Fundamentals of Horticulture 2(1+1)

Lecture 1

Horticulture: Horticulture is derived from the Latin word '*Hortus*' meaning enclosure and culture meaning cultivation. Thus, Horticulture means growing of crops in an enclosure.

In modern science, horticulture include all aspects of cultivation, processing and utilization of a variety of crops such as fruits, vegetable, ornamentals, plantation crops, spices, medicinal and aromatic plants and mushrooms.

Branches of Horticulture:

1. **Pomology**- Pomology word derived from two Latin word Pome meaning fruit and logos meaning culture. This branch deals with cultivation of fruit crops, e.g. Citrus, Mango, Guava, Apple etc.
2. **Olericulture**- Olericulture word derived from Latin word 'Oleris' means 'pot herb'. This branch deals with the cultivation of vegetable crops, e.g. Tomato, Chilli, Carrot, Potao etc.
3. **Ornamental Horticulture**- This branch deals with the art and science of growing ornamental foliage and flowering tree, shrubs, climber, seasonal flowers, cacti, orchids, indoor and outdoor garden plants, e.g. Marigold, Rose, Gerbera, Chrysanthemum etc.
4. **Plantation crops and Spices**- Cultivation and processing of tropical crops grown on a large scale, e.g. Tea, Coffee, Black Pepper, and Turmeric etc.
5. **Medicinal and Aromatic plants**- Medicinal plants are rich source of alkaloids and steroids, having property for treatment in several disease and used in pharmaceutical industries for preparing medicines, e.g. Ashwagandha, Senna, Sarpgandha, Isabgol etc.
   Aromatic plants are rich source of essential oil and are use in cosmetic and perfumery industries e.g. Lemon grass, Vetiver grass, Palmrosa grass etc.
6. **Preservation of fruits and vegetables**- This branch deals with the principles and practices for preservation of fruits and vegetables.
7. **Mushroom growing**- Mushroom are richer in high quality protein than any other vegetable e.g. White button mushroom (*Agaris bisphorus*), Oyster (*Pleurotus* spp.), Paddy straw mushroom (*Volvoriella volvacea*).

Lecture 2

Importance of Horticulture:

1. **Nutritive value**- Fruit and vegetable are a rich source of vitamins and minerals are called as "Protective Foods". ICMR recommended 400 g (280 g vegetables + 120 g fruits) per day per capita.

Sr N.	Nutrient	Example	Quantity
1.	Vitamin A	Mango	4800 IU/100 g
		Papaya	2020 IU/100 g
2.	Vitamin B1	Cashew nut	630 mg/100 g
3.	Vitamin B2	Bael	1191 mg/100 g
4.	Vitamin C	Aonla	600 mg/100 g
5.	Carbohydrates	Raisin	77.3 %
		Dry apricot	72.8 %
6.	Protein	Cashew nut	21.2 %
7.	Iron	Dry karonda	39.1 %
		Date pind	10.6 %

2. **Income generation**- Fruits, vegetable and plantation crops are more and prolific yielder than other crops, and spices, medicinal, aromatic and flowers are high value crops. These crops fetch more prices in the market.
3. **Employment generation**- Horticultural crops are labour intensive. As on average one hectare of fruit production generate 860 man-days per annum as against 143 man-days in cereal crops. Horticultural based industries and cultural intensive crops like grapes, banana and pineapple, generate much more employment ranging from 1000-2500 man-days per hectare.
4. **Economic and export value**- Horticulture sector has become one of the major drivers of the growth in the agriculture sector. The horticultural crops cover 15 percent of total area under agriculture; they contribute 30.4 % of GDP from agriculture. Agriculture share 17.32 % in GDP of India. Fruits, vegetables, floriculture, processed products, spices and plantation are export to UAE, USA, Bangladesh, Nepal etc.
5. **Aesthetic, religious and social value**- Used in garden for enhanced aesthetic look. Many plants part like leaves, flower, fruit etc. posses religious value and are used in many ceremonies eg. Festunes of mango leaves, entrance gate banana, bael leave for offering to lord shiva. Flowers for loves and friendship etc.

Scope: As per Indian Horticulture Database (2017) horticultural crops cover area 24.9 million hectare with production 295.1 million tonnes. India is the second largest producer of fruit and vegetable after China. India is largest producer of Banana, Mango, Lime &

Lemon, Papaya and Okra. Rising of demand of horticultural crops for consumption, export and processing industry is increasing. In view of these points, there is a lot of scope of increasing production and productivity of horticultural crops.

1. Research and development- To develop high yield and quality varieties.
2. Use of waste land- Ber, custard apple etc
3. Transport and market facilities- improve
4. Storage and preservation-
5. Lawn facility
6. Use new technique eg. PGR, micro-propagation, polyhouse, hydroponic etc
7. Supply of fruit and vegetable for fulfil of demand- Availability fruit is 126 g and vegetable 286 g per day per capita (25 % loss + 5 % export & processing).

Lecture No. 03

Horticultural classification

Based on climatic requirement-

1. **Temperate crops**: In temperate region, during winter the temperature fall below the freezing point and during summer temperature range 10-14^0 C and humidity range 80-100 percent. Under this condition, crops shed their leaves and go into the rest period. These chilling temperatures help the plant to put forth new growth, flowering and fruiting with the onset of spring season. This type climate observed at 1800-3500 m from ground level eg. Apple, Pear, Peach, Plum, Apricot, Cherry etc.
2. **Sub- tropical crops:** In sub-tropical climate, summer is hot and dry, and winter is less mild (less severe). There is a clear cut distinction between summer and winter seasons, fluctuation in day and night temperature is high. The temperature range 25-30^0 C and humidity up to 100 percent during monsoon. This type climate observed at 900-1800 m from ground level eg. Citrus, Phalsa, Fig, Guava, Pomegranate, Cucurbits, Tomato, Chilli, Brinjal etc.
3. **Tropical crops:** Climate conditions in such areas are hot and humid in summer and mild in winter. There is no distinct summer and winter, and there is no much fluctuation in day and night temperatures. The temperature range 22-27^0 C. This type climate observed at 300-900 m from ground level eg. Mango, Banana, Papaya, Pineapple, Sapota, Cashew, Coconut, Arecanut, Rubber etc.

Classification of vegetable based on cultural practices-

1. **Perennial vegetables**: These crops remain in the field for more than two years and include asparagus, ivy gourd, pointed gourd, drum stick, curry leaf, globe artichoke etc.
2. **Leafy vegetables**: All vegetables belonging to this group are direct seeded crops eg. spinach, palak, coriander, fenugreek, amaranthus etc.
3. **Cole crops**: Cole crops belong to Cruciferae or Brassicacae family. These are winter season and transplanted crops eg. cabbage, cauliflower, sprouting broccoli, knoll-khol, Brussels sprouts etc.
4. **Root crops**: These crops have prominent and fleshy underground structures and direct sown in winter season eg. carrot, radish, turnip, beetroot etc.
5. **Bulb crops**: These are species of Allium and belong to family Alliaceae eg. Onion, Garlic etc.
6. **Tuber crops**: eg. Potato, sweet potato, cassava/tapioca, yams etc.
7. **Solanaceous crops**: Belong to family Solanaceae commonly known as nightshade family eg. Tomato, Chilli and Brinjal .

8. **Cucurbits**: These crops belong to Cucurbitaceae family commonly known as the gourd family eg. gourd, melons, pumpkin and squash.
9. **Pod vegetables**: These are legume vegetable and belong to Fabaceae eg. Pea and beans.
10. **Salad vegetables**: These vegetables are mainly eaten raw eg. lettuce, celery, chicory and parsley.

Classification of vegetable based on growing season-

1. **Summer or spring-summer season crops**- Brinjal, tomato, chilli, watermelon, muskmelon, round melon, bottle gourd, bitter gourd, snake gourd, ash gourd, ridge gourd, sponge gourd, pumpkin, squash, cucumber, okra, cowpea, cluster bean etc.
2. **Rainy season crop**- Okra, brinjal, chilli, gourds, cowpea, cluster bean etc.
3. **Winter or autumn**-winter season crops- Cole crops, radish, carrot, turnip, spinach, palak, onion, garlic, pea, fenugreek, lettuce, potato etc.

Botanical Classification of Horticultural crops:

Sr. No.	**Family**	**English Name/ Common name**	**Botanical Name**
Fruit and Plantation crops			
Monocot			
	Arecaceae	Coconut	*Cocus nucifera*
		Date palm	*Phoenix dactylifera*
		Arecanut	*Areca catechu*
	Bromeliaceae	Pineapple	*Ananas comosus*
	Musaceae	Banana	*Musa acuminata*
Dicot			
	Anacardiaceae	Mango	*Mangifera indica*
		Cashew nut	*Anacardium occidentale*
	Annonaceae	Custard apple	*Annona squamosa*

	Apocynaceae	Karonda	*Carissa carandas*
	Caricaceae	Papaya	Carica papaya
	Euphorbiaceae	Aonla	*Emblica officinalis*
	Moraceae	Jackfruit	*Artocarpus heterophyllus*
		Mulberry	*Morus alba*
		Rubber	*Ficus elastica*
	Myrtaceae	Guava	*Psidium guajava*
	Punicaceae	Pomegranate	*Punica granatum*
	Rhamnaceae	Ber	*Ziziphus mauritiana*
	Rosaceae	Apple	*Malus pumila*
		Peach	*Prunus persica*
		Pear	*Pyrus communis*
		Strawberry	*Fragaria vesca*
	Rubiaceae	Coffee	*Coffea robusta*
	Rutaceae	Bael	*Aegle marmelos*
		Mandarin	*Citrus reticulata*
		Sweet orange	*Citrus sinensis*
		Kagzi lime	*Citrus aurantifolia*
	Sapotacae	Sapota/sapodilla	*Manilkara zapota*
	Sapindaceae	Litchi	*Litchi chinensis*
	Sterculiaceae	Cocoa	*Theobroma cocoa*
	Theaceae	Tea	*Camelia sinensis*
	Vitaceae	Grape	*Vitis vinifera*
Vegetable crops			
Monocot			
	Amaryllidaceae	Onion	*Allium cepa*
		Garlic	*Allium sativum*
	Araceae	Arvi	*Colocasia esculentum*
Dicot			
	Amaranthaceae	Amaranth	*Amaranthus tricolor*
	Asteracae	Lettuce	*Lactuca sativa*
	Chenopodiaceae	Beet root (Table beet/ Garden beet)	*Beta vulgaris*
		Palak (Spinach beet)	*Beta vulgaris* var. *bengalensis*
		Spinach	*Spinacea oleracea*
	Cruciferae (Brassicaceae)	Cabbage	*Brassica oleracea* var. *capitata*
		Cauliflower	*Brassica oleracea* var. *botrytis*
		Radish	*Raphanus sativus*
	Cucurbitaceae	Cucumber	*Cucumis sativus*
		Muskmelon	*Cucumis melo*
		Water melon	*Citrullus lanatus*
		Pumpkin	*Cucurbita moschata*
	Euphorbiaceae	Cassava	*Manihot esculenta*
	Fabaceae (Leguminosae)	Pea (garden)	*Pisum sativum ssp. hortense*
		Cluster bean (guar)	*Cyamopsis tetragonolobus*
		Cow pea	*Vigna unguiculata*
	Malvaceae	Okra	Abelmoschus esculentus
	Solanaceae	Potato	*Solanum tuberosum*

		Tomato	*Solanum lycopersicum*
		Brinjal	*Solanum melongena*
		Chilli	*Capsicum annuum*
Spices			
	Apiaceae	Coriander	*Coriandrum sativum*
	Fabaceae	Fenugreek	*Trigonella foenum- graecum*
	Myrtaceae	Clove	*Syzygium aromaticum*
	Piperaceae	Black pepper	*Piper nigrum*
	Zingiberaceae	Ginger	*Zingiber officinale*
		Turmeric	*Curcuma longa*
Aromatic & Medicinal plants			
	Apocynaceae	Sarpagandha	*Rauwolfia serpentina*
	Burseraceae	Guggal	*Commiphora mukul*
	Fabaceae	Senna	*Cassia angustifolia*
	Graminae	Lemon grass	*Cymbopogon flexuosus*
	Lamiaceae	Mints	*Mentha spp.*
	Liliaceae	Aloe	*Aloe vera*
	Meliaceae	Neem	*Azadirachta indica*
	Plantaginaceae	Isabgol	*Plantago ovata*
	Solanaceae	Ashwagandha	*Withania somnifera*
Floriculture			
Shade, ornamental and flowering trees			
	Annonaceae	Ashoka	*Polyalthia longifolia*
	Fabaceae or Leguminosae	Karanj	*Pongamia pinnata*
		Palas	*Butea monosperma*
		Amaltas	*Cassia fistula*
		Sita-Ashoka	*Saraca indica*
		Gulmohar	*Delonix regia*
	Meliaceae	Neem	*Azadirachta indica*
	Moraceae	Banyan tree	*Ficus benghalensis*
	Moraceae	Pipal	*Ficus religiosa*
Ornamental and flowering shrubs			
	Apocynaceae	Chandni	*Tabernaemontana divaricata*
		Lal kaner	*Nerium indicum*
		Pilakaner	*Thevetia peruviana*
	Malvaceae	China rose or Gurhal	*Hibiscus-rosa-sinensis*
	Oleaceae	Chameli	*Jasminum grandiflorum*
	Rubiaceae	Ixora	*Ixora parviflora*
	Rutaceae	Kamini or Orange jessamine	*Murraya paniculata*
	Solanaceae	Raat-ki-rani (Queen of night)	*Cestrum nocturnum*
Climbers			
	Apocynaceae	Yellow allamanda	*Allamanda cathartica*
	Bignoniaceae	Golden shower	*Bignonia venusta*
	Combretaceae	Madhu-malati, Rangoon creeper	*Quisqualis indica (syn. Combretum indicum)*
	Convolvulaceae	Railway creeper	*Ipomea cairica*
Summer annuals			
	Amaranthaceae	Cock's comb	*Celosia argentea*
	Amaranthaceae	Gomphrena	*Gomphrena globosa*

	Asteraceae	Gaillardia or Blanket flower	*Gaillardia pulchella*
	Asteraceae	Zinnia	*Zinnia elegans*
	Asteraceae	Tithonia	*Tithonia speciosa*
	Asteraceae	Sunflower	*Helianthus annus*
	Asteraceae	Cosmos	*Cosmos bipinnatus*
	Asteraceae	Coreopsis	*Coreopsisgigantea*
	Balsaminaceae	Balsam	*Impatiens balsamina*
	Chenopodiaceae	Kochia	*Kochia scoparia*
	Geraniaceae	Geranium	*Pelargonium spp.*
	Portulaceae	Portulaca or Sunplant	*Portulaca grandiflora*
Rainy annuals			
	Amaranthaceae	Cock's comb	*Celosia argentea*
	Amaranthaceae	Gomphrena	*Gomphrena globosa*
	Asteraceae	Gaillardia	*Gaillardia pulchella*
	Asteraceae	Marigold	*Tagetes spp*
	Asteraceae	Sunflower	*Helianthus annus*
	Asteraceae	Zinnia	*Zinnia elegans*
	Balsaminaceae	Balsam	*Impatiens balsamina*
	Linderniaceae	Torenia/wishbone flower	*Torenia fournieri*
	Lamiaceae	Salvia	*Salvia officinalis*
	Portulaceae	Portulaca	*Portulaca grandiflora*
Winter annuals			
	Asteraceae	Aster	*Callistephus chinensis*
	Asteraceae	Dahlia	*Dahlia variabilis*
	Asteraceae	Daisy	*Bellis perennis*
	Brassicaseae	Stock	*Matthiola incana*
	Caryophyllaceae	Sweet william	*Dianthus barbatus*
	Primulaceae	Primrose	*Primula vulgaris*
	Solanaceae	Petunia	*Petunia hybrida*
	Verbenaceae	Verbena	*Verbena hybrida*
	Violaceae	Pansy	*Viola tricolor var. hortensis*

Soil and climate for horticultural crops

Soil: Soil and climate are the chief natural factors on which the success or failure of horticultural crops is dependent.

The ideal soils for horticultural crops should be:

1. Soil should be fertile, well drained and neutral in reaction p H range 6.5-7.5
2. It should be sufficiently deep especially for fruits (2-2.5 m).
3. The water table should be approximately 4 m deep from ground level.
4. It should be retentive of nutrients and water.
5. Soil should be free from high water table, high salt concentration and hard pan.

- Guava and date palm fruit plants tolerate comparatively high water table whereas citrus, loquat and papaya are damaged fast from excessive water in the sub-soil.

(1) **Alluvial soil**: Alluvial soil developed by deposition of silt carried out by the river in course of their massive flow during rainy season. Soils are poor in organic matter but rich in K and lime. They are neutral to slightly alkaline in nature, eg. Guava, Jackfruit, Jamun, Khirni etc.
(2) **Tarai soil**: Soil is deep and fertile and occurs in foot hills of the Himalayan ranges mostly in the state of U.K., Bihar, and West Bengal, eg. Mango, Litchi, Orange, Morus etc.
(3) **Arid Soil**: This type of soil found in water deficient zones of Rajasthan, Haryana, Punjab, Gujarat. Shifting sand dunes and undulating plains are major features of arid soil. Such soil contain soluble salts and possess high pH range 8-8.8, eg. Ber, Date, Aonla, Kair, Lasoda, Phalsa etc.
(4) **Black soil**: These soil are found mostly in Maharashtra. Highly adhesive and become sticky when wetted and get very hard upon drying. Soil is poor in N and organic matter, eg. Citrus, Banana, Sapota, Mango etc.
(5) **Red soil**: Due to the presence of Iron oxide, the soil looks red. Low percent of clay and hence water retention capacity of soil is very poor. Soil is distributed in AP, KT, TN, Orissa, part of M.P. & MH, Goa, Assam and North-eastern India, eg. Coconut, Arecanut, Black pepper etc.
(6) **Laterite soil**: Soil is gritty and porous in nature. Rich in Al & iron oxide. Soil pH is very low, eg. Tea, Coffee, Rubber, Cashew nut etc.
(7) **Marshy soil**: These soil occur in high rainfall area and are acidic in nature, having pH about 3.5. The acidity due to formation of H_2SO_4 and decomposition of organic matter, eg. Syzygium spp, Eugenia spp etc.

Climate: Agro-climatic zones of India are following: The Planning Commission of India has divided the India in 15 broad agro-climatic zones.

1. Western Himalayan Region
Area: Jammu and Kashmir, Himachal Pradesh and the hill region of Uttarakhand
Major Crops: Saffron, maize, barley, oats and wheat; peaches, apricot, pears, cherry, almond, litchis, walnut
2. Eastern Himalayan Region
Area: Arunachal Pradesh, the hills of Assam, Sikkim, Meghalaya, Nagaland, Manipur, Mizoram, Tripura, and the Darjeeling district of West Bengal
Major Crops: Rice, maize, potato, and tea; orchards of pineapple, litchi, oranges and lime
3. Lower Gangetic Plain Region
Area: West Bengal (except the hilly areas), eastern Bihar and the Brahmaputra valley
Major Crops: Rice, jute, maize, potato, and pulses
4. Middle Gangetic Plain Region
Area: Parts of Uttar Pradesh and Bihar
Major Crops: Rice, maize, millets, wheat, gram, barley, peas, mustard and potato
5. Upper Gangetic Plains Region
Area: Central and western parts of Uttar Pradesh and the Hardwar and Udham Nagar districts of Uttarakhand
Major Crops: wheat, rice, sugarcane, millets, maize, gram, barley, oilseeds, pulses and cotton
6. Trans-Ganga Plains Region
Area: Punjab, Haryana, Chandigarh, Delhi and the Ganganagar district of Rajasthan
Major Crops: wheat, sugarcane, cotton, rice, gram, maize, millets, pulses and oilseeds

7. Eastern Plateau and Hills
Area: Chhotanagpur Plateau, extending over Jharkhand, Orissa, Chhattisgarh and Dandakaranya
Major Crops: rice, millets, maize, oilseeds, ragi, gram, potato, tur, groundnut, soyabean, urad, castor, and groundnut
8. Central Plateau and Hills
Area: Bundelkhand, Baghelkhand, Bhander Plateau, Malwa Plateau, and Vindhyachal Hills
Major Crops: millets, wheat, gram, oilseeds, cotton and sunflower
9. Western Plateau and Hills
Area: Southern part of Malwa plateau and Deccan plateau (Maharashtra)
Major Crops: Wheat, gram, millets, cotton, pulses, groundnut, oilseeds, sugarcane, rice, wheat, oranges, grapes and bananas
10. Southern Plateau and Hills
Area: Interior Deccan and includes parts of southern Maharashtra, the greater parts of Karnataka, Andhra Pradesh, and Tamil Nadu uplands from Adilabad District in the north to Madurai District in the south
Major Crops: millets, oilseeds, pulses, coffee, tea, cardamom and spices
11. Eastern Coastal Plains and Hills
Area: Coromandal and northern Circar coasts of Andhra Pradesh and Orissa
Major Crops: Rice, jute, tobacco, sugarcane, maize, millets, groundnut and oilseeds
12. Western Coastal Plains and Ghats
Area: Malabar and Konkan coastal plains and the Sahyadris
Major Crops: Rice, coconut, oilseeds, sugarcane, millets, pulses and cotton
13. Gujarat Plains and Hills
Area: Hills and plains of Kathiawar, and the fertile valleys of Mahi and Sabarmati rivers
Major Crops: Groundnut, cotton, rice, millets, oilseeds, wheat and tobacco
14. Western Dry Region
Area: West of Aravalli (Rajasthan)
Major Crops: Bajra, jowar, moth, wheat and gram
15. Island Region
Area: Andaman-Nicobar and Lakshadweep
Major Crops: rice, maize, millets, pulses, arecanut, turmeric and cassava

PROPAGATION

Propagation defined as the controlled reproduction of plants to perpetuate selected individuals. Simply means of propagation is an art of multiplication of plants.

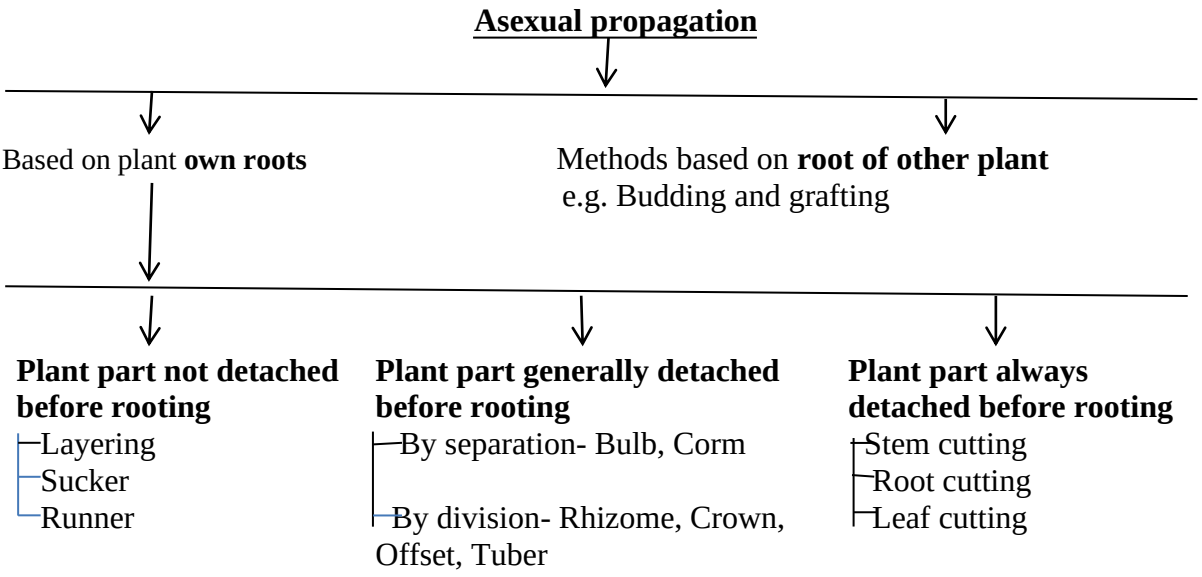
Types of propagation: two types- sexual and asexual propagation.

A. Sexual propagation:

Propagation by true seeds developed through normal meiosis, pollination and fertilization. e.g. Phalsa, Papaya, Karonda, Acid lime, Coconut, Coffee, Cocoa, Oil palm, Tomato, Brinjal, Chilli, Gaillardia, Sunflower, Coriander, Fenugreek etc.

B. Asexual/ Vegetative propagation:

a. Multiplication of plants by using vegetative plant parts such as shoot, root or leaves.



Advantages of sexual propagation

- Seedling are hardier and longer lived.
- Propagation by seed is simple and easy.
- Plant which are difficult to propagate e.g. papaya and phalsa by vegetative method can only be propagated by seed.
- In breeding for evolution of new varieties, the hybrids are first raised from the seed.
- Seed propagation is the only means of creating diversity. Diversity yield better plant type known as chance seedling eg. Mostly commercial varieties in mango eg. Dashehari, Langra, Chausa etc.
- The rootstock on which the fruit varieties are budded or grafted are usually obtained by sexual propagation.

Disadvantages of sexual propagation

- The seedling are not uniform in their growth, yield and fruit quality as compared to those propagated vegetatively.
- Seedling take more time to bear the first crop (Long juvenile period)

- Seed propagated plants are not true to type to the mother plants.
- Seed propagation exclude the benefits of rootstock
- Seedling plants are usually large in size, thus cost of harvesting, pruning and protection is more.
- Seedling plants produce yield of inferior quality.
- Some viruses transmitted by seed eg. Psorosis in citrus, mosaic in peach and cherry.

Advantages of asexual propagation

- Asexual propagated plants are true to type, since they are uniform in growth, fruit quality.
- Plant producing seedless fruit (eg. Banana, pineapple) can only perpetuated vegetatively means.
- Its bearing earlier (short juvenile phase).
- Possible to regulate tree size, fruit quality and precosity by using different rootstock.
- The benefit of rootstock and scion are exploited through asexual propagation eg. American grape (V. rupestris) var. St. George rootstock resistant to phylloxera pest, Trifoliate orange and Citrange are resistant to citrus nematode etc.
- Fruit maturity of a scion variety can be hastened or delayed by using different rootstock eg. For Kinnow Mandarin, Troyer citrange hasten fruit maturity while Karna Khatta delay fruit maturity.
- Plants are smaller in size, harvesting and spraying become easy.
- Damage part of the tree trunk and portion of plant can repaired by bridge grafting.
- Using asexual method, possible to convert a non-productive local variety into productive improved type variety by top working.

Disadvantages of asexual propagation

- Usually short lived.
- No new variety can be evolved by vegetative means of propagation.
- In citrus (tristeza virus) is transmitted through bud wood.
- Its specialized task and require some technical skill.

Propagation by cutting:

The cutting is the process of propagating plants by the use of vegetative part which, when detached from mother plant and placed under suitable condition, will develop into complete plants. Types1. Stem cutting 2. Root cutting 3. Leaf cutting

Stem cutting: A portion of stem is taken for propagation. Four types

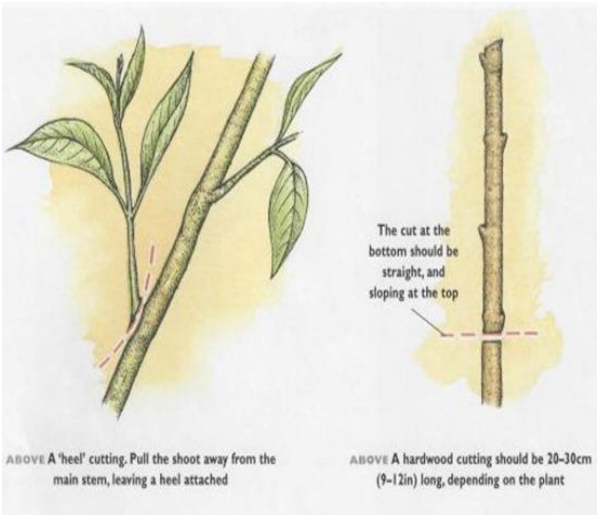
i. **Hard wood cutting:** One year old and mature shoots are selected for hard wood cutting. The length of cutting should be 10-45 cm. The cutting must possess at least 2 to 3 buds. The lower cut is made round just below the node and the upper cut is given about 1 to 2 cm above the upper node in slanting manner. Cutting in this manner helps in identifying

lower and upper portion of cutting (Polarity) and slanting cut also restrict stagnation of water drop on the top of cutting. Hard wood cutting taken during November to February before commencement of sproutinge.g.Grape, Fig, Pomegranate, Rose, Morus alba, Bougainvillea, hibiscus etc.

ii. **Semi-hard wood cutting:**For semi-hard wood cutting 4 to 9 months old shoot of semi-hard nature with 7 to 20 cm length is used. Terminal 2 to 4 leaves are left intact with shoot. This type of cutting is prepared during rainy season. Treatment of IBA @5000 ppm is effective in inducing rooting. Mist chamber and Bottom heat treatment (BHT) use for growing this type of cutting. Mango, Guava, Jackfruit, Lemon etc.

iii. **Soft wood cutting:**Soft wood cuttings are prepared from the soft succulent terminal portions. There is care should be taken to maintain high humidity to prevent from drying due to excessive moisture loss. Soft wood cutting are 8 to 15 cm long with 2 to 3 nodes e.g. Apple, Peach, Coleus, Money plant, Rubber plant, Carnation, Chrysanthemum,, Petunia, Dahlia etc.

iv. **Herbaceous cutting:** mostly ornamental plant propagated by herbaceous cutting. The shoot 1 to 2 old months are selected e.g. Alternanthera, Coleus, Pilea, Iresine etc.



Root cutting: The root of plant is utilized as propagating material. Root is 1 cm thick and 10-15 cm length used. In temperate fruits, the root cutting is prepared during December e.g. Blackberry, Raspberry, Anemone, Salvia, Aralia, Apple etc.

Leaf cutting: Leaf cutting is successful in propagation of some ornamental plants. Mostly succulent plants having thick and leathery leaves are propagated through leaf cutting e.g. Begonia, Crassula, Bryophyllum, Kalanchoe etc.

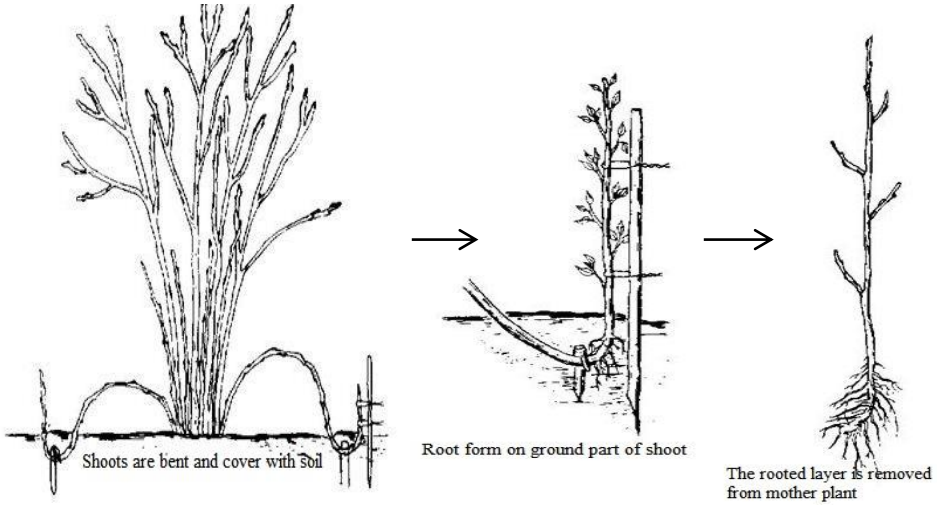
Propagation by layering:

Layering is the method of propagation in which roots are developed on a stem while it is still attached to the parent plant.

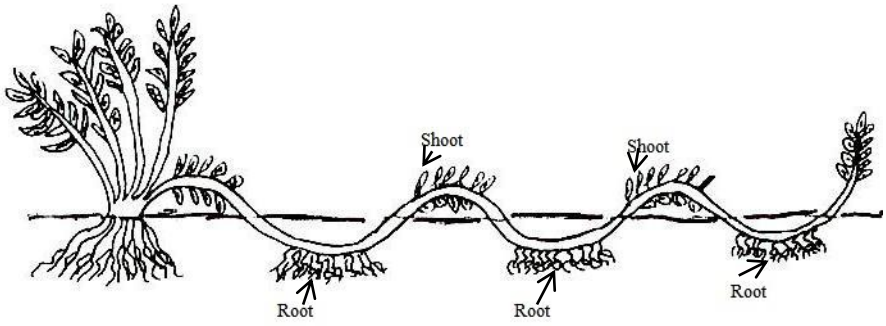
High success of layering is obtained by ringing or wounding, etiolation (Absence of light), use of rooting hormone (IBA) and favourable environmental condition (Temperature and humidity).

Types of layering-

i. **Simple layering:** A mature branch of one season growth is selected close to the ground, a sharp slit is made slanting towards the tip about 60-75 cm from the tip to form a tongue and a small stick is inserted in the slit to keep the cut portion away from each other. The branch is buried in the soil, after 3-4 months when root have formed, separate from mother plant e.g. Guava, Lime, Lemon, Jasmine, Oleander etc.

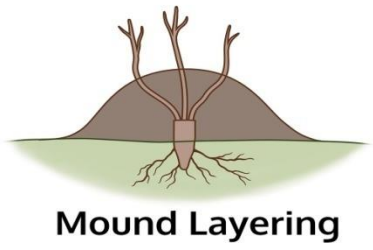


ii. **Serpentine or compound layering:**This layering is modification of simple layering. Long shoots that alternately covered and exposed over their entire length is known as compound layer. They normally form root at each node where they are covered and develop new shoots from buds a nodes that are not covered.

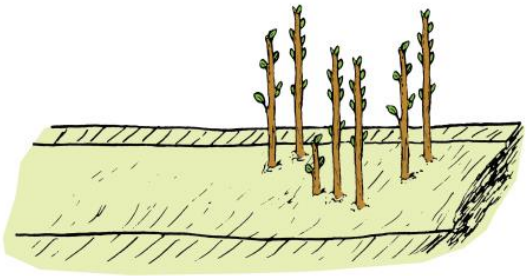


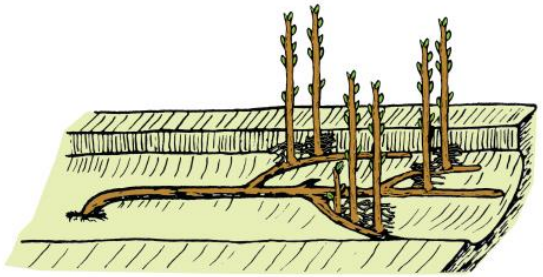
iii. **Mound layering or stooling:**

In mound layering the plant is pruned severely at 2.5 cm above ground level before the start of new growth. As a result many shoot emerge out from the base of the plant, they are girdled at base, use rooting hormone (IBA 3000-5000 ppm- Lanolin paste) if needed and covered with soil to a height of about 15-20 cm. Root emerge out in about 3-4 months. After rooting shoot is separated from mother plant and planted in nursery e.g. Guava, Apple, Pear etc

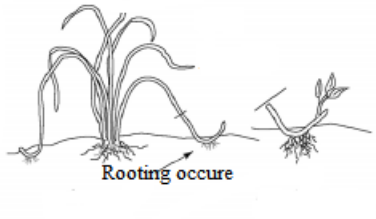

Mound Layering

iv. **Trench or continuous layering:**This method consists of completely covering a branch under soil. This is also known as the etiolation method of layering e.g. Vigorous rootstock of apple M-16 and M-25.





v. **Tip layering:**Tip layering is a natural method of reproduction of raspberries and blackberries. In these plant rooting place near the tip of the current growth.



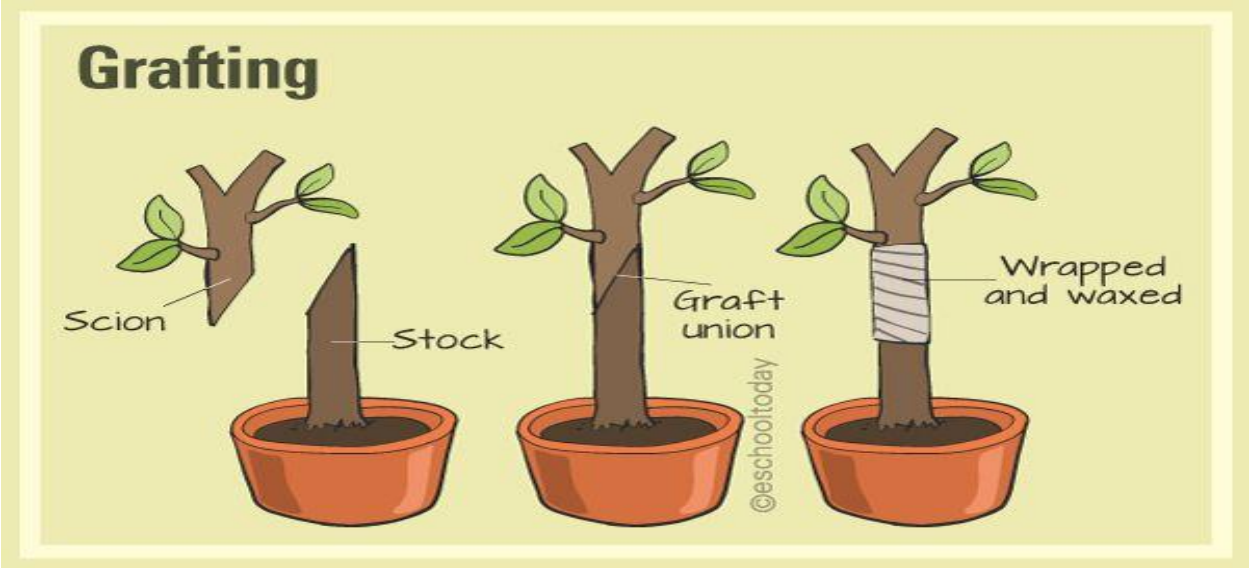
vi. **Air layering, goottee or Marcottage:**

One year old or previous season shoot of pencil thickness is selected. About 5-7 cm away from the base of selected shoot, a girdle of 2.5-3 cm size by removing the bark is prepared. Stem is girdled and rooting hormone (IBA- 3000-5000 ppm) is applied to upper part of cut. The moist rooting medium (Sphagnum moss) is wrapped with the help of small polythene trip (200-300 gauge). Rooting appears in about 2-3 months, layered shoot is separated from mother plant giving 2-3 cuts in installments. Air layering usually practiced in July-August e.g. Guava, Litchi, Kagzilime, Jackfruit, Cashewnut, Ficus, Crotons etc.

Propagation by grafting:

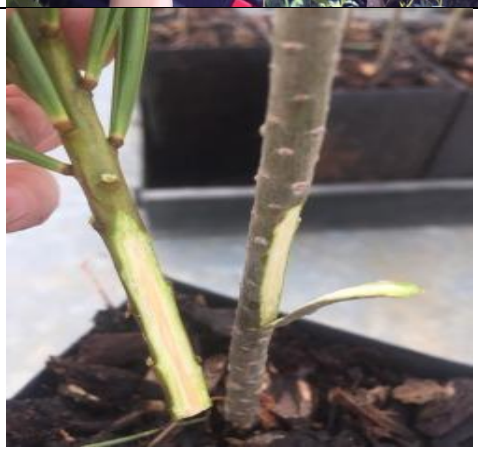
Grafting is a technique of propagation in which scion stick (shoot containing more than one bud) and rootstock is connected in a manner such that they may unite and subsequently grow and develop as a successful plant. The upper part of the composite plant is termed as 'scion' and the part which forms the root system is termed as 'rootstock'.

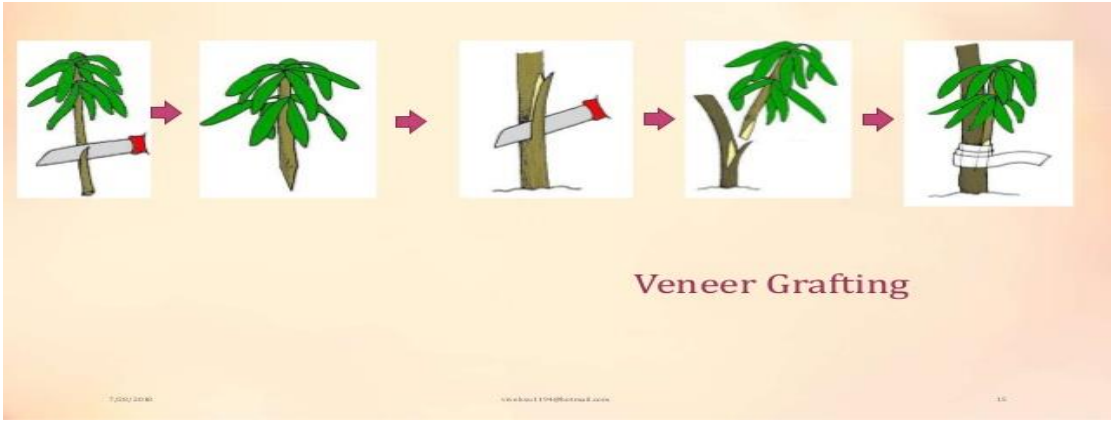
In temperate fruits better success is achieved by grafting just before the end of dormant season and in June-July grafting gives better result in tropical and sub-tropical fruits. When graft starts growing, the portion of rootstock above graft union is removed. Types-



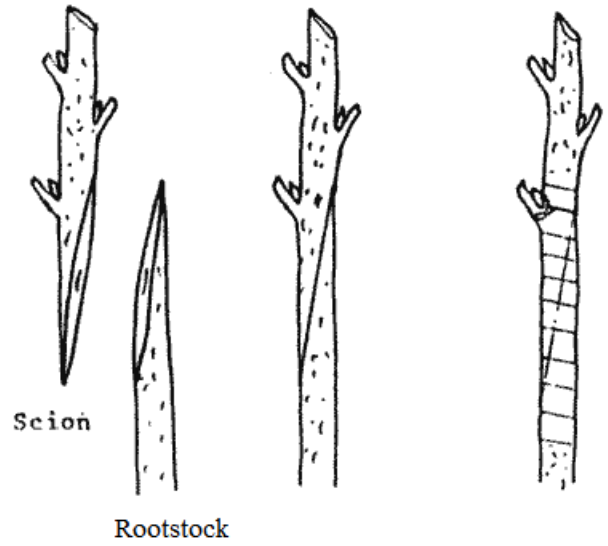
i. **Veneer and side grafting:**Terminal shoot of 10-15 cm length having pencil thickness is used as a scion. About 10 days before grafting, the scion shoot is defoliated to facilitate swelling of bud. Shallow, downward and inward cut ensuring V-shape incision in lower portion of incision on rootstock is prepared. Side grafting differ from veneer grafting, in veneer grafting only one side of the scion is sliced away in a

sloping manner whereas in side grafting the scion is sliced on both sides of the lower portion in the form of wedge and vertical flap of stock is completely removed. Both rootstock and scion are tied together using 300 gauge polythene tape of 0.5 cm width. In 3-4 weeks, union is completed and upper portion of rootstock above graft union is removed in 2-3 installments. Time of veneer grafting is May to September e.g. Mango.

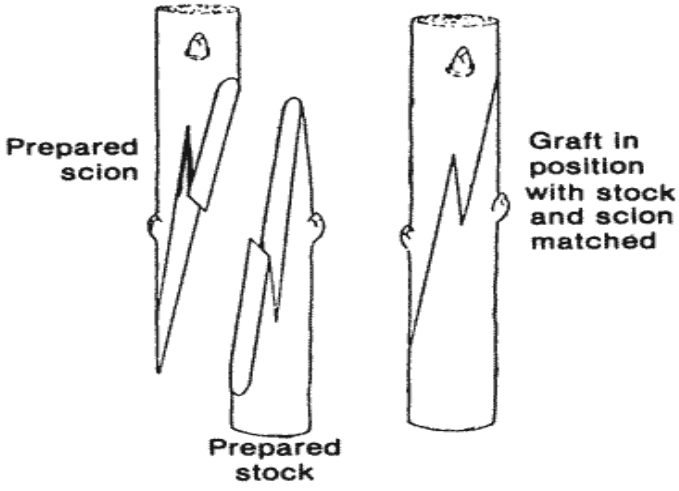




ii. **Whip or Splice grafting:** One year old rootstock is used. A slanting cut of 2 to 4 cm is given on the stock and a cut of similar length is made on the scion, cut surface are placed together and tied tightly. Splice grafting done in early spring.

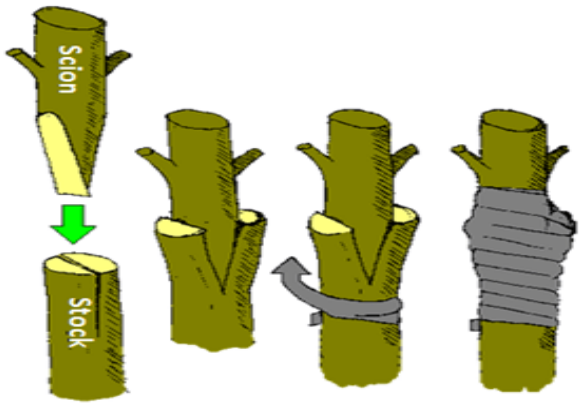


iii. **Tongue grafting:** This is a modification of whip grafting. A slanting cut similar to whip grafting is prepared on rootstock and scion. A second cut is given in reverse direction on previous cut in rootstock and scion. The second cut is started downward at about one third distance from tip and continue to about ½ the length of first cut e.g. Apple, Pear, Walnut etc.



iv. **Wedge, Saddle or Cleft grafting:**

The rootstock beheaded at 45 cm above ground level and rootstock in center the vertical split to about 5 cm deep prepared. The scion is prepared by giving two slanting cut each on opposite sides. Cleft grafting is mainly done in the end of dormant season or before the tree resume active growth for the purpose of top working in temperate fruit tree e.g. Walnut, Hazalnut, Pecannut, Cactusetc.



v. **Soft wood grafting:**This is very successful technique of in-situ grafting. Commonly practiced in mango. To ensure germination 2 to 3 seeds are sown in each pit. When the plant become one year old and attains pencil thickness used for grafting. The grafting is done at permanent site of planting in the field itself. The process of grafting is done during rainy season when new growth appears on rootstock and new growth leaves start turning yellow from coppery colour grafting is performed. The scion shoot of 10-15 cm length, 3-5 months of age and pencil thickness is selected. The leaves on the stock must be retained while grafting to get high success. The wedge shape scion is inserted into vertical split of rootstock.

vi. **Epicotyl or Stone grafting:** The age of rootstock is 7 to 10 days, when its leaves remain coppery in colour and scion shoot of 2 to 3 months age having pencil thickness are selected for performed epicotyl grafting. The vertical slit of 2.5-4 cm length is given on beheaded portion of rootstock. This technique commercialized for rapid multiplication of mango in konkan region of Maharashtra. This grafting done when relative humidity more in June-July.

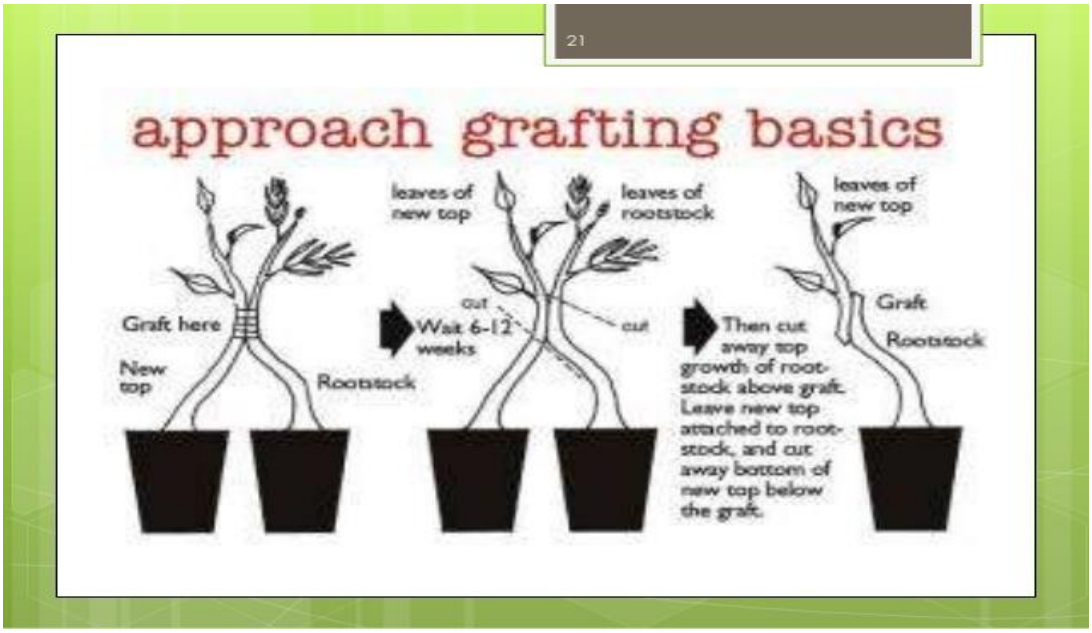
Fig: 1 ten days old seedling

Fig: 2 scion prepared for the grafting

Fig: 3 scion union at the base of grafted rootstock

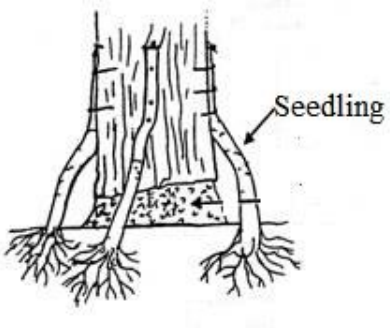
Fig: 4 one year old graft for sale

vii. **Inarching or Approach grafting:**In contrast to other method, in approach grafting the scion is detached after completion of union, also known as attached method of grafting. In this method rootstock is grown in pot or container. The rootstock is brought close to the scion and shallow cut of 2.5 to 4 cm length is prepared on scion. Similar matching cut is also given on rootstock. Both rootstock and scion are brought close to each other and wrapped using polythene tape. This grafting done in July-August. Union is complete in about 2-3 months than upper portion of rootstock is cut and scion shoot is detached from mother plant in 2-3 cuts e.g. Mango, jackfruit, Sapota, Loquat, Custard apple, *Allamanda violacea* etc.



viii. **Bridge grafting:** This method is practiced in plants in which scion is healthy and some portion of rootstock near collar region is damaged. Damaged portion of rootstock is scratched. In healthy portion of rootstock incision is made on top and bottom portion of the stock. The scion portion of suitable length is inserted stick should be removed time to time. It grows slowly in diameter and covers the damaged portion. This used for repairing damaged wood in Apple, Pear, Cherry, and Walnut etc.

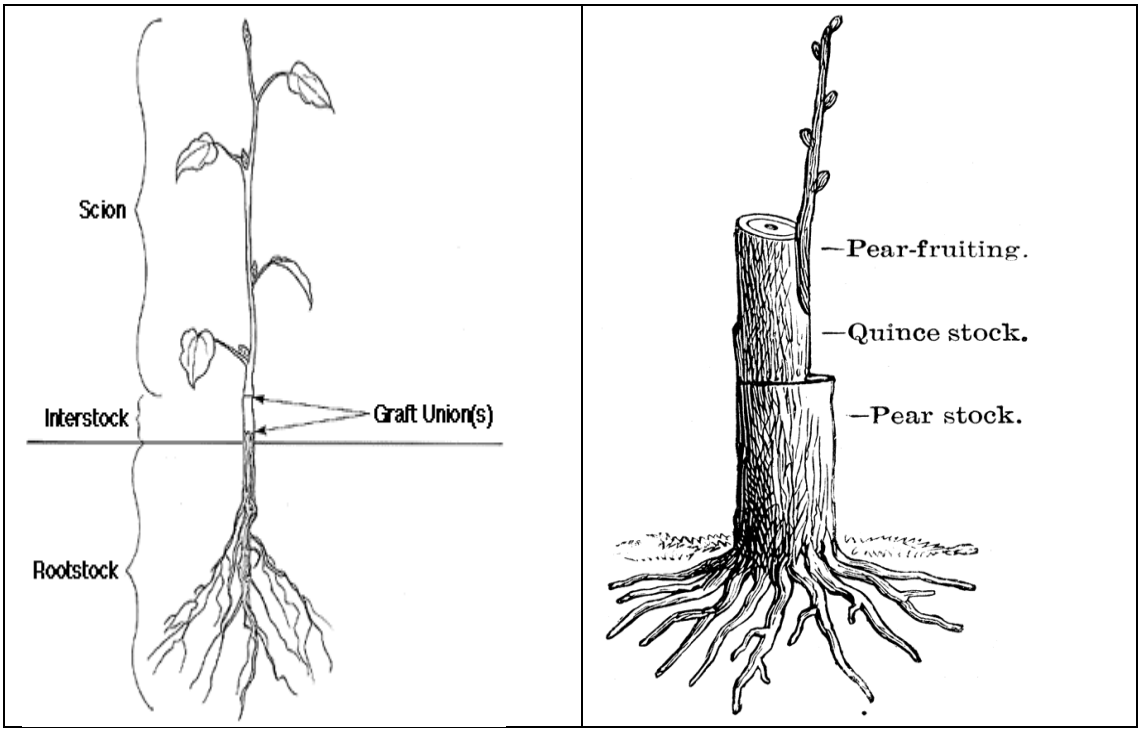
ix. **Buttress grafting:** This is used to rejuvenate old or ancient historic tree or whose root is rotting. Four rootstock seedlings are planted around the circumference of trunk.



x. **Top working:** The process of converting an undesirable plant into desirable type. Usually seedling of fruit plants are considerable suitable for top working. Plant is headed back within 1 meter height from ground level during spring and budding/grafting done in month of June-July. The young plant with a trunk diameter 2.5-20 cm is considered ideal for top working.

Successfully top worked mango tree

xi. Double working: The use of three grafted parts to make a tree, the rootstock, interstock and scion, instead of the more usual two (rootstock and scion). There are two main reasons for using interstem or interstem. Fistly, they can be used to achieve a combination of rootstock characteristics such as free stantind and drought tolerant in Apple. Secondly, interstock can also be used to minimize graft incompatibility between rootstock and scion.Old Home interstock for Bartlett var. Pear on Quince rootstock.



Propagation by budding:

The budding is a form of grafting in which a single vegetative bud is taken along with a small section of a desired variety or plant (scion) and is inserted into the stem tissue of another plant (rootstock) so that the two unite together and develop into a composite plant. Budding is a cheaper, easier, quicker and better method than grafting.

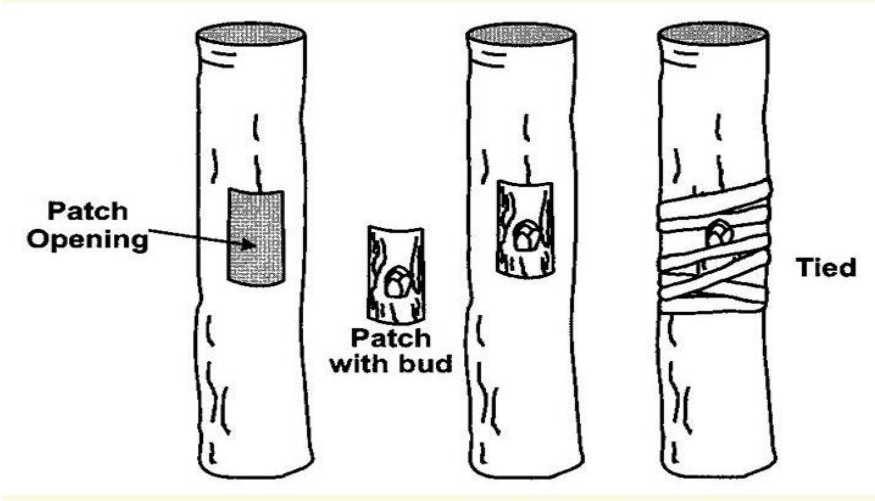
Budding is practiced during the active sap flow is going on and plant is growing successfully, during this period, taking out bud from scion stick become easy and also due to continued division of cambium cell, the chance of success of budding increase.

Time of budding- spring (March-April), summer (May-June) and rainy season (July-September).

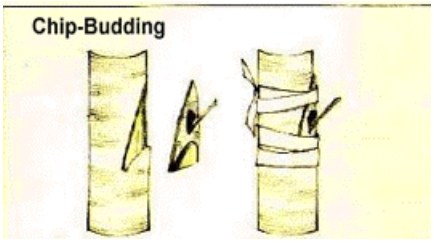
Types of budding-

i. **Shield or 'T' budding:** A 'T' shaped cut is made on the smooth surface of the stock at a height of 15-20 cm from the ground level for bud insertion, it is known as shield budding. First a vertical cut of 2.5 cm is given then a right angle horizontal cut at the top. Two flaps at the junction of cuts are then loosened slightly. Desired boat shaped scion buds are selected from current season growth with dormant bud. The bud is inserted by gentle push downward into the exposed flaps of the T- cut on the stock plant and tied with polythene strip leaving the bud. The ideal time for carrying out the operation is during the active growth stage of stock plant when the bark slips easily (rainy season). Shield budding done in Citrus, Rose, Apple, Pear, Peach, Plum, Apricot and Cherry.

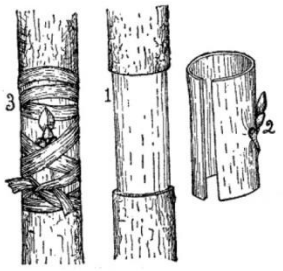
ii. **Patch budding:** A rectangular patch of a bark is removed completely from stock and replaced with a patch of bark of the same size containing a bud. The optimum time for patch budding is when the bark slips well, mid-May to mid-August in aonla suitable time for budding e.g. Aonla, jamun, Jackfruit and Mango.



iii. **Chip budding:** In chip budding, a long slanting downward and inward cut (2-3 cm) is given on the rootstock. A second cut, at 45^{o} angle and remove a chip of bark along with wood. A chip of similar size containing a bud is placed on the cut surface of rootstock and tied with polythene strip. When the bark is not slipping due to poor flow or adverse growing conditions such as lack of water or low temperature. Chip budding done in February-March e.g. Grape, Apple and Pear.

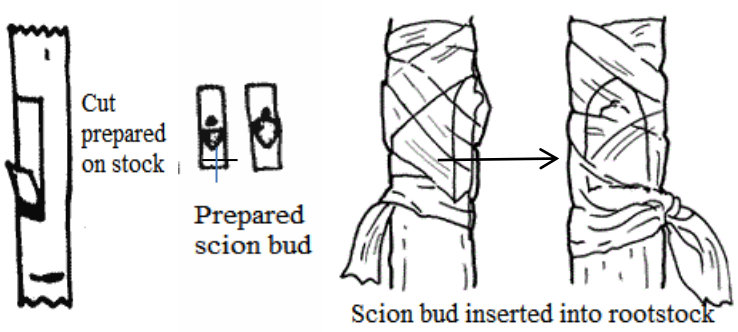


iv. **Ring or Annular budding:** A ring of bark is removed from the stock and bud stick preferably of same size is inserted e.g. Ber, Mulberry etc.



v. **Forkert budding:**Patch shaped bud use for budding, making incision on rootstock and vertical flap of bark is left intact with lower portion of the rootstock. For this purpose, two vertical cuts of 2 to 3 cm in length are made on a smooth surface of rootstock which is then connected by a transverse cut (1-2 cm) above the vertical cuts and the bark is peeled off slowly. A rectangular piece of bark containing the bud is

taken from scion plant. The patch of scion is then placed on the rootstock and the flap is drawn over then tying as usual. The vertical flap gives additional protection against adverse climatic condition e.g. Jackfruit, Cashew and Mango.



vi. **Flute budding:** It differ from the other forms in that a portion of the bark is removed entirely from the stock and a similar piece is fitted into its place.

Propagation by specialized organs:

Various modified plant organs such as corm, bulb, tuber, rhizome etc. which are primarily storage organ for food, are used as planting materials.

Two different methods are useful for propagation by the modified plant parts-

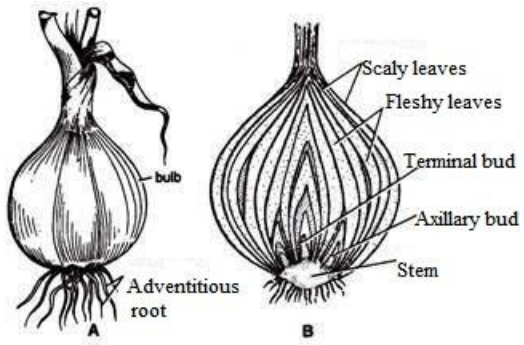
i. Separation- denotes the process of propagation of plants using naturally detachable structures e.g. bulb, corm

ii. Division- division indicates the propagation of plants using cut into section of a particular part like rhizome, tuber and offset.

Bulb: It is a specialized underground storage organ produced by monocotyledons plants. It consists of a shoot and fleshy vertical stem axis which bears growing point at its apex. Types of bulb-

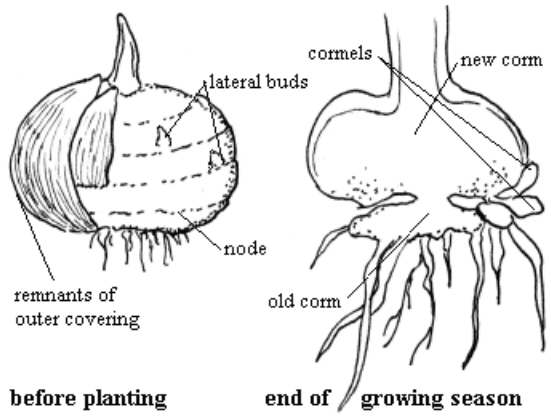
i. Tunicate bulb: Bulb covered by dry and membranous scale. Covering provide protection against drying and mechanical injury e.g. Onion, Garlic, Tulip, Daffodil etc.

ii. Non-tunicate bulb: Bulb do not possess any covering around them e.g. Lily



Bulb of onion and its L.S.

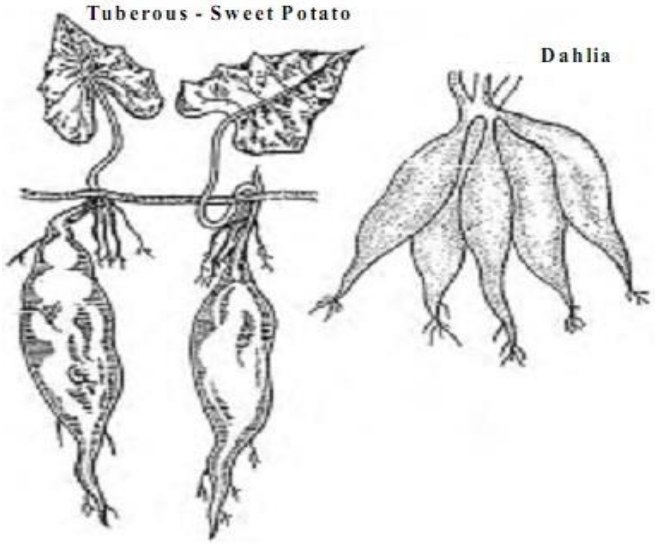
Corm: Corm is a short solid, swollen specialized underground structure which possesses distinct nodes and internodes. It remains enclosed by dry, scale like leaves e.g. Gladiolus, Water chestnut etc. Cormels are the small corms developed in between old and new corms which require two years growth to come into flowering stage.



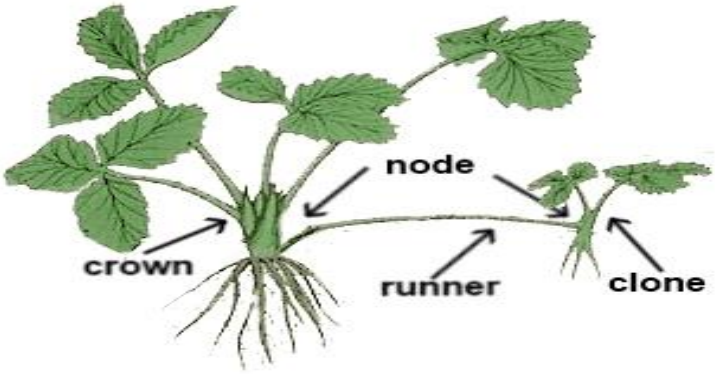
Rhizome: The rhizome is an elongated, horizontal fleshy underground stem having nodes and internodes. The rhizomes are cut into pieces, each with one or two viable bud for planting of rhizome e.g. Ginger, Turmeric, Iris, Banana, Canna etc.

Tuber: Specialized swollen underground stem which possesses food reserve, and eyes in regular order over the surface. A tuber consists of all the parts of stem such as nodes, internodes, lateral and terminal buds. The eyes represent the axillary or terminal bud. Tuber can be planted as a whole or cut into pieces, each having at least one eye and used as a planting material e.g. Potato

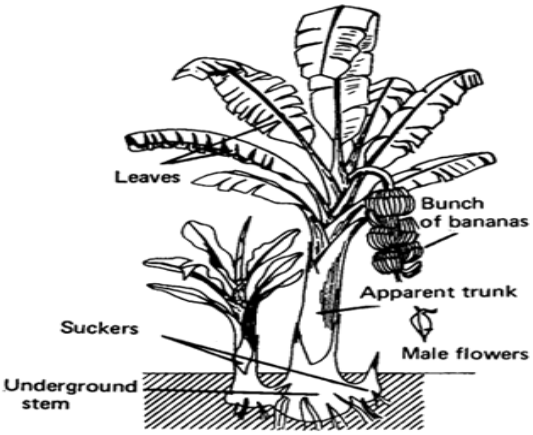
Tuberous roots: Tuberous roots are fleshy modified roots acting as a storage organ, bearing growing point on the stem end without nodes and internodes. Care should be taken when tuberous roots are separating from mother plant, at least a small portion of the stem as the new growth originates from the point of attachment with the stem e.g. Sweet potato, Cassava, Dahlia, Spine gourd etc.



Runner: A long prostrate shoot arises from the leaf axil and gives rise to a new plant at the end e.g. Strawberry. The runner production is increase by long day and high temperature.

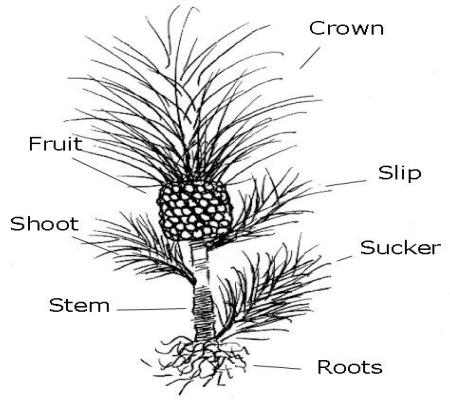


Sucker:A shoot arising on an underground part of stem or on horizontal root systems is known as sucker. These shoots separated from mother plant and transplanted, produce adventitious roots e.g. Raspberry, Blackberry, Date palm, Pineapple, Banana, Ixora, Chrysanthemum etc.



Offsets or Offshoots: Offset is a short rosette like stem arising from the base of the main stem. Usually these are shortened and thickened shoot of common occurrence in Date palm, Pineapple etc.

Crown: Crown is a very short condensed part of plant at the surface of the ground which gives rise to new shoots. Crown grown on the top of the pineapple fruit is a vegetative growth attached to the central core of the fruit. Splitted crown, into 4 t0 8 pieces, can also use but they take longer time to bearing e.g. Pineapple.



Micro propagation: Micro propagation refers to propagation of plant from very small plant part (explant), tissue grown aseptically in a test tube or container under controlled nutritional and environmental conditions.

Advantages of Micropropagation

- Large scale multiplication in lesser time and space
- Production of virus-free plants
- Year round production of plants
- Highly beneficial in those plants where vegetative propagation is difficult and seeds are not viable e.g. Papaya, Banana
- Somatic hybridization helps in evolving new cultivars in a short time
- For propagation of plant require a miniature plant part, whereas in conventional methods a shoot of considerable length is required

Disadvantages of Micro propagation

- The cost involved in setting up and maintenance is very high
- Require technical skilled manpower
- Some infection may damage the entire lot of plants
- Establishment of tissue culture plants in field is difficult task until they properly hardened

Stages of Micro propagation

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Stage- 0

Selection and maintenance of stock plants for culture initiation, duration at least 3 months

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Stage- I

Establishment and stabilization, duration 3 months to 2 years

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Stage- II

Shoot multiplication, duration 10-36 months

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Stage- III

Root formation, duration 1-6 weeks

↓

Stage- IV

Acclimatization, duration 4-16 weeks

Methods of Micro propagation

- Meristem culture
- Embryo culture
- Callus culture
- Cell culture
- Anther culture
- Protoplast culture

Plant Propagation Structures

The structure which facilitate propagation of plants are called propagating structure. Different types of propagation structure viz. greenhouse, hot bed, cold frame, lath house, net house, mist chamber, pot yard etc.

1. **Greenhouse**

A green house is a house covered with glass or polythene for protection against adverse climatic condition as well as to provide optimum environment for growth of the nursery plant.

Modern greenhouses are regulatory mechanism for controlling temperature, light intensity, air, humidity, CO_2 etc.

2. **Hot bed or hot frame**

Hot bed is a plant growing structure, used for growing small tender seedling and rooting of cuttings. The standard size is 0.9 x 1.8 m^2. There are three basic components- frame, cover and heating unit. Cover made by polythene or glass, and for heating steam piping, hot water piping, electric cable etc is used for heating the bed.

3. **Cold frame**

   Cold frame construction is similar to hot bed except that no provision is made for supplying bottom heat. Cold frame utilizes only the heat of the sun retained by the transparent covering. It is used mainly for hardening and conditioning of cutting and young sapling and protects small plant from wind and low temperature.

4. **Lath house**

   Lath house (lath- thin strip of wood) is a shade providing propagation structure used for protecting the young tender seedling or rooted cutting, which are highly sensitive to strong sunlight and high temperature.


5. **Net house**

   Net house are widely used as propagation structure in tropical areas, where artificial heating is not required and artificial cooling is expensive. Net house used for growing shade loving plants.

6. **Mist chamber**

   Mist chamber is widely used for rooting of softwood leafy cutting by nurserymen in throughout the world. The misting is to maintain high humidity, thus reducing transpiration and keeping the cutting turgid until rooting take place.

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Seed Dormancy

Seed dormancy: Seed dormancy is a condition where seeds will not germinate even when the environmental conditions (water, temperature, aeration) are permissive for germination.

Primary dormancy of seed itself or dormancy induced in the seeds at the time of dispersal from the mother plant i.e. the dormancy may be induced before maturity, during maturity and after maturity but before seed is dispersed from mother plant.

Secondary dormancy occurs only in a matured and imbibed seed by certain environmental conditions, which are unfavourable to germination.

Rest period: A period when the internal condition of a wood plant is unfavourable for growth of buds even though external conditions are favourable.

Methods of breaking seed dormancy:

1. **Scarification:** In this method of seed breaking, scratching, altering or softening the seed covering to make it permeable to water and gases. Scarification can be achieved by .

    - **Mechanical-** cracking of seed with hammer, rubbing with sand paper use for breaking dormancy, eg. Ber, Peach, Walnut.
    - **Hot water-** Impermeable seed coat of guava can be softened by hot water scarification. Seed placed in hot water at 77-100^0 C and immediately remove then soak in cool water for 12-24 hours.
    - **Acid-**Guava seed treated with concentrated Sulphuric acid for 3 minutes, in Ber for 5-6 hours and strawberry seed treated with 0.25 % nitric acid or Hydrogen peroxide.

2. **Stratification:** Dormant seed of temperate fruit eg. Apple, Pear, Cherry, Apricot etc. treated at temperature 1-5 ^{0} C for 1-5 months.

3. **Use of Hormones:** Use of growth regulators. Seed of apple, cherry, peach, strawberry treated with 100-500 ppm GA_3 for 24-48 hours. Guava and strawberry seed- 5000 ppm Ethrel.
4. **Use of Chemical:** Use 0.2 % Potassium nitrate, Peach, grapes- 5000 ppm Thiourea.

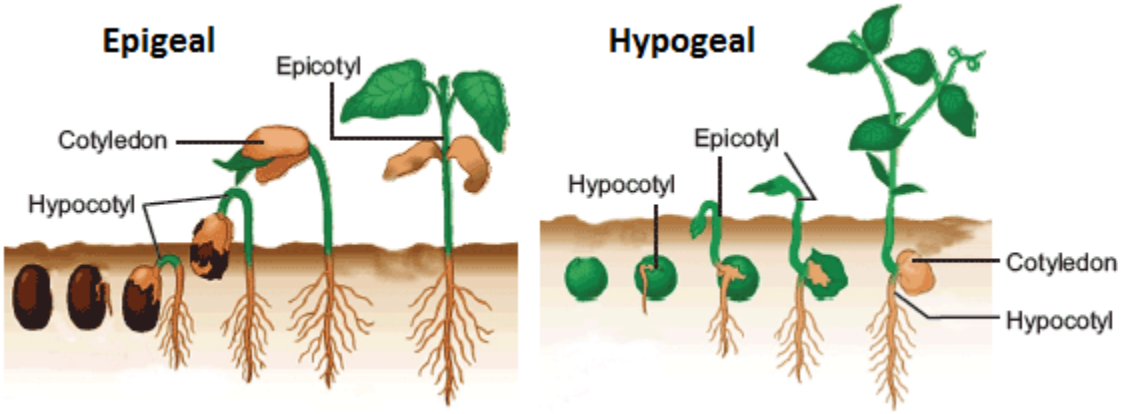
Types and causes of seed dormancy:

Type of Dormancy	Cause of Dormancy
A. Primary dormancy	
a. Exogenous dormancy	➢ Imposed by factors outside the embryo
1. Physical	➢ Impermeable seed coat
2. Chemical	➢ Inhibitor in seed covering
b. Endogenous dormancy	➢ Imposed by factors in the embryo
1. Morphological	➢ The embryo is not fully developed at time of the seed shed
i. Rudimentary	➢ Small undifferentiated embryo
ii. Linear	➢ Small differentiated embryo
2. Physiological	➢ Factors within embryo inhibit germination
i. Non deep	➢ Positively photo dormant (require light) & negatively photo dormant (inhibited by light)
ii. Intermediate	➢ Embryo germinate if separated from the seed coat
iii. Deep	➢ Embryo does not germinate when removed from seed coat
c. Combinational dormancy	➢ Combination of different dormancy
1. Morphophysiological	➢ Combination of under developed embryo and physiological dormancy
i. Epicotyl	➢ Radicle begins growth but epicotyl remain dormant
ii. Epicotyl and radical (double dormancy)	➢ Epicotyl and radical both are dormant
2. Exo-endodormancy	➢ Combination of exogenous and endogenous dormancy
B. Secondary dormancy	
a. Thermo dormancy	➢ High temperature induces dormancy
b. Conditional dormancy	➢ Change in ability to germinate related to time of the year

Seed Germination

Seed: Seed is ripened ovules. Seed have seed coat, embryo and seed endosperm.
Seed germination: Seed germination is the process by which an organism grows from a seed. Types

1. Epigeal germination: Germination in which the cotyledons appear above the ground, eg. Common Bean etc.
2. Hypogeal germination: Germination in which the cotyledon remain in the ground during germination, eg. Mango, Coconut, Pea etc.



Factors Affecting Seed Germination:
There are some major factors that affect seed germination. These include

A. External factors
   1. **Water:** Water is extremely necessary for the germination of seeds.The poor or additional supply of water affects the seed germination. The uptake of water by seeds is called imbibition, which leads to the swelling and the breaking of the seed coat.
   2. **Oxygen:** Germinating seeds respire vigorously and release the energy required for their growth. Therefore deficiency of oxygen affects the seed germination. It is an important and essential source of energy required for seed growth.
   3. **Temperature:** This affects the growth rate as well as the metabolism of the seed. Seeds of several other species germinate over a wide range of temperatures. Seeds of cool-season crops, such as lettuce, celery, etc. germinate best at relatively low temperature of 0 to 10°C, whereas seeds of warm-season crops like pumpkin, bottle gourd, etc. require relatively high temperature ranging from 20 to 30°C.
   4. **Light or Darkness**: Light or darkness can be an environmental trigger for germination. Many seeds (Forest spp.) refuse to germinate until sunlight falls on them.

B. Internal factors:

   1. The seed coat, which is resistant to water and gases, restrict water uptake and oxygen exchange.
   2. The seeds with undeveloped or immature embryo do not germinate.
   3. Certain seeds contain plant growth regulators which inhibit seed germination.

Seed viability: Seed viability (Germinability) is the capability of the seed to germinate and produce normal seedling under suitable conditions.

Seed longevity: Seed longevity is referred to the span up to which seed viability can be retained after harvest. So, seed longevity may be synonymous to storability of the seed.

Seed longevity in normal storage, eg. Mango (up to 1 month), Papaya (3 weeks), Guava (2-3 weeks), Onion (1 year), Okra, Carrot, Chilli (2 years), Tomato, Brinjal (4 years).

Germination test: Germination test is the most commonly used test to determine the viability of seed. In this test, germination is taken as the emergence and development of the seedling to a stage where the presence, absence and formation of essential structures can be assessed thus, indicating whether or not the seedling is able to develop further into a satisfactory plant under favourable conditions on soil. Generally, seeds are germinated on wet filter paper in petridish or germination box.

1. **Tetrazolium test (TZ test):** It is widely recognized and quick method of predicting seed viability. This test developed by Lakon in 1942. In this method, the seeds are soaked overnight at room temperature for complete hydration of all tissues. Then the hydrated seeds are cut longitudinally. One half of each seed is placed in a petridish and covered with 1 % solution of tetrazolium chloride and kept in dark for 3-4 hours.

   $$\text{Viable seed (\%)} = \frac{\text{Number of half seed properly stained red}}{\text{Total number of half seeds}} \times 100$$

2. **Excised embryo test**
3. **Mobilization efficiency test**
4. **X-ray test**