaining economically acceptable production level.

o The causes to this problem can be many and they have been broadly grouped into **two categories**

(A) Internal factors

(B) External factors.

A. Internal factors associated with unfruitfulness: There are a number of internal factors which are associated with unfruitfulness or sterility. They have further been categorized into three major categories, they are

1. Evolutionary tendencies.
2. Genetic influence.
3. Physiological factors.

1 **EVOLUTIONARY TENDENCIES**: In the process of evolution, a number of situations may lead to imperfect flowers or varied developmental periods leading to unfruitfulness unless suitable measures are adopted.

i. **Monoecious and Dioecious nature:**

- A plant with stamens and carpels in different flowers on the same plant is **monoecious. Eg.** Coconut, Arecanut, Pecan nut, Capri fig and Hazel.
- In monoecious fruit plants in general there is no or very little problem of pollination, fruit setting and fruitfulness. Nevertheless, pollinators need to be ensured.
- Plants which bear male and female flowers on different plants are known as **Dioecious. Eg.** Papaya, Date palm and Strawberry.
- Likewise a few varieties of plum produce too little pollen to call them bisexual.
- Profuse flowering without fruit set in ornamental pomegranate is a result of their being unisexual.
- A number of sex forms have been reported in papaya by different scientists.
- In case of figs two types of flower clusters are borne namely staminate and pistillate flowers.
- In Capri fig staminate flowers are borne near the eye and pistillate flowers are borne near the end. To ensure good fruit set, retention of a few staminate trees (9:1) is essential as pollinizers.

ii. **Heterostyly:**

- A condition in the flower where length of the style, relative to other parts of the flower, differs in the flowers of different plants.
- In this case in some flowers styles are short with long filaments and in some of the flowers of some species or varieties styles are long with short filaments.
- Thus styles and stigmas at different height prevent self pollination.
- In case of brinjal there are 4 types of flowers according to their length of style i.e. long, medium, pseudo short and true short. Out of these pseudo short and true short do not produce any fruit.
- Similarly in delicious group of apples extreme upright positions of the stamens accompanied by spreaded petals do not permit bees to do pollination while collecting nectar.
- When the pistils of heterostyled plants are pollinated with pollen from the same flowers or from other flowers containing stamens of an equal height the union may be fruitful but it is likely to be of varying degree of sterility. Here arrangement for cross pollination needs to be created.

(ii) **Dichogamy:**

 When stigmatic receptivity period does not coincides with pollen viability in monoecious plants it is known as dichogamy.

 In dichogamy self pollination is prevented in perfect flowered plants, due to maturity of two sex elements at different times.

 If the stamens ripe before the stigmas become receptive the flowers are known as **protoandrous** and if stigmas become receptive before the stamens produce viable pollens it is known as **protogynous**. This results in low production of fruits.

 Protogyny is present in monoecious plants like walnuts, hazels, etc. whereas protandry is present in many coconut varieties.

 Majority of dioecious plants are also protogynous.

(iii) **Abortive Flowers or aborted pistils or ovules**:

 This occurs in the developing flower‗s pistils and stigmas of many species and is responsible for failure in fruit setting.

 Abortion of partially developed flower buds is common. Setting and maturity of two sexes depend on the erosion of two properly formed sex cells.

 Any interference with their development and functioning may lead to sterility or unfruitfulness; such things can be observed in some grape varieties and tomato varieties.

 The late flowers of strawberry cluster are always abortive. This is more common in indeterminate type of plants.

 Degeneration of pistils takes the form of abortion and it is more common in ornamental pomegranate.

 Certain olive varieties have 10-60% abortive embryos.

 It is also common in some apple varieties. Embryo sac abortion becomes a cause of seedlessness in certain instances than fruitfulness.

(iv) **Impotence of pollen**:

 Many varieties of grapes produce non viable or impotent pollens though they appear as perfect flowers.

 Sterility in grape varieties was the result of impotent pollens. Sterile pollen in the grape results from degeneration processes in the generative nucleus or arrested development prior to mitosis in the microspore nucleus.

 This is also common in ‗J.H. Hale peach, Washington Navel orange and ‗Tahiti‗ lime.

2. GENETIC INFLUENCES

 Self sterility is a condition determined by the inheritance received but can develop in favourable environment. Self sterility affects it's off springs as well as hybrids.

(i) Sterility and unfruitfulness due to hybridity:

 Generally wider the crossing, greater is the degree of sterility encountered.

 The cross between peach and plum bears abundance of flowers but they are without pistils with malformed stamens.

 Flower characteristics were constant sterile and barren.

 A hybrid between the pear and the quince was seedless.

 Most of the citranges (cross between sweet orange and *Citrus trifoliata*) produce no fertile female gametes.

 Seedlessness in most of the banana and pineapple varieties is due to hybrid nature of their ancestors.

 Most of the triploid apple varieties produce aborted pollen.

 A number of hybrids between *Vitis rotundifolia* and *Euvitis* are completely sterile.

 Similar was the case with hybridization of *Vitis vinifera* and *Vitis rotundifolia.*

(ii) **Incompatibility** :

 One of the most common causes of self unfruitfulness and self sterility is due to incompatibility between the pollen and ovules of the same plant or of the same variety.

 Pollen and ovules are fertile but they fail to affect conjugation.

 In apple, pear, plum and aonla self incompatible varieties require another pollinizer varieties for fruit setting.

Self incompatibility has been reported in some of the mango varieties like Langra', Dashehari' and Chausa'.

 Self sterility and self unfruitfulness has been reported in apple, pears, plums, almond, apricot, the Clementine' mandarins, may be attributed to incompatibility where normal processes of fertilization fails somewhere between production of functional gametes and the fusion of sex cells.

3. PHYSIOLOGICAL INFLUENCES:

(i) Slow pollen tube growth:

 Slow growth of the pollen tube results in unfruitfulness.

 Differences have been found in the rate of growth in selfed and crossed apples, pears, cherries and certain citrus fruits.

 This may be considered one type of incompatibility due to chemotropic or hormone influences.

 Besides this, fertilization should take place within a short time failing which abscission will take place at the base of the style, ovary pedicel or peduncle and fruit setting does not take place.

(ii) Premature or delayed pollination:

 Premature or delayed pollination leads to unfruitfulness.

 Tobacco flowers are very susceptible to injury from premature pollination.

 When mature pollen grains are applied to immature pistils they germinate, penetrate the style, enter the ovule and if the ovules are not ready for fertilization the flowers fall.

 However, in case of oranges premature pollination did not have any deleterious effect whereas some injury was noticed in tomato.

 Lower setting due to premature pollination was noticed in persimmon, Pear, plum and peach.

 Similarly, if pollination is delayed the flowers fall without setting.

 Delay in pollination for 1 or 2 days did not affect fruit set. However, further delaying may result into polyembryonic seeds in some species.

(iii) Nutritive Condition of Plant:

 Nutritive condition of plant just before or at or and just after the time of blossoming is an important factor determining the percentage of flowers carrying for setting and for maturity.

 It may affect the pollen viability or fertility of pistils.

a. **Effect on pollen viability** - There was significant difference in germination percentage of pollen collected from old apple trees and from strong young trees of the same variety.

b. **Effect on defectiveness of pistils:**

 Exhaustion of tree by over bearing, drought or poverty of soil leads to production of defective pistils.

 Over bearing weakens the fruit tree and in coming season production is adversely affected.

 Close correlation was reported between defective pistils and unfruitfulness in American plums.

 In case of *Vitis vinifera* carbohydrate deficiency is the common cause of flower drop. Due to carbohydrate deficiency flower abortion and ultimately unfruitfulness also occur in green house grown tomatoes.

(iv). Fruit setting of flowers in different positions:

 Fruits borne on terminal growth have more competition in many fruit crops and mature and set under normal nutritional conditions but percentage of set is small.

 This positional competition takes place between fruits and branch as well as between different fruits influencing fruitfulness.

Strong and weak spurs:

 Nutritional condition of spurs has positive correlation with fruit setting in apple. Spurs on vigorous limbs with large leaves set more fruits than those borne on weak limbs.

 More flowers ultimately lead to more fruit set and more flowers are generally borne on strong limbs. Likewise flowers borne singly set fruits and mature as fruit and majority of those borne in clusters drop down.

 Ringing or girdling also lead to accumulation of an extra store of food material leads to fruitset and develop parthenocarpically.

 In the process of fruitifications the embryo is more important for development *i.e.* if nutritive condition is favourable, it accompanies the development of the seed coat and fruit wall, if not, only the latter portions are in high degree retardation in development.

 Under insufficient nutrient supply the numbers of seed forming ovules are diminished and under extreme nutrition deficiency both fruit wall and large number of ovules are diminished leading to enabling to form seed.

 In case of green house cucumbers, nutritional deficiency leads to arrest of growth of growing fruits depending upon the position of the fruits and time of pollination. If a few of the cucumbers are harvested remaining fruits resume growth.

 In case of strawberries producing bisexual flowers may lead to produce pistillate flowers if nutritional deficiency was observed.

 However, nutritive condition has indirect influence on compatibility.

B. Unfruitfulness associated with external factors

1. **Nutrient supply**:

 In certain families like Graminae, Cruciferae and Leguminaceae sterility normally occur due to over feeding.

 _Jonathan' apple self sterile in rich soil becomes self fertile in poor soils.

 High fertility level is generally associated with good pistil development and low level with poor pistils and good stamens in grapes.

 In olives low fertility leads to partial or complete degeneration of pistils.

2. **Pruning and Training**: Pruning tends to produce more true hermophrodite condition in grape variety _Hope‘. If pruning is not done the variety tends to remain sterile and produces aborted pistils.

3. **Locality**: Jonathan apple which is sterile in one location is reported to be self fertile in another location.

4. **Season:** Hybrid grape Ideal‘ is self impotent early in season but becomes self potent later on.

5. **Temperature**: High temperature at flowering dries up stigmatic secretion and prevents pollination. Tomato varieties grown at high temperature do not produce any fruit.

6. **Light**: Exposure of strawberry plants to long photoperiod results in development of stamens and pistils in strawberry flowers.

7. **Pests and diseases**: Mango hopper, powdery mildew, etc. adversely affect the fruit set and development in mango and grape.

 Spraying the trees when they are in bloom i.e. spraying at flowering reduces fruit set.

 Some of the fungicides gave inhibitory effect on pollen grains i.e. copper fungicides at 200 to 10000 ppm prevent the germination of pollen grains on the stigma.

Steps to overcome the problem of unfruitfulness:

 Having known that there could be many reasons for unfruitfulness, it is necessary to make necessary corrective measures which should begin from planning level and extend to an established orchard.

 Choice of the crop and variety should be made on the basis of climatic and edaphic conditions of the site of orcharding.

 Provision of windbreak and shelter belts for areas prone to wind damage.

 Before planting an orchard soil should be brought to optimity by incorporating organic matter, amendments and nutrients based on soil analysis.

 In case of problems of pollination due to heterostyly, dichogamy incompatibility, sterility, embryo abortion, hybridity, etc. a mixture of varieties should be grown by introduction effective pollinizer varieties and pollinators (Honey bees).

 Unfruitfulness due to slow growth of pollen tube, premature and delayed pollination, use of plant regulators can be affected after standardization in terms of chemical concentration and timing of application.

 The problem due to old age could be overcome by replanting or rejuvenation of old trees.

- Problem due to overbearing can be managed through thinning at appropriate stage.
- Irrigation management would be key role in situations with drought and waterlogged conditions.
- Problem due to uneven distribution of flowers on tree should be managed through thinning and crop regulation.
- Maintenance of critical nutrient status in tree leaves for optimum crop production by adopting correct nutritional programme based on plant and soil analysis.
- In crops requiring regular pruning standard practices will have to be adopted based on crop, variety and its phenology.
- Unfruitfulness due to pathogens should be managed through effective plant protection measures following integrated approach.
- Problem of unfruitfulness due to tendency of alternate bearing should be over come through replacement of regular bearing varieties and crop regulation.

It is important to analyse the problem and then corrective measures should be suggested. Basically the planning should be so done that future is problem free and then should be followed by adoption of correct package of practices.

Lecture: 17 Pollination, Pollinizer and Pollinator

Pollination is an important factor in growing fruits and nuts, since for most of these crops pollination is a prerequisite for fruit production. **Pollination** is the transfer of pollen from the stamen, or male part of a flower, to the pistil, or female part of a flower. Pollen is transferred by wind, splashing rain, moths, butterflies, birds, or honeybees, depending on the plant species. Most fruit trees are pollinated primarily by bees, while most nut trees are pollinated primarily by wind. The agent of pollen transfer (for example, a bee) is called the “pollinator” whereas the “pollinizer” is the source of pollen. After pollination occurs, the pollen grain must germinate and grow into the ovary of the flower where the male pollen cell unites with the female egg cell in a process called fertilization. The success of pollination and fertilization depends upon the favorable environmental conditions as well as the right pollen grain reaching the pistil of the right flower, as pollen can only fertilize specific, compatible flowers. For example, pollen from a peach flower will not pollinate apple flowers

To better select fruit for planting, growers should become familiar with the terms used to describe pollination characteristics and fruitfulness of different fruit types. Some of the most basic terms that need to be understood are, *self-pollination cross-pollination, self-fruitful, cross-fruitful, parthenocarpic,* and *perfect-flowered.*

Self-pollination occurs when flowers are pollinated by pollen within the same horticultural variety from the same or different trees. Most peach varieties, such as Red Haven, are fruitful when self pollinated and therefore can be planted in very large blocks without using a second variety.

Cross-pollination occurs when flowers of one variety are pollinated by pollen from a second variety. For example, Golden Delicious variety is often used in apple orchards to cross-pollinate Red Delicious varieties.

Self-fruitful implies that a single variety of a given fruit type will produce satisfactory fruit crops when grown by itself. This may occur because the variety is self-pollinating (such as peach) or because they are parthenocarpic (such as some persimmons, figs, and satsumas).

Cross-fruitful implies that cross-pollination is required among two or more varieties to produce satisfactory crops. Red Delicious apple varieties, for example, are cross-fruitful when cross-pollinated with variety of Golden Delicious.

Parthenocarpic basically means fruit are produced without complete seed development, resulting in seedless fruits. Satsuma, for example, has sterile pollen, mostly nonviable ovules, and is highly parthenocarpic, which results in the production of seedless fruit.

Perfect-flowered means that flowers of that variety have functional male and female parts. Carlos is a perfect-flowered muscadine grape that is self-fruitful and is used as a pollinator for female type varieties such as Fry.

Pollinator: Bees, wind, moths, butterflies, other insects, animals, and humans, may act to physically transfer pollen from stamens to the stigma of the flower pistil.

Pollinizer: The source of pollen. Usually used when referring to cultivars planted for the purpose of crosspollination.

Whether a fruit type is self-fruitful or requires cross-pollination influences how varieties are arranged in a planting. For self-fruitful plants, single varieties perform well when planted alone. For fruit types requiring cross pollination, two or more varieties of each type should be planted. Planting entire rows with the same variety makes management of cultural practices and harvesting much easier and more cost effective. When only the minimum number of pollinators is desired, a pollinator variety should be planted as every third plant in every third row.

Lecture 18: IMPORTANCE OF PLANT BIO REGULATORS IN HORTICULTURE

Plant bio-regulators (PBRs): It refers to both natural as well as synthetic compounds which affect the growth and developmental process in plants. It includes plant hormones, synthetic and physiologically active growth substances, growth inhibitors, synthetic enzymes, vitamins, organic acid and other compounds which affect the biological activity of the plant system.

Plant growth regulators (PGRs): It refers to organic compounds other than nutrients which in small quantities promote, inhibit or otherwise modify the physiological process of the plant.

Plant hormones or phytohormones: It refers to the compounds, produced within the plant system which usually move within the plant from the site of production to the site of action and regulate plant physiological process in physiologically very low concentration.

These phytohormones are classified into five broad groups- Auxin, Gibberellins, Cytokinins, Ethylene and Abscisic acid. However, apart from these other phytohormones are brassinosteroides, jasmonic acid, oligosaccharides, fusicoccin has also been reported as plant hormones.

Applications of plant growth regulators in fruit production

1. **Propagation:** Most of the fruit crops are vegetatively propagated except papaya, capegooseberry, phalsa, mangosteen. Sexual propagation is the only means for hybridization and rootstock production. Poor seed germination in some of the fruit crop is major hindrance for sexual propagation. Gibberellins (200-500 ppm) are mostly used for seed germination and substitution of chilling requirement. Application of IBA @ 500-1250 ppm for soft wood, 1000- 3000ppm for semi hardwood and 2000-5000 ppm for hardwood is common for the initiation of rooting in cutting in different fruit crops. Apart from auxin, a large number of physiologically and chemically unrelated compounds such as phenols and allied simple aromatic compounds, glucosides, growth inhibiting, growth retarding and ethylene producing chemicals significantly influence the rooting of cuttings. In a few cases, growth retardant such as SADH has also proved beneficial in root induction. GA has antagonistic effect on rooting of cutting.

2. **Use in micropropagation:** Auxin and cytokinin are used to support basic level of growth of explants grown under in vitro condition. For shoot initiation high cytokinin: auxin (BA: IAA) ratio is

required while for root induction high auxin: cytokinin (IBA: BA) is essential. Usually 0.1 and1.0 mg/l Benzyl Adenine (BA) helps in terminal and lateral shoot formation in almond-peach hybrid under in vitro condition, respectively while 0.1-0.2 mg/l IBA is most suitable for root induction.

Somatic embryogenesis from nucallar explants occur in the presence of 2,4-D at low concentration.

3. **Breaking of seed and bud dormancy:** Seeds of many fruit crops often require an extended period of after ripening at low temperature before germination. Breaking of rest is of great significance to overcome dormancy. GA (200-500 ppm) is used for accelerating seed germination in different fruit crops. The treatment of GA (200 ppm) significantly reduced/substituted the period of seed stratification. Termination of bud rest by GA (200-250 ppm) spray is a common practice in temperate fruit. It also successfully reduces the period of chilling requirement.

4. **Control of vigour:** In fruit crops, tree size control is important for producing dwarf trees suitable for high density orcharding. The use of different growth retardant like SADH/ paclobutrazol is effective in reducing the growth of apple, apricot, lemon, litchi, mango, pear, peach, plum.

5. **Flowering:** Ethylene is the active principle responsible for flowering in pineapple. Apart from this Acetylene, calcium carbide, ethephon, NAA are other chemicals which helps in floral induction in fruit crops. NAA @ 10-15 ppm alone and Ethrel or ethepon @ 25 ppm in combination of urea (2%) and $CaCO_3$ (0.04%) is very effective for the induction of flowering in pineapple.

   Paclobutrazol (PP_{333}) has shown great promise for regulating flowering fruiting in mango. PP_{333} (800-1000 ppm) alone or in combination of urea (2%) successfully induced vegetative flush in fruiting shoot of mango simultaneously.

   NAA replaces girdling for improved flowering by mobilization of assimilates in the tree while SADH promotes flowering in apple, pear, peach, lemon, blue berry and reduced shoot growth. Grape and lemon respond to cycocel (CCC) treatment for increased flowering.

6. **Parthenocarpic fruit development:** In general, auxins (IAA, IBA, phenoxy acetic acid) -induce parthenocarpy in fruit crop particularly in pineapple, citrus, banana etc. In apple, pear, peach, apricot, almond- GA while in Grape- cytokinin and in Fig- 4-CPA is commonly used to induce parthenocarpy.

In mango- BA@ 250 ppm at anthesis followed by GA@250 ppm and β-NoA@ 10 ppm at fortnight interval

7. **Fruit thining**: Auxins at higher concentratin (100-300 ppm). In grape- GA @ 40-60 ppm at post-bloom stage

8. **Fruit growth and maturity:** Auxins- increase fruit size. In grape- GA (40-60 ppm) alone or in combination with brassinosteroids after fruit set increases fruit sized and shape.

9. **Control of fruit drop:** Auxins (2,4-D, NAA, 2,4,5-T) at low concentration (10-30 ppm) is very effective for preventing fruit drop in different fruit crops

10. **Improvement of fruit quality:** In grape- GA (40-60 ppm) at colour break stage increase TSS and sugar content and reduced acidity.

11. **Fruit ripening:** Ethylene @ 250 ppm at fruit maturity is effective for ripening of fruits.Ethephone @ 1000 ppm- causes degreening in citrus whileCycocle (500 ppm) applied twice at 15 days interval at early maturity in Kagzi lime- results harvesting 20 day earlier.

12. **Harvesting:** Ethrel- in temperate fruit while cycloheximide- in mango, citrus is most effective for this purpose. However, GA- 10 ppm inhibit degreening process and extending the shelf life of the fruit

Lecture 19: IRRIGATION-METHODS

It is defined as ―the artificial application of water to the plants in the event of shortage of natural rains in order to obtain rapid growth and increased yields‖.

- It is an essential item in the cultivation of crops.
- Success in gardening depends on how efficiently irrigation is provided to gardens because it is governed by many factors such as frequency, duration, intensity, source and method of supply.

Factors affecting the supply of irrigation water to plants:

• Topography and soil characteristics.

• Kind of plant (root depth, water absorption capacity, growth habit, etc.).

• Weather condition.

When to irrigate?

- The time when a plant needs irrigation can only be judged by a keen observing eye.
- The plants need water when their new leaves begin to show a wilting appearance. A little before the trees show the sign of wilting.
- The shedding of broad leaves in orchard shows distress symptoms.

How much to irrigate?

• If water supply is limited, only a light irrigation can be given at a time with higher frequency of irrigation.

• If water is available in plenty, the irrigation may be heavy with longer intervals between successive irrigations.

• However, inadequate irrigation reduces the growth and fruiting of the trees while, over irrigation serves no useful purpose and it may even prove to be harmful.

• It may create water logging, the nutrients may get leached and fruits may become watery and develop poor quality.

• Plants which have suffered from drought should not be given liberal doses of irrigations all at once. That may result in the splitting of fruits and even the splitting of bark of the branches and trunk.

SYSTEMS OF IRRIGATIONS:

Different systems of irrigation are followed in different parts of the country. The best system is the one which meets the moisture seepage and evaporation.

Principally, irrigation systems can be divided under three broad headings:

I. **Surface irrigation :** a. Flooding b. Basin type c. Furrow type d. Ring type

II. **Sub-surface irrigation :** a. Trench method b. Through underground pipelines

c. Perforated pipelines.

III. **Overhead or aerial irrigation :** a. Sprinkler b. b. Revolving nozzles

IV. **Drip or trickle irrigation**

I. SURFACE IRRIGATION:

a. **Flooding:**

- When the land is flat, letting in water from one end floods the entire area.
- This system is commonly practiced in canal or tank bed areas.
- It is the easiest method and permits the use of bullock drawn implements in the orchards.
- But in this there is wastage of water and leads to soil erosion also.
- It encourages growth of weeds and spread of diseases like gummosis in citrus and collar rot in papaya.

b. **Basin system:**

- In this system, circular basins are provided around the trunk of the tree.
- The basins are inter-connected in series and are fed through the main channel running perpendicular to the tree rows.
- When compared to flooding, this system minimises the loss of water.
- In this system of irrigation, the water close to trunk may bring about certain diseases like gummosis and nutrients are likely to be carried over from one basin to the other.

c. **Furrow system:**

- Unlike the flood system, here the entire land surface is not covered with irrigation water.
- The furrows are opened in the entire orchard at 4‖ or less apart, depending upon the age of the trees.
- Water is let in these furrows from the main channels.
- In orchards, two furrows on each side of the rows are generally made.
- It is suited to such lands, which have a moderate slope to the extent of 1-2% if the water is to run freely and reach the ends of the furrows.
- Where the slope is sharp, the furrows are made to follow the contour more or less closely.
- This method has disadvantage of excess of water penetration at the head than at the farther end, which may result in variation in vigour and growth of trees.

d. **Ring system:**

- This is an improvement over the basin system.
- In this system, a ring is formed close and around the tree and water is let into the basin.
- This method is recommended for citrus trees thereby reducing the chances of collar rot to which these trees are often susceptible.
- The size of the ring will increase as the tree grows.
- In this system, the spread of diseases like collar rot, etc., are prevented.
- However, it involves more labour and capital and it does not permit uniform distribution of water throughout the bed or basin as in the basin system of irrigation.

SUB-SURFACE IRRIGATION:

- This system consists of conducting water in number of furrows or ditches underground in perforated pipelines until sufficient water is taken into the soil so as to retain the water table near the root zone.
- In limited situation, this may be a very desirable system of irrigation.
- In general, however, it must be used with great caution because of the danger of water logging and salt accumulation.

- If the sub-strata are so slowly permeable that practically no water moves through, water added may stand in soil sufficiently for long time which results an injury to the plant root due to poor aeration.
- Where irrigation water or the sub-soil contains appreciable amount of salt, sub-soil irrigation is usually not advisable.
- Land must be carefully levelled for successful subsoil irrigation so that raising the water table will wet all parts of the field equally.

III. OVER HEAD OR AERIAL IRRIGATION:

- In this system, water is applied in the form of spring, somewhat resembling rainfall.
- This is accomplished by pumping water from original source into the main supply line from where it is distributed to perforated pipes, which operate at low pressure (80 to 120 lb per square inch) and supply the water in a fairly uniform rectangular pattern
- They have a high rate of application, usually 1‖/hour or higher. Because of the high application rates, their use is restricted to soils with high infiltration rates, such as sandy or gravelly.
- Revolving nozzle is also at times used, which operated on either low or high pressure. Usually the rate of application followed in the rate of 0.2‖ to 0.3‖ per hour.

SPRINKLER IRRIGATION:

- May have definite economic advantages in developing new land that has never been irrigated, particularly where the land is rough or the soil is too much porous, shallow or highly erodable.
- It is quite useful where only small streams are available, such as irrigation wells of small capacity.
- It is helpful in irrigating at the seedling stage when the furrowing is difficult and flooding leads to crusting of soil.
- Fertilizer materials may be evenly applied by this method.
- This is usually done by drawing liquid fertilizer solutions slowly into the pipe.
- It has several disadvantages like
- High initial cost,
- Difficult to work in windy location,

- Trouble from clogging of nozzle,
- Interference in pollination process and
- Requirement of more labours while removing or resetting.
- In general, this system is best adopted for areas where ordinary surface systems are inefficient.

IV. DRIP OR TRICKLE SYSTEM:

- This is the most recent system of irrigating the plants.
- It is usually practise for high value crops, especially in green houses and glass houses.
- There will be an installation of pipelines with nozzles very close to the soil.
- The nozzle is fitted in such a way that water is dripped almost in the root-zone of the plants.
- Water is allowed to move in pipes under very low or no pressure and it drop at regular interval.
- This system of irrigation has advantages like no disturbance of the soil; soil moisture is maintained, lesser leaching of nutrients from the soil.

Lecture 20: FERTILIZER APPLICATION IN HORTICULTURAL CROPS

The Nutrients are chemical elements which are absorbed by the plants in more or less quantity to transform light energy into chemical energy and to keep up plant metabolism for the synthesis of organic materials.

 These materials constitute among other things, foods for humans and animals and a range of raw materials for various industrial uses.

 Feeding of plants with nutrients is termed as nutrition.

 Successful growth and production of the plants in general requires a proper supply of the 16 elements. These elements are regarded as essential to life in higher plants.

Allen and Arnon (1955) laid out following criteria for categorising nutrients essentiality to plants:

1. Complete or partial lack of the element in question must make normal plant growth impossible
2. Deficiency symptoms must be reversibly by the addition of the elements in question
3. The element must play specific role in the plant metabolic symptom

They are:

1. **Basic elements :** Carbon (C),Hydrogen(H) and Oxygen(O) (03)
2. **Macro elements :** Nitrogen (N), Phosphorus(P) Potash(K), Calcium(Ca) Magnesium (Mg) and Sulphur(S) (06)
3. **Micro elements :** Manganese (Mn), Molybdenum (Mo), Chlorine (Cl), Zinc (Zn), Boron (B), Copper (Cu) and Iron (Fe) (07) **Macro elements:** The nutrients that are required in relatively large quantity are termed as macro elements. **Micro elements:** are those required in relatively less quantity are termed as micro nutrients.

 Besides some nutrients like Aluminium (Al), Cobalt (Co), Sodium (Na), Silica (Si) and Vanadium (V) are not considered necessary always because either their essential character has been proved only in some plants or in certain metabolic processes that are not always necessary.

TYPES OF FERTILIZERS

Inorganic fertilizers

• Industrially manufactured chemicals.

• Contains higher nutrient than organic manures.

• Nutrient input is lost through leaching, runoff, volatilization, fixation by soil or consumption by weeds etc.

Organic fertilizers

• These are plant and animal wastes that are used as nutrients after decomposition.

• Improves the soil tilth, aeration, water holding capacity and activity of micro-organism.

WHERE TO APPLY THE MANURES?

• In fully grown trees, the manures and fertilizers should be given over the area, where their active roots are spread.

• Fertilizer should be given in restricted area i.e., in the surrounding area of about 1 to 1.5 m away from the trunk of the trees.

TIME OF FERTILIZER APPLICATION

• It must be applied when the plants need it.

• Timing depends on the type of fertilizer and climate.

• Fruit trees require more nutrients at the emergence of new flushes and differentiations of floral buds.

• Utilized more during the course of fruit development.

• Nutrients should be available to them in February –March.

• So, it would be better to apply them in October-November to be available to the trees in February to March.

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 detrimental 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.

• 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 up to their root system for varying duration in starter solution.

• The starter solution is prepared either by dissolving concentrated 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.

 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- Tomato 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 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 and 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 the highly mobile Elements.

 Foliar application proves to be most effective where problems of nutrient fixation in soil exits. So far the most important use of foliar sprays is 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/lit)- Papaya, Pineapple, Citrus and Guava.

Precaution:

 While applying foliar sprays, care should be taken to ensure correct concentration of spray solution.

 Apply in the morning or evening hours on a clear sky day.

ORGANIC FARMING:

 Green revolution has brought spectacular increase in production as well as productivity of crops in our country.

 But after the initial success, it had shown the symptoms of fatigue evident from the undesirable side effects on natural resources, such as soil, water and biodiversity and thus human health.

 The vast areas of soils once fertilizer was degraded due to soil erosion, salinisation or general loss of soil fertility.

 Water resources have been over-exploited and polluted due to excessive requirement of irrigation water for high yielding varieties and intensive use of agro-chemicals.

 Many plants and animal species were wiped out and are endangered.

 Residues of harmful pesticide in food and drinking water endangered both farmers and consumer health point of view and thus excessive use of external inputs consumes a lot of energy from non-renewable resources.

 Organic farming is a way of conserving the soil and maintaining the fertility, protect soil flora and fauna/diversity.

 It has lesser effect on pollution either of ground water, lakes and rivers.

 Organic agriculture does not utilize non-renewable external input and energy.

 Since no chemical or pesticide is used in crop production, there is very low chance of pesticide residues in food.

 At the same time the organic products are healthier and have better product quality like taste, aroma and storability.

 Input cost is drastically reduced in organic cultivation but the market price leading to higher income for farmers.

Aims of organic production and processing:

 To produce sufficient quantities of high quality food, fibre and other products.

 To work compatibly with natural cycles and living systems through the soil, plants and animals in the entire production system.

 To recognise the wider social and ecological impact of and within the organic production and processing systems.

 To maintain and increase long-term fertility and biological activity of soils using locally adopted cultural, biological and mechanical methods as opposed to reliance on chemical inputs.

 To maintain and encourage agricultural and natural biodiversity on the farm and surroundings through the use of sustainable production systems and protection of plant and wildlife habitats.

 To maintain and conserve genetic diversity through attention to on-farm management of genetic resources.

 To promote the responsible use and conservation of water and all life therein.

 To use, as far as possible, renewable resources in production and processing systems and avoid pollution and wastes.

 To foster local and regional production and distribution.

 To create a harmonious balance between crop production and animal husbandry.

 To provide living conditions that allows animals to express the basic aspects of their innate behaviour.

To utilise biodegradable, recyclable and cycled packaging materials.

 To provide everyone involved in organic farming and processing with a quality of life that satisfies their basic needs within a safe, secure and healthy working environment.

 To support the establishment of an entire production, processing and distribution chain which is both socially and ecologically responsible.

 To recognise the importance of, and protect and learn from, indigenous knowledge and traditional farming systems.

Organic food products exported from India:

 Organic cereals: Wheat, Rice and Maize or Corn.

 Pulses: Red gram and Black gram.

 Fruits: Banana, Mango, Orange, Pineapple, Passion fruits, Cashew nut and Walnut.

 Oilseeds and oils: Soybean, Sunflower, Mustard, Cotton seed, Groundnut and Castor.

 Vegetables: Brinjal, Garlic, Potato, Tomato and Onion.

 Herbs and spices: Chilli, Peppermint, Cardamom, Turmeric, Black pepper, White pepper, Amla, Tamarind, Ginger, Vanilla, Cloves, Cinnamon, Nutmeg and Mace.

 Others: Jiggery, Sugar, Tea, Coffee, Cotton and Textiles.