Principles of Horticulture

1. Introduction

- The term Horticulture first appeared in the writings of **17th century**
- In English, term horticulture first mentioned by **E. Philips** in **"The New World of English Words"** (London, 1678)
- The word is derived from the **Latin word -** ***'Hortus'*** meaning '**Garden'** and '***Cultura'*** meaning **'Cultivation'**
- Horticulture – **Cultivation of garden crops** (Fruits, Vegetables, Spices, Flowers, Plantations, Medicinal and Aromatic crops)
- In India, about 55-60 % of the total population depends on agriculture and allied activities

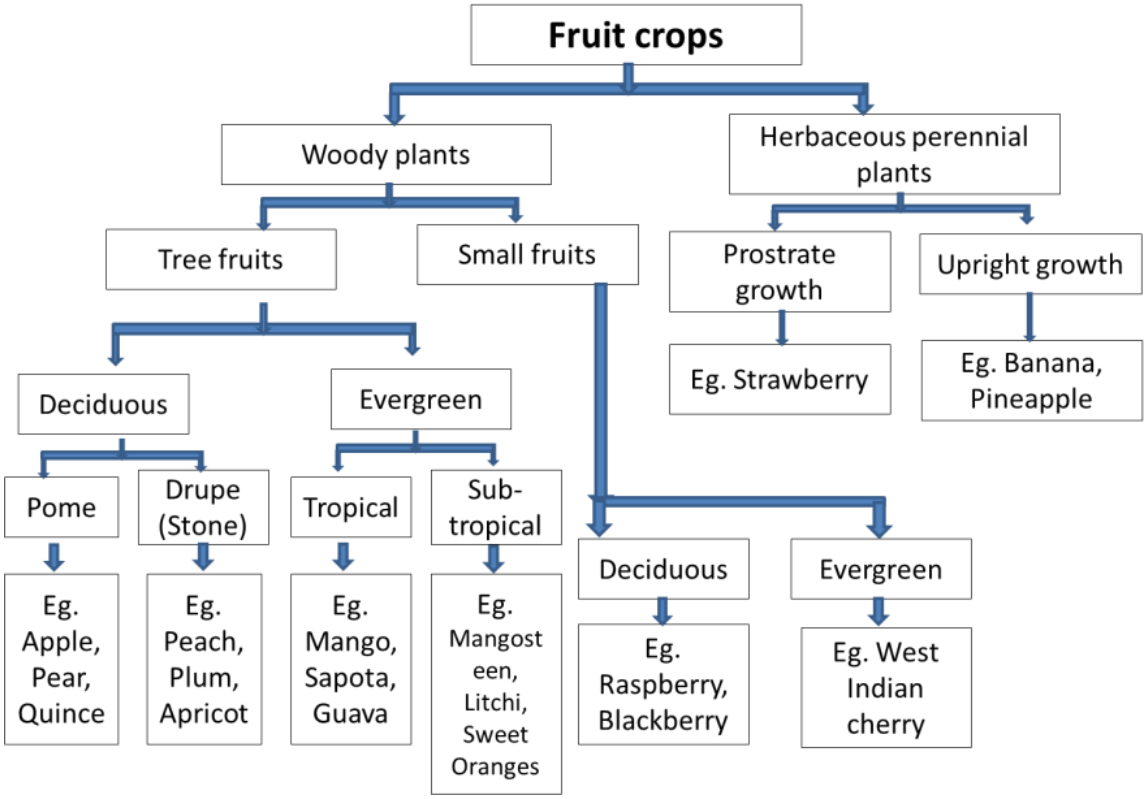
Horticultural science can be distinguished from agricultural or forestry science

Horticultural science	Agricultural or Forestry science
✓ Produces – utilized in fresh state and highly perishable	✓ Dried state and high in dry matter content
✓ **Intensive cultivation**	✓ **Extensive cultivation**
✓ Propagation, training, pruning & PH – specific to horticultural crops	✓ No such specific activity
✓ Sources of **Vitamin** and **minerals**	✓ Sources of **Protein** and **carbohydrates**
✓ Aesthetic sense or gratification	

Divisions of Horticulture

1. Pomology

- Pomology is the **study of fruit crops and science**
- **Latin** word ***Pomum* – fruits** and **Greek** word ***Logy* – science**
- Fruits occupy **1.0 %** of the total cultivable area with 4.9 % of the total income
- India is **second largest** producer of fruits after China
- India accounts for **10 per cent** of the total world production of fruits
- The leading fruit growing states are **MH, Karnataka, AP**, Bihar and UP
- **Pusa Aditi** – is a newly developed variety of **Grapes**
- World largest producer of litchi – **India**



- ✓ **Deciduous plants** – have a distinct rest period
- ✓ **Evergreen plants** – do not have any distinct rest period

Definite cyclic growth – season (North Indian conditions)

- ✓ Spring – New growth of flush and flowers
- ✓ Summer – Fruit set and fruit maturity
- ✓ Autumn – Shedding of leaves
- ✓ Winter – Rest period

Definite cyclic growth – season (South Indian conditions)

- ✓ February to June – New growth, flowers and fruits
- ✓ After July – Gradual stoppage of growth
- ✓ October to November – Shedding of leaves
- ✓ December to January – Enter into rest

Based on temperature requirement

- ✓ Temperate
- ✓ Sub-tropical
- ✓ Tropical

- **Temperate fruits** – Deciduous fruits
- **Tropical and Sub-tropical fruits** – Evergreen fruits

Based on tolerance to the relative humidity of the atmosphere

- ✓ Arid
- ✓ Semi-arid
- ✓ Humid zone fruits

Peculiar eco-climatological features of arid and semi-arid regions

- **Deficiency of moisture restricts** but not necessarily inhibits plant growth
- Rainfall is **very low (0 - 250 mm)** and is confined to 2 – 4.5 months
- Higher solar radiation incidence **(450 – 500 cal cm^{-2} day^{-1})**
- High wind velocity **(20 km hr^{-1})** results in a high Potential Evapotranspiration **(6 mm day^{-1})**
- Soils – poor quality – low fertility level – **poor water holding capacity (20 – 25 %)** and with high infiltration rate **(9 cm hr^{-1})**
- Ber, Annona, Date palm, Phalsa – **Arid and Semi-arid crops**
- Mangosteen, Litchi, Mandarin oranges – **Humid zone fruits**

Classification of fruits based on rate of respiration

- **Climacteric fruits**:
  - ✓ **Respiration rate will be increased sharply** after harvesting
  - ✓ Eg. Mango, Banana, Papaya, Guava, Sapota, Apple etc.,
- **Non-climacteric fruits**:
  - ✓ **Respiration rate will be steady** and ripening will be slow after harvesting
  - ✓ Eg. All citrus fruits, Grapes, Pomegranate, Pineapple, Wood Apple, Fig, Litchi, Cherry, Raspberry, Blackberry, Strawberry, etc.,

2. Olericulture – study of vegetables

- **Latin** word ***Oleris* – Pot herb**
- **English** word ***culture* – Rising of plants**
- **Area 10,259 M ha, Production 184394 t, Productivity 17.97 t per ha**
- India share in world vegetable production – **13.7 %**
- Vegetable share in maximum export – **Onion**
- Sodium rich vegetable crop – **Lettuce**
- Acid tolerant vegetable crop – **Watermelon**
- God send vegetable is known as – **Winged bean**
- Which vegetable crop leading area in India – **Potato**

- The highest broccoli producing country in world – **USA**

Fruits and Vegetables

- Fruits and Vegetables are regarded as **'Protected foods'** since they **supply minerals** such as Calcium, Iron and Phosphorus. **Vitamins** like A, B, C. Fruits and Vegetables are **good laxatives**
- The nutrition expert group presents a daily a minimum of 2400-3900 calories of energy, 55g protein, 0.4-0.5 g calcium, 20g of Iron, 3000 mg of B carotene (Vitamin A) 1.2-2.0 mg thiamine, 1-2.2 mg riboflavin, 16- 26 mg nicotinic acid and 50 mg ascorbic acid
- To obtain this, dieticians recommended **300g of vegetables** i-e. **125 g of leafy vegetables, 100g of roots and tubers, 75 g of other vegetables, 90 g of fruits**
- But the per capital availability works to 30g fruits 92 g vegetables only

3. Spices, Plantation, Medicinal and Aromatic crops

- **Spices** – Food adjuncts to **add aroma and flavour** (eg. Pepper, Cardamom, Clove and Nutmeg)
- **Condiments** - Food adjuncts to **add taste only** (eg. **Coriander** and **Cumin**)
- **Plantation crops** – **Extensive scale** of cultivation (eg. Coconut, Arecanut, Tea, Coffee, Rubber)
- **Medicinal crops** – Plants yielding alkaloid and steroid principles which have got preventive and curative properties (eg. Periwinkle, Pyrethrum, Aswagandha, Coleus and Fox-glove)
- **Aromatic crops** – Yields aromatic **essential oil** (eg. Geranium, Patchouli and Lemon grass)
- **India** is the largest producer and exporter of spices

4. Floriculture – Science of flower production

- **Loose flowers/traditional flowers** – Jasmine, Marigold, Chrysanthemum
- **Cut flowers** – Rose, Gerbera, Carnation, Orchids, Gypsophila
- Landscape gardening – Art of beautifying a piece of land using garden design
- Arboriculture – Growing of trees for aesthetic or scientific or educational purpose

Other branches of Horticulture

1. Fruit nurseries
2. Vegetable/Flower seed production
3. Fruit/Vegetable processing
4. Medicinal plants extraction
5. Essential oil (oleoresin)

- Horticulture crops occupy only 7**.0% of the total cropped area**. But its contribution to natural income is **18-20%** of total value of agricultural produce.
- The export of agricultural crops contributes 25% of our export out of this, horticulture crops alone contributes **56%** of total earnings from agricultural sector

- Horticulture crops fetch **20-30 times more foreign exchange/unit** are than creates due to higher yields of price

Scope and Importance of Horticulture

- Horticultural crops contribute to **national income**. This can be well judged from the total value of the produce available annually from these crops.
- Horticultural crops occupy only 7.00 per cent of the cropped area but their contribution to the national income is roughly 18 to 20 per cent of the total value of the agricultural produce.
- The agriculture sector accounts for about 25 per cent of our export basket. Of this, horticultural crops alone account for over 56 per cent of the total earnings from agriculture sector. These crops fetch 20 – 30 times more foreign exchange per unit area than cereals dueto higher yields and higher prices available in the international market
- As a source of nutrients, **vitamins, minerals, flavour, aroma, alkaloids, oleoresins, fibre**, etc.
- As a source **of medicine**.
- As an economic proposition as they give higher returns per unit area in terms of energy, money, job, etc.
- **Aesthetic consideration and protection of environment**.
- Religious significance.
- Fruits and vegetables are regarded as **'Protective foods'**
- Horticultural crops **yield more produces per unit area** compared to cereals
- Horticultural crops generate **more employment opportunities**, especially in the rural sector, uplifting the rural economy
- Horticultural crops are also highly remunerative and profitable than cereals
- Fruits yield **more calorific value**
- Many horticultural produces and their by-products are the important raw materials for many industries, thus providing more employment opportunities e.g. Rubber, Coir and Sago industries
- **Social importance:**
    - ✓ It is a part of civilization, wherever civilization is highly advanced, Horticulture is widely developed
    - ✓ Flowers are being used for worshipping Gods in temples
    - ✓ Every woman in our country considers here adornment complete only when her hair is decorated with aromatic and attractive colourful flowers
    - ✓ Flower offering is a symbol of affection in other countries
    - ✓ Often in hotels and business establishment, keeping the cut flowers in vases is becoming very common in India

- **Horticultural Therapy:** In some parts of the U.S.A., people who are unhappy and do not have mental power and balance are given horticultural therapy, a treatment by means of which their **attention is diverted to ornamental gardening, flower decoration** *etc.* and thus they are made free from

their unhappy mood. Also, by making them to be with flowers of particular colour, the **mental stress or depression can be removed**

- **Therapeutic garden**
  - ✓ A **therapeutic garden** is an outdoor garden space that has been specifically designed to meet the physical, psychological, social and spiritual needs of the people using the garden as well as their caregivers, family members and friends
- **Healing Garden**
  - ✓ Throughout history gardens have been used to aid in the healing process — from the **Japanese Zen Garden to the Monastic Cloister garden**
  - ✓ However, with the advances in medical technology in the **20th century**, the use of gardens as healing elements began to diminish

In brief it can be stated that horticulture has great scope for the following reasons

- To exploit great variability of agro climatic conditions.
- To meet the need for fruits, vegetables, flowers, spices, beverages in relation to population growth based on minimum nutritional and other needs.
- To meet the requirement of processing industry.
- To substitute import and increase export.
- To improve the economic conditions of the farmers and to engage more labourers to avert the problem of unemployment.
- To protect environment

2. Climatic Zones of India for Horticulture Crop Production

Advantages of classification

- ✓ To expose the agricultural potentiality of an area
- ✓ Location of homo climatic zones-enables identification of soil + climatic problems
- ✓ Helps in introduction of new crops eg. **Oil palms in Kerala**
- ✓ Development of crop production technologies specific for the regions
- ✓ To take up research work to solve regional problems
- ✓ To transfer the technology developed

Temperate Northern region

- ✓ J& K, H.P., hills of U.P., W.B.
- ✓ Crops: Temperate fruits & vegetable

North Western arid region

- ✓ Rajasthan, Gujarat, parts of Punjab & Haryana
- ✓ Crops: Ber, Pomegranate, Aonla, **Seed spices**

North Eastern sub-tropical humid region

- ✓ Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland & Tripura
- ✓ Crops: Banana, Pine Apple, Citrus, Jack fruit, Tea & Cardamom

North Central sub-tropical region

- ✓ Parts of U.P., Bihar, entire M.P., and part of Maharashtra
- ✓ Crops: Mango, Sapota, Sweet Oranges & Guava

South Central tropical region

- ✓ Western & Eastern Ghats of T.N., A.P., Karnataka & part of Maharashtra
- ✓ Crops: Mango, Guava, Sapota, Pine Apple, **Turmeric**

Coastal tropical humid region

- ✓ The entire coastal belt of Bay of Bengal & Arabian sea.
- ✓ Crops: Banana, Mango, **Cashew, Coconut**

Southern hilly zone

- ✓ Western & Eastern Ghats above 800 M MSL.
- ✓ Crops: **Coffee, Tea, Cardamom, Pepper**, Oranges, Pine Apple

AGROCLIMATIC ZONES OF TAMIL NADU

Geographic location

- ✓ Southernmost, $8^{o}5'$ and 13^{o} 10' North Lat. & 76^{o} 15' and 80^{o} 20^{o}' East.
- ✓ Coastal line about 1000km in East & South.

Physical characters

- ✓ Coastal plains, Eastern Ghats, Central plains and Western Ghats

Climate

- ✓ Semi-arid (Thornthwaite and Mather)

Rainfall

- ✓ Mean – 937 mm
- ✓ Seasons – Winter, summer, South West and North East.
- ✓ Variation exists between regions

Temperature

Plains –	Mean day	-	29^{o} to 38^{o}c
	Mean night	-	19^{o} to 27^{o} c
Hills	Mean	-	19^{o} to 24^{o}c
	Mean night	-	8^{o} to 11^{o} c

Factors limiting horticultural crop production

I. BIOTIC

a. Diseases

- ✓ Banana : Bunchy top, Panama wilt, sigatoka leaf spot
- ✓ Grapes : Mildews, anthracnose
- ✓ Tomato : Spotted wilt, leaf curl, leaf spot
- ✓ Chillies : Anthracnose
- ✓ Bhendi : Yellow vein mosaic
- ✓ Coconut : Tanjavur wilt

b. Pests

- ✓ Mango : Stem borer, Nut weevil
- ✓ Coconut : Rhinoceros bettle, Eriophyid mite, Red palm weevil
- ✓ Tomato, Brinjal : Fruit borer
- ✓ Banana : Pseudostem weevil

c. Nematodes: Banana, Crossandra, Grapes, Turmeric, Potatoes, Citrus, Solanaceous Vegetables

d. Other microbes

e. Plant genetic make up

1. A hybrid or selection
2. Vigorous feeder or not
3. Water loving or not
4. Resistance to biotic & abiotic stresses
5. Nature of life cycle

II ABIOTIC

Soil

i. Soil type

a) **Sandy soil** – coarse, large pore space, poor water & nutrient holding, suits propagation activities

b) **Loamy soils** – have sand, silt & clay, classified accordingly. Sandy loam is suited for early crops, highly suitable for hort. crops.

c) **Clay soils** – fine textured, very small pore space, not suited for horticultural crops. It should be improved with organic manure. It has better water & nutrient holding capacity

d) **Organic soils** (High organic matter – **20%**)

- ✓ **Microorganism** – enzymatic digestion (Organic matter – plant & animal waste)
- ✓ Green manure cropping
- ✓ Found in swamps, bogs and Lake Bottom and river beds
- ✓ Peat – **50-90% organic matter** – High WHC – crops like Tuber, Root, Cole crops)
- ✓ Muck – **20-50% organic matter** – low WHC

ii. Soil fertility

- ➢ It is important to nourish & sustain the soil productivity
- ➢ Soil, air, soil moisture, soil microbes & humus help absorption
- ➢ Top layer is more fertile usually
- ➢ Crops like Coffee, Cardamom, Pepper, Ginger, Clove and Vanilla prefer fertile soils
- ➢ Good soil management practices necessary

iii. Soil reaction

- ➢ It influences nutrient availability eg. **Boron** - deficient in **alkaline soil** - unavailable in very **acidic soil**
- ➢ **Activity of soil bacteria** is also influenced and thereby nutrient status

- Diseases are promoted – eg. **Club roots disease of Cole crops high in acidic soil**
- Slight acidic soil better for most crops
- Apply **Gypsum & Aluminium sulphate** to alkaline soils
- Apply **lime or epsum (Magnesium sulphate)** to acidic soils
- Alkaline soils – **sodicity** is dangerous
- Knowledge on soil salinity is important

Classification of soils based on salinity tolerance

- ✓ Tolerant: 8mmhos. (eg. Dates, Guava, Fig, Grapes)
- ✓ Moderate: 3 - 6 mmhos (eg. Pome, grape fruit, apple, pear & plum)
- ✓ Sensitive: 1.5-3 mmhos (eg. Orange, peach, avocado, strawberry)

iv. Soil depth

- ✓ A depth of **2.0 m** is essential for fruit crops
- ✓ No hard & compact subsoil layers like Canker, rock & heavy clay should be present

v. Soil drainage

- It depends on nature of subsoil
- Better tree stand in good subsoil
- Poor aeration-another effect
- Water table below 2.0m
- Higher water table-poor aeration
- Root rotting by prolonged submergence
- Higher disease incidence
- Eg. **Sweet orange** failed in U.P & Punjab

Climate

i. Temperature

- Specific temperature is required for each crop
- Classification: temperate – subtropical – tropical
- If temperate crop is grown in tropical (or) vice-versa, growth & development will be affected
- Exception – eg. **Grapes (temperate crop)** – can be grown in tropical region
- Temperature requirement varies with stage also
  - ✓ Eg. **Tomato** at early stage – requires higher night temperature of **18-27^{o}C for fruit set** it requires 13 to 17^{o}C It affects flowering
  - ✓ Eg. **Banana** requires **10^{o}C - 40^{o}C.** At 10^{o}C (or) < **chocking of bunches** is observed.
  - ✓ **Temperature affects quality** of low temperature in grape - high acidity is noticed high

temperature of grape - sweetness.

- Winter kill –death by low temp/chilling injury
- Hardy plants – **Asparagus – resistant to cold injury**
- Tender plants – **cucumber – susceptible to cold injury**
- Cold injury – Ice formation
- High temp. – Desiccation

ii. Light

- ✓ Intensity
- ✓ Quality
- ✓ Duration
- ✓ Influences all activities
  - **Photoperiodism** – response of plants to photoperiod. It also affects sex of plants
    - **Eg. Cucurbits** – Long Day - Male Flowers
      Short Day - Female Flowers
  - Coffee, Cardamom, Cocoa - Filtered shade **(Sciophytes)**
  - Apple & Mango - good light - good colour& quality

iii. Humidity

- ✓ Humid zone
- ✓ Semi-arid
- ✓ Arid

- High humidity at flowering & fruiting results in high pest and disease incidence mango, grapes, potato, tea
- Vegetative propagation methods more successful at high humidity levels

iv. Rain fall

- If continuous rains exist at flowering-pollen washing is resulted, insect pollination reduced thereby pollens get injured stigmatic fluid is diluted.
- **Coffee: Feb-March (Blossom) showers** decides flowering in the successive two years
- **Cardamom: Feb to April - Panicle initiation**
- Grape - rainy season crop leads to poor quality

Rainfall range:

- ❖ Mango 25 to 250 cm/year
- ❖ Pepper 125 to 200 cm/year
- ❖ Cardamom 200 to 250 cm/year

- ❖ Rubber 200 to 250 cm/year
- ❖ Dates 15 to 25 cm/year

v. Wind

- Lower & fruit shedding-breaking of branches, trees uprooted-rapid moisture loss are some of the effects need for irrigation is very frequent

vi. Air pollutants

- **0_3, So_2, No_2** reduce assimilation rate, growth & development eg., Mango orchards in **Punjab, U.P., Bihar, West Bengal** are affected by **black tip disorder** since they were located **1.5 km from brick kiln**.
- **CO_2, So_2 and acetylene** are responsible

vii. Frost

- Formation of thin layer of ice crystals during winter at **2000m MSL** is noticed
- It damages tea, potato and Cole crops.

viii. Hail storms

- Hails at pre-blooming or blooming of apple, plum, peach affect fruit set.

xi. Altitude

- Critical factor deciding climate particularly temperature
- For every warm temperature fruits require 1800 m MSL
- Every 100m elevationincreases 1 to2^{o}C temperature decrease is noticed
- Humid zone fruits & plantation crops -100 to 1800m
- Tropical fruits requires <1000m.
- **Coconut at 1000-1200m** MSL takes 10-12 year for flowering
- Papaya at hills has only poor taste
- Tea - yield and quality is affected. **High altitude resulted in good quality**

3. Methods of Propagation of Horticultural Crops and Their Advantages and Disadvantages

- **Plant Propagation** – refers to multiplication or perpetuation of plants
  - ✓ Seed or sexual propagation
  - ✓ Vegetative or asexual propagation

Seed propagation

- Seed propagation or sexual propagation – by means of seed

Seed formation

- Megasporogenesis – Microsporogenesis – fusion of male female gametes –meiotic division – double fertilization – seed (fertilized ovule containing embryo)

Seed Maturity

- **Ripening stage** – increases both moisture content and dry matter content
- **Maturation stage** – moisture content losses but increases dry matter content (ability to withstand desiccation)

Albuminous seed: Endosperm is large and contains most of the stored food

Exalbuminous seed: Endosperm is lacking or reduced to a thin layer surrounding the embryo

Different parts of flowers converted into following parts

Flower structure	Converted into
Ovary	Fruits
Ovule	Seeds
Integuments	Testa (seed coat)
Nucellus	Perisperm
Two polar nuclei + Sperm nucleus	Endosperm (3n Triploid)
Egg nucleus + Sperm nucleus	Embryo (2n Diploid)

Seed germination

- Seed is an embryonic plant surrounded with protective seed coat or covering and supplied with stored food
- It is the physiological process through which development of seed into a seedling takes place when exposed to favourable environmental conditions
- While germination, **radicle comes out first** followed by **plumule**
- The radicle gives rise to the rootsystem of plant while the plumule gives rise to shoot system

- **Epigeous germination**:
  - ✓ The hypocotyl elongates and raises the cotyledons above the ground
  - ✓ Eg. Mango, Jack, Cashew nut, Tamarind
- **Hypogeous germination**:
  - ✓ Lengthening of hypocotyl does not raise the cotyledons above the ground
  - ✓ Eg. Peach

There are 3 factors which are associated with germination of seeds

- ✓ Seed must be viable *viz.,* embryo should alive
- ✓ Seed should be subjected to favourable environmental condition
- ✓ Internal conditions associated with seed which prevent the germination have to be eliminated

Germination is a complex biochemical change, which involves mobilization of reserved food within seed and utilization by the embryo for growth

Environmental conditions affecting seed germination

- ✓ When seed is sown, it absorbs moisture
- ✓ This is followed by increase in enzyme activity, respiration, cell division and elongation resulting in emergence of radicle
- ✓ This will occur in favourable environment

The factors affecting seed germination are as follows

i. Water

- Imbibition of water by seed is the first step in germination process
- There are two important factors which affect the water uptake

  They are
  - ✓ Nature of seed and its covering
  - ✓ Amount of available water in the surrounding medium

Some seeds germination only above the 'permanent wilting point' of moisture in soil. Some can germinate below permanent wilting point (P.W.P)

According, vegetable seeds are classified as

- ✓ Group I: Those, which germinate with moisture from P.W.P to above field capacity eg. Snap bean, peas, Beet.
- ✓ Group II: Only in soil with moisture near field capacity eg. Celery
- ✓ Group III: Low moisture content and below field capacity eg. Spinach

ii. Temperature

According to the requirement range of temperature for germination, seeds are classified into 3 groups

- **Low temperature**
  - ✓ Here, seeds will germinate only at relatively low temperature eg. **Alpine**
  - ✓ For cool season plants, it is 4.5°C and for warm season plants, it is 10-15° C. These are the lower critical levels.
  - ✓ Below these temperature ranges, seeds fail to germinate or chilling injury can occur.
- **High temperature**
  - ✓ Seeds of all tropical plants require high temperature for germination
  - ✓ So, the upper limits of soil temperature for survival of most of vegetable seeds are between 80° F (30° C) and 104° F (40° C). Over and above, heat injury will occur.
- **Optimum temperature**
  - ✓ The temperature which is favourable for germination is called optimum temperature.
  - ✓ In this temperature, highest rate of germination will occur
  - ✓ The optimum temperature for most of the plants is between **26.5° C - 35° C**

iii. Oxygen

- ✓ Seed gets O_2 through respiration. It is a must to produce energy.
- ✓ Sugar + Oxygen = Carbon dioxide + Water + Energy
- ✓ $C_6H_{12}O_6 + 6O_2 = 6CO_2 + 6\ H_2O$ + **673 K.cal**

- This will take place as long as the seeds are alive
- After sowing, during germination the rate of respiration will increase considerably
- **Seeds of Bermuda grass, lettuce, petunia and rice** will germinate even at **low O_2 level**
- It is because of the presence of anaerobic energy liberating system within the seeds
- Cate tails (*Typha latifolia*) give poor germination in air but prompt germination under water, because of anaerobic energy liberating system

iv. Light

- It has a significant effect on initiation of germination an on seedling growth
- Normally when the seeds are sown in soil and light is cut off, it results in start of germination
- But, certain seeds will germinate only in the presence of light

  Eg. *Viscum album*

  Ficus aurea

  Lactuca sativa

- But, in plants like **Allium** and **Amaranthus**, germination is affect by light
- A photo chemical reversible reaction, involving the response of pigment known as **Phytochrome,** affects seeds germination
- Light requirement can be partially replaced by alternating temperature, potassium nitrate, kinetin, GA and Thio-urea.

Germination process

There are 3 stages

1. **In the first stage,** water is absorbed by a dry seed and moisture content increase rapidly. This is purely a physical process called **imbibition**. As a result swelling seed takes place and the seed coat may break. **Protein synthesis** and **enzyme action** will also be initiated.
2. **The second stage** of germination involves **digestion** and **translocation**. Enzymes appear and begin to digest reserve substances like fats, proteins, CHO in the storage tissues to similar chemical compounds. These are translocating to growing points of embryonic axis to be used for growth and the production of new plant parts.
3. **The third stage** of germination consists of **cell division**. Here, fresh weight and dry weight of seedling increase but weight of storage tissue decreases.

Role of hormones in the process of germination

Three plant hormones play important role in germination. They are

- **Gibberellins – control of food mobilizing system**
- **Cytokinins** – Natural endogenous hormones will also control germination through **DNA to RNA transcription system**
- **Abscisic acid** is an inhibitor that can prevent germination. It affects **RNA synthesis**.

Categories of seed dormancy

Dormant seed: Seed exposed to favourable environment for germination does not germinate which implies the presence of dormancy.

Four groups of Dormancy

Group I: Seed coat dormancy

- Hard seed covering, impermeable to moisture. Eg. **Leguminoceae, Malvaceae**
- Hard seed covering resistant to embryo expansion eg. **Walnut**
- Seed covering containing chemical inhibitors. These are by leaching with water eg. **Citrus. Cucurbits.**

Group II: Seeds with morphologically undeveloped **(rudimentary) embryos**

Embryos are not well developed at the time of harvest and will grow before germination occurs. Eg. **Palmae, Annona**

Group III: Seeds with **internal dormancy** (endogenous)

Germination is regulated by the inner tissues of seeds – endosperm and inner integument layer. There are three groups in this category

- **Physiologically shallow dormancy**
  - ✓ This type is present is most freshly harvested seed and disappears with dry storage over a period of days or months
  - ✓ It may be due to endogenous inhibitors in fresh seeds
  - ✓ Treatments with GA, Kinetin, and Potassium nitrate may be used to overcome
- **Physiologically intermediate dormancy**
  - ✓ Moisture chilling stimulates germination
  - ✓ This is found in **conifers** and in **woody plants**
  - ✓ Temperatures just above freezing (2 to 7oc) are generally most effective to break dormancy
- **Physiologically deep dormancy**
  - ✓ This will disappear with prolonged moist chilling
  - ✓ This is to regulate embryo and seed covering to facilitate germination
  - ✓ Eg.Temperate zone herbaceous plants

Group IV: Combined or double dormancy

- ✓ Both seed coat (external) dormancy and embryo (internal) dormancy occur
- ✓ Here treatments must be given in sequency
- ✓ Eg. Woody trees and shrubs of temperate region, ***Cercis occidentalis***

Pre-conditioning of seeds or breaking dormancy

Mechanical scarification

This is done to modify hard or impervious seed coats. Scarification is a **process of breaking or scratching or mechanically altering the seed covering to make it permeable to water and gases**.

1. Rubbing the seed on sand paper.
2. Cutting with a file
3. Cracking the seed cover with a hammer
4. Scratching in pestle and mortar.

For large scale operation, special mechanical scarifiers are used. Here, seeds may be tumbled in drums lined with sand paper or in concrete mixtures combined with coarse sand or gravel. The sand and gravel should be of a different size than the seed to facilitate separation. Eg. **Leguminous seeds**

Acid scarification

- **Concentrated sulphuric acid** is used to modify hard or impermeable seed covering
- Dry seeds are placed in glass or earthen ware containers and treated with concentrated sulphuric acid in the ratio of about one part of seed to two parts of acid. The mixture should be stirred in intervals to produce uniform results.
- The length of treatment should be carefully standardized. At the end of treatment, the acid is poured off and the seeds are washed with copious amount of water.

Soaking seeds in water

- It is done to modify hard seed coat, remove inhibitors, soften seed coat and reduce the time of germination
- This will overcome seed coat dormancy and stimulate germination
- The seeds can be soaked either in cold or hot water depending on the species
- **Seeds of winged bean** are very hard and normally soaked in **cold water for 48 hours** so as to **hasten the germination**.
- In hot water treatment, temperature of water will range from **77^{o}c to 100^{o}c**
- After treating for one or two minutes, the heat is immediately removed, and the seeds are allowed to soak in gradually cooling water for 12 to 24 hours
- Following this, un swollen seeds can be separated from the swollen ones.

Stratification: (Moist chilling)

- Here, seeds are exposed to low temperature
- It permits physiological changes to occur in the embryo
- Temperature range is from **0^{o}C to 10^{o}C**
- So dry seeds should be soaked in water for 12 to 24 hours, drained, mixed with moisture retaining medium and then stored for the required period of time
- The usual storage temperature is 2^{o}C to 7^{o}C. For most of the seeds, low temperature stratification ranged from 1 to 4 months. After it underwent the stipulated period, seeds are sown without drying.

Chemical stimulants

i. GA

- It will promote germination in some kind of dormant seed

- Seeds are treated with GA by soaking for 24 hour in water solution at concentration from **100 to 500 ppm**. This will **improve seed germination**.
- Eg. Apple, Cherry, Peach, Strawberry

ii. Cytokinin (Kinetin)

- Commercial preparation of kinetin are available
- A common synthetic cytokinin is **Benzyl Adenine** (Eg. Apple and Peach @ 10 – 20 ppm)
- Seeds are soaked in 100 ppm kinetin solution for three minutes
- First, the chemical is dissolved in small amount of dil. Hel, then made up with water to get the required concentration.

iii. Ethylene

- When ethylene was applied to seeds, it stimulated germination of some seeds experimentally
- In peanut or groundnut (Virginia type), ethylene is used in the form of ethrel to break the dormancy.
- **Guava** and **Strawberry** – Ethrel @ 5000 ppm

iv. Potassium nitrate

- Freshly harvested dormant seeds germinate better after soaking in potassium nitrate solution.
- **Potassium nitrate solution of 0.1 to 0.2%** concentration will improve seed germination in Kentucky bluegrass.
- Eg. Guava and Ber

v. Thio-urea

- It is used to stimulate germination of some dormant seeds, particularly those that do not germinate in darkness or at high temperature or that require a moist chilling treatment.
- Concentration varies from **0.5 to 3%.** Soaking is done for 24 hours.
- Eg. Peach, Plum

Seed in vigouration

- In most of the species, as the seed ages, it slowly loses the germination capacity due to a number of factors like accumulation of inhibitors etc.,
- These aged seeds when treated with specific chemicals like **potassium di hydrogen orthophosphate (KH_2PO_4), sodium di hydrogen orthophosphate ($Na\ H_2\ PO_4$), di potassium hydrogen phosphate ($K_2H\ PO_4$)** at a **concentration of 200 ppm for 24 hours**, drying to original moisture and then sowing has improved the germination tremendously.
- In some cases even water soaking has improved the germination eg. **Papaya and chillies**

Seed storage

Orthodox seeds	Recalcitrant seeds
Desiccation tolerance during development and may be stored in the dry state for predictable periods under defined conditions Eg. Apple, Peach, Plum, Phalsa, Passion fruit, Ber, Custard apple, Fig, Guava	Recalcitrant seeds do not survive drying to any large degree and are thus not amenable to long term storage Eg. Mango, Mangosteen, Citrus, Jack, Litchi, Rambutan, Avacado, Durian, Bread fruit, Rubber, Cocoa, Oil Palm, Loquat

Apomixis

- It is the occurance of an **asexual reproductive process in place of normal sexual reproductive process of reduction division and fertilization**
- Apomixis: Asexual reproduction through seeds
- Term coined by Hacke (1893) and discovered by Winkler (1908)
- Simply, it is an asexual seedling developed from a seed viz., a seedling that arises from tissue of the seed other than embryo
- Plants that produce only apomictic embryos are known as obligate apomicts, (Eg. **Mangosteen**) those that produce both apomictic and sexual embryos are facultative apomicts eg. **Acid lime**

Type of apomixes

Recurrent apomixes

- Here, embryo develops from the egg mother cell which doesn't under go any meiosis
- So, egg has normal diploid number of chromosome
- The same as in the mother plant. The **embryo subsequently develops directly from the egg nucleus without fertilization**.
- In some cases, the embryo develops with stimulus of pollination (eg. Allium) and in some cases, without stimulus of pollination (eg. *Malus* spp., *Rubus* spp.)

Adventitious or Nucellar embryony

- Here, embryo will rise from a cell or group of cells either in the nucellus or in integuments.
- Here, embryo develops outside the embryo sac in addition to the regular embryos. Eg. **Citrus**

Non-recurrent apomixes

- Here embryo arises from the egg nucleus without fertilization.
- Since the egg is haploid, the resulting embryo will also haploid.

- ❖ The case is very rare. Eg. ***Solanum nigrum, Lilium* sp.**

Vegetative apomixes

- ❖ In some cases, vegetative buds or bulbils are produced in the inflorescence in place of flowers
- ❖ eg. Agave, *Allium sativum, Furcurea, Dioscorea bulbifera* and grass species

Polyembryony

- ❖ term coined by Brau (1859)
- ❖ The phenomenon in which **two or more embryos are present within a single seed** is called polyembryony
- ❖ Eg. Mango, Citrus
- ❖ Cleavage Polyembryony: Coconut

Significance of apomixes

- ✓ Apomictic seedlings are true to its mother and apomictic cultivar can be considered as a clone
- ✓ They are uniform and vigorous
- ✓ Virus diseases are not seed borne. So, it is the best method to rejuvenate virus affected plant crops.

Advantages of seed propagation

1. Long lived
2. Deep root system
3. Possibility of obtaining chance seedlings – Mango variety – **Chinnaswarnarekha, Mudappa**
4. Polyembryony produces true to type nucellar embryonic seedlings – used as rootstocks – eg. **Mango** variety **(Vellaikolamban, Olour and Pappakkai), Citrus (all Citrus sp except *Citrus grandis*)**
5. Seed propagation is necessary when vegetative propagation is unsuccessful or expensive or difficult **(eg. Papaya, Coconut)**
6. Exploitation of hybrid vigour is possible only through seed propagation
7. When seedlings are required in large number, seed propagation is the only mean

Disadvantages of seed propagation

1. Progenies are not true to type
2. Choice tree or hybrid trees cannot be perpetuated true to type by seed
3. Seedlings have a long juvenile period
4. Seeds lose viability in a short period. In crops like citrus, cocoa and rubber the seeds must be sown afresh. *i.e.* immediately after extraction

II. ASEXUAL PROPAGATION

- Asexual propagation is the method of **multiplication of a plant from the vegetative part of the plant other than zygote** which is formed by the combination of male and female gametes.
- The cellular basis for this method of multiplication is mitosis viz., regeneration of a daughter plant from the somatic tissue. The different methods of asexual propagation are.

A) Cuttings

Principles and methods of vegetative propagation by cuttings

- Cuttings are vegetative plant portions such as stems, leaves and roots taken from plants to produce new independent plant which, in most cases, will be identical with the parent plant
- This is one of the least expensive and easiest methods of vegetative propagation
- Cuttings are taken from 1) Stem, 2) Leaf, 3) Leaf bud and 4) Root

In the case of stem cuttings, it has four groups

1. Hard wood cutting - Spring – February, March
2. Semihard wood cutting - Summer – April, May
3. Soft wood cutting - Fall (or) Autumn – June, July & August
4. Herbaceous cuttings - Winter – September, October, November, December and January

Hard wood cutting: (Deciduous)

- The cuttings are fully matured with more reserve food and anatomically, the **maximum of sclerenchyma** can be seen
- The cuttings are **prepared during dormant season** (late fall, winter or early spring) from wood of **previous season's growth**
- In some species, such as **fig, olive and certain plum varieties, two year old wood** can be used. Fruits propagated through **hard wood cuttings** are **fig, olive, mulberry, grape, gooseberry, pomegranate, some plums** and **rose**
- Cuttings should be taken from healthy plant grown in full sunlight. Length may vary from 4 to 30 inches (Common 6-8") the diameter of cuttings may range from ¼ inch to even 2" depending upon the species
- At least, **two nodes** are included in the cutting
- The basal cut is usually just below a node and a top cut ½ to 1" above a node. After preparing cuttings, bundles of cuttings may be buried out of doors in sandy soil or stored in a refrigerated room before planting in spring
- While planting, cuttings should be planted 3 or 4" apart and deeply enough (1/3 of its length

placed inside the soil)

Evergreen hardwood

- **Grapes, pomegranate** and **some citrus fruits** are propagated through hard wood cuttings
- Length of cuttings range from 4-7" with 5 to 6 nodes. Cuttings are taken during late winter. **Spring season** is good for planting.

Semi-hard wood cuttings

- Stem cuttings of trees and shrubs that are taken from **current season shoots**, which are **partly matured** are known as semi hard wood
- They have lesser reserve food compared to hard wood and similarly, the formation of sclerenchyma in the anatomical development is also comparatively less
- Length of cuttings range from 3 to 6". Here we can retain one or two terminal leaves.

Soft wood cutting

- Cuttings of 3-6" length prepared from **soft, succulent and new growth** may be called as soft wood cuttings eg. **Vernonia**

Herbaceous cuttings

- This type of cuttings made from **succulent herbaceous plants** just near the terminal buds is called herbaceous cuttings (**Chrysanthemum, Geranium, Coleus, Alternanthra and Sweet potato**) Length of cuttings is 3-5" with leaves.

Leaf cuttings

- **Leaf blade** is utilized in starting a new plant. Adventitious roots and an adventitious shoot form at the base of leaf. (eg.) **Sansevieria, Begonia & Bryophyllum** and some succulents like **sedum**

Leaf bud cuttings

- They consist of a **leaf blade, petiole** and a **very short piece of stem** with attached axillary bud.
- This type of cuttings will be very useful in species which have a tendency to produce root from the leaf, stem or petiole but do not produce a shoot system out of any one of the three parts
- In this case, the axillary bud serves as a source for new shoot system. Eg. **Tea, Rhododendron**

Root cuttings

- Root piece of 2-4" length are planted horizontally at 1" to 2" depth
- Eg. **Bread fruit, Crab apple, Black berry, Rasp berry**
- **Fibrous roots - Dahlia**

Anatomical and physiological basis of rooting

- The **formation of adventitious roots** in cuttings or layering can be divided into two phases. One is **initiation** which is characterized by **cell division and the differentiation of certain cells** into root initials and then into recognizable **root primordia**. The second phase is the growth and emergence of new roots, by a **combination of cell division and cell elongation** including rupturing of other stem tissues and **formation of vascular connections** with the conducting tissue of the cutting
- These root initials are formed **adjacent to vascular tissue**. In **herbaceous plants** which **lack a cambium**, the **root initials are formed near the vascular bundle close to the phloem**.
- In **woody perennials**, the adventitious roots in stem cuttings usually originate in the young, **secondary phloems** although they may also arise from other tissues such as vascular rays, cambium or piths.
- In some plants, adventitious root initials form during early stage of intact stem development and are already present at the time of preparation of cuttings. These are termed **'preformed' of latent root initials**.
- These generally lie **dormant until the stems are made into cuttings** and placed under environmental conditions favourable for further development and emergence of the primordial as adventitious roots.
- **Willow, Hydrangea, Poplar, jasmines, Citrons** are some of the species which produce preformed root initials.
- The position of origin of these preformed root initials is same as that of other adventitious roots. After elaborate studies with easy and difficult to root plants, some insight into the physiological basis of rooting has been established.

The important aspects are summarized below.

- ✓ **Auxin level is closely associated with adventitious rooting of stem cuttings**
- ✓ Nutritional status of plants especially **high carbohydrate levels with optimum N** is associated with **vigourous root growth**.
- ✓ **Few organic compounds interact with auxin to affect rooting** and they are called rooting co-factors

Summary of cuttings:

- Root cutting: Red raspberry, Seedless Bread fruit etc.,
- Stem cuttings:

- ✓ Hardwood –prepared during dormant season (fig, Olive, grape, gooseberry, rootstocks of rose, pear,etc.,)
- ✓ Semi hard wood – prepared from evergreen species during summer (coleus, geranium, sweet potato etc.,)
- ✓ Softwood–otherwise called as green wood cuttings, prior to lignification process(lilac, jasmine etc.,)
- ✓ Herbaceous – Chrysanthemum, coleus, geranium, sweet potato etc.,

❖ Leaf cuttings: Red Begonia, Bryophyllum, Sansevieria *etc.*,

❖ Leaf bud cuttings: eg.Tea, Camellia, Rhododendron and Hydrangea

❖ Type of soil suitable for cuttings: **Sandy soil**

Factors affecting regeneration of plants from Cuttings

- ✓ **C:N ratio** (High Carbohydrate and Low Nitrogen)
- ✓ **Sex of the plant** (male tree – better eg. Red Maple)
- ✓ **Age of the stock plant** (increasing age – Apple, Pear and Eucalyptus)
- ✓ **Time of the year** – Cuttings should be taken from broad leaved evergreen plants after a flush of growth has been completed – Spring to Fall
- ✓ **Presence of leaf area** – photosynthetic leaf area – better rooting
- ✓ **Vegetative shoot** – better rooting (eg. Jasmine)
- ✓ **Growth regulators** – synthetic auxin compounds – NAA, IBA and 2,4-D

B) Grafting

❖ Process of operation of inserting a part of one plant into an or placing it upon, another in such a way that a union will be formed and the combination will continue to grow as on plant.

❖ Graft combination – upper portion – preferred variety - scion – canopy

Lower portion – resistant character – rootstock – root system

Root grafting

- ✓ Whip graft - Apple and Pear

Crown grafting

- ✓ Whip and tongue graft – Persian Walnut, Apple
- ✓ Cleft graft – Camellia, Plums
- ✓ Side graft - Narrow leaved evergreen, Mango

Top grafting

- ✓ Cleft – various fruit trees
- ✓ Notch graft

- ✓ Bark graft
- ✓ Side graft
- ✓ Whip and tongue graft
- ✓ Veneer grafting
- ✓ Approach grafting – **Mango and Sapota**

Budding

- ✓ T budding (Shield budding) – **Pome fruits, Rose, Ber**
- ✓ Patch budding – **Citrus, Mango, Rubber, Annona**
- ✓ Ring budding – **Cinchona**
- ✓ Flute budding
- ✓ Chip budding – **Grapes and Citrus**

Layering

- ❖ It is a propagation method by which adventitious roots are caused to form on a stem while it is still attached to the parent plant
- ❖ The rooted stems are then detached and established in a medium to become a new plant growing on its own roots.

Types of layering

Ground layering

- ✓ Tip layering : **Black berry and Raspberry**
- ✓ Simple layering: **Rose, Jasmine, Guava, Pomegranate, Crotons** etc.,
- ✓ Mound layering or stooling: **Goose berry, Rootstocks of apple and pear**
- ✓ Compound or serpentine layering : **Grape, Clematis, Peperomia, Honey suckle** etc.,
- ✓ Trench layering or Etiolation method eg. **Cherry, Plum and Apple rootstocks**

Air layering (Gootee (or) Marcottage): **Litchi, guava, crotons, *Ficus elastic*** etc.

- ❖ In air layering, roots form on aerial part of plants where the stem has been girdled and covered with rooting medium
- ❖ It should be done during humid months because root initiation will be high under high humid conditions.

Steps:

1. The branch selected should be of pencil thickness
2. The stem should be girdled for about a length of 1cm to 1" to induce adventitious root formation above the cut. It should be given at 12-15" from the tip of the branch
3. A ball of slightly damp sphagnum moss is placed around the girdled stem.

4. A wrap of polythene film is placed around the **sphagnum moss** and tied airtight on both ends.

Time of removal

- ✓ It is better determined by observing root formation through the transparent film. In some plants, rooting occurs in two or three months
- ✓ Layering made in spring or early summer is the best and it will give high percentage of success.
- ✓ The rooted layers should be potted in a suitable container and placed under cool humid conditions as a hardening process before it is used for planting.

Ground layering

1. Simple layering

- ❖ Branches that have formed roots in one area only are called simple layers
- ❖ Such layers are made by bending the branches to the ground and covering the portion with soil.
- ❖ This should be done in early spring for temperate species before growth has started
- ❖ For other tropical species an actively growing period is selected
- ❖ The tip of the shoot is left exposed to carry out normal process of the plant
- ❖ Eg. **Rose, Jasmine, Guava**

Procedure

1. A healthy shoot of pencil thickness from a lower branch near the ground level has to be selected.
2. The common practice is to injure the portion to be covered, by notching, girdling, cutting or twisting. This practice destroys the phloem tissue partially or completely and retards the downward movement of food material as well as hormones manufactured by leaves. Injury is given 6-12" back from the tip
3. The bent part of shoot is inserted into the soil
4. The usual time for layering depends on species eg. for temperate species, it is done in early spring and for this, dormant, one year old shoots are used.
5. The rooted layers may be removed from the parent plant and kept under cool humid conditions for curing.

2. Compound or serpentine layering

- ❖ It is essentially the same as simple layering, except that the branch is alternately covered and exposed along its length
- ❖ So that, the roots strike wherever the plant is covered by soil
- ❖ Eg. **American grapes, Ornamental vine like Clematis, Green house plant like Peperomia**

3. Mound layering (or) stooling

- Here, the plant is pruned close to the ground level and all the branches are covered with soil.
- Striking of roots takes place at a number of places and the plant also produce new shoot system which come out of the mound
- Each shoot with part of roots formed will be separated and planted in pots for further establishment
- **Apple rootstocks** and **Pear** are propagated by this method.

4. Trench layering or etiolation: Eg. Cherry, Plum and Apple rootstocks

5. Tip layering: Black berry, Rasp berry

Propagation through specialized plant parts

1) Bulbs

- Bulb is a **specialized underground organ** consisting of a **short fleshy, usually vertical stem axis bearing at its apex a growing point or a flower primordium enclosed by thick fleshy scales**
- (Eg.) Onion, Garlic, Tulip and Hyacinth

2) Corm

- Corm is a **swollen base of stem axis enclosed by dry scale like leaves** with distinct nodes and internodes. Eg. **Gladiolus.**

3) Stolons

- Modified stems that grow horizontal to the ground. Eg. **Grass**

4) Tubers

- It is a modified stem structure which develops below ground as a consequence of the **swelling of the sub apical portion of a stolon and subsequent accumulation of reserve materials**.
- Eg. **Potato, Jerusalem Artichoke**

5) Rhizomes

- It is a specialized stem structure in which the main axis of the plant grows horizontally or just below the ground surface
- eg. **Bamboo, Banana, Ginger, Turmeric, Cardamom**

6) Crowns – Pineapple

7) Tuberous roots

- Plants produce **thickened underground structures** which contain large amount of stored foods.

- ❖ This thickened structures are tuberous roots. Eg. **Sweet potato, Dahlia** (massive enlargement of secondary roots)

Advantages of asexual propagation

1. In most horticultural plants, the genetic makeup (genotype) is **highly heterozygous**. The unique characters of such plants are immediately lost if they are propagated though seed
2. It is necessary to grow cultivars that produce **non-viable seeds**, eg. **Bananas, Fig** and **Grape**
3. Propagation of some species may not be easier through seeds. For eg. Cotoneaster seed – it has **complex dormancy** condition but it is easily propagated through cuttings
4. To reduce prebearing period/or **to reduce long juvenile stage**.
5. To induce dwarfness eg. **Apple**
6. To induce disease and pest resistance. **'Troyer citrange'** is used as a rootstock for citrus. It is **resistant to tristeza virus.**
7. To induce hardiness in cultivars.Eg. '**Alnarp' apple** used for its winter hardy properties

DISADVANTAGES

1. Longevity is not high when compared to the seedling progeny.
2. Asexual method is uneconomical and impractical in the case of vegetable crop propagation and grains (Eg. Tomato, Brinjal, Amaranthus *etc*.) since cost of cultivation is high when compared to sexual method
3. Most of the virus disease is not seed borne. When propagated vegetatively the virus are carried to the next generation. Eg. '**Katte' disease of cardamom.**

Genetic variation in asexual propagation

- Gene or chromosome change
- By mitosis, it becomes permanent
- It is found in a part of the plant only
- The plants with normal and mutated cells are called **'Chimeras'**
- Eg. **Coleus, crotons, Bougainvilleas**.

Kinds of Chimeras

Sectorial Chimeras - Growing point of the stem is found with two types of tissues.

- The leaves & lateral buds are also mutated

Periclinal - The mutated tissue occurs as a **thin skin with several cell layers**

- The **most common type** of chimeras
- **Relatively stable**
- This type will **revert back** if propagated by seed or root cuttings

Mericlinal - Similar to periclinal

- **The outer of mutated cells does not surround fully**
- It occupies as a **segment of the whole part only**

Bud-sport

- ✓ Bud-sport is one where a branch of a tree alone is found with genetic change from the rest of the part
- ✓ The characters of bud-sport are **inheritable**
- ✓ They can be **vegetatively propagated**
- ✓ Eg. **Apple** – varieties –'**Starking'** and **Richa Red** are bud-sports from **'Delicious apple'**

The anatomical development of roots

Stem cuttings

- ❖ Propagation through cutting/layering is common in dicotyledonous plants
- ❖ However, cuttings of some monocots, such as asparagus can be rooted under proper conditions

Process of root initiation in stem

It is divided into three stages

- ✓ Cellular differentiation of cambium leading to initiation of meristematic cells. Proliferation of certain cells to form root initials near vascular bundle.
- ✓ These differentiated cells group into recognizable root primoridia
- ✓ The growth and emergence of new roots.

Initiation of root primordia in herbaceous plants

- ✓ Origin is usually just outside and between the vascular bundles (from cambium)
- ✓ Small group of cells, the root initials, continue dividing, forming groups of many small cells which develop into root primordial (it looks like root tip)
- ✓ A vascular system develops in the new root and becomes connected with adjacent vascular bundle

Initiation of roots in woody plants

- ✓ Origin is in the young secondary phloem, sometimes from vascular rays or cambium
- ✓ The time at which root initials develop after cuttings are placed in the propagating bed varies widely

Callus

- ❖ After stem cuttings have been made and placed under favourable environmental conditions, callus will usually develop at the basal end of cuttings

- This is an irregular mass of undifferentiated parenchyma cells
- It was believed that callus formation would be essential for rooting
- In most cases, formation of callus and formation of roots are independent of each other and if they occur simultaneous it is due to their dependence upon similar internal and environmental condition.

Principles of grafting and budding

- It is the process of operation of inserting a part of one plant into another or placing it upon another in such a way that an union will be formed and the combination will continue to grow as one plant
- The part of graft combination which is to become the upper portion if termed as the 'scion' (ion) and the part which is to become the lower portion or root is termed as 'root stock' or 'under stock' or the 'stock' Rootstocks are commonly grown from seeds, cuttings or layers
- All methods of joining plants are popularly termed as 'grafting' but when the scion part is only a small piece of bark (and sometimes wood) containing a single bud, the operation is termed as 'budding'.

Reasons for grafting and budding

1. When other methods of asexual propagation are not successful in perpetuating a clone, e.g. Mango and sapota can be successfully propagated on commercial scale by grafting only.
2. Plants propagated on their own roots may be weak, susceptible to pests and diseases, or to any adverse environmental conditions may not adaptable to a particular soil or climate. For many plant species, rootstocks are available which tolerate all the above cases and hence they may be exploited as a rootstock through grafting or budding.
3. For converting poor trees into more desirable one by top-working
4. For overcoming pollination problems, self-fertile varieties may be grafted over self-steriletrees
5. For fancy purposes, different types of scion may be grafted in the same plant
6. To modify the growth of the plant as dwarf one by employing suitable dwarfting rootstocks
7. Occasionally the roots, truck or large limbs of trees are severely damaged by winter injury, cultivation implements, certain diseases or rodent. But use of bridge grafting or in arching such damage can be repaired and the tree saved.

Rootstocks

Rootstocks also influence the growth and productivity of scion. Root stocks can be divided into two groups as follows.

1. Seedling rootstocks

- Variation among seedlings can possible make them undesirable as rootstocks
- **Variability in rootstock seedlings** may cause variability in the growth and performance of the grafted trees
- Seedlings which are weak should be avoided
- Seedlings of ½ to 2 years old with pencil thickness are considered optimum
- In Tamil Nadu seedling rootstocks are employed for Mango, Plums and Peaches.

2. Clonal rootstock

- **To avoid variation in rootstocks**, thus to impart uniformity in the scion, often rootstocks are also propagated by **cuttings or layers**
- Such rootstocks which are perpetuated a sexually are termed as clonal rootstocks
- **Nucellar seedling (poly embryony)** in certain varieties of mango and all the species in citrus **(excepting *C .grandis*)** can be also considered as clonal rootstocks as they arise from the tissues other than the true sexual embryo
- In Tamil Nadu clonal rootstocks are used in the propagation of apple and pear.

Factors for successful graft union

1. Botanically the closer a rootstock and scion, the more will be the compatibility between these two.
2. Proper season of grafting is essential. For deciduous plants, grafting is done at the winter season or early spring season and for evergreen trees, it should be done during its active growing season
3. Any grafting or budding method should ensure intimate contact between the cambium of scion and rootstock
4. Immediately after the grafting operation is completed all the cut surfaces must be carefully protected from desiccation.
5. Proper care should be given to the grafts for a period of time after grafting

Formation of graft union

In graftage, freshly cut scion tissue capable of meristematic activity is brought into close, intimate contact with similar freshly cut stock tissue in such a manner that cambial regions of both are in close proximity. The healing of graft union takes place in a sequential step as indicated below

1. **Production of callus tissues** (Parenchyma cells) by the cambium regions
2. **Intermingling and interlocking of parenchyma cells** of both graft components

3. **Differentiation of certain parenchyma cells** of the callus into new cambium cells connecting with the original cambium in the stock and scion
4. **Production of new vascular tissues** by the new cambium permitting passage of nutrients and water between the stock and scion.

Limitation of grafting or budding

- One of the requirements for a successful graft union is the close matching of the callus-producing tissues near the cambial layers
- Grafting is generally confined to **dicotyledons.**
- These plants have a vascular cambial layer existing as a continuous tissue between the xylem and phloem
- For grafting, it should be borne in mind that the plants to be combined are capable of uniting.
- Generally, the more closely the plants to be grafted are related botanically, the more favourable is the chances of the graft union being successful.

1. **Intra-varietal grafting:** When a scion can be grafted back on the same plant or a scion from a plant of a given clone can be grafted to any other plant of the same clone eg. **Elberta peach on Elberta peach**
2. **Inter-varietal grafting:** When different varieties of a species are employed as graft parents eg. **Mango**
3. **Inter-specific grafting:** In this case, grafting between the species of the same genus is done. But this is usually difficult but widely used between species in the genus citrus. **Japanese plum (*Prunussalicina*) is grafted commercially on peach (*Prunuspersica*)**
4. **Intergeneric grafting:** When the plants to be grafted together are in different genera but in the same family the changes of union are more remote. But successful union has been reportedin the following cases
    - *Citrus* spp. on trifoliate orange (*Poncirustrifoliata*)
    - Sathugudi (*Citrus sinensis*) on wood apple (*Ferroniaelephantum*)
    - Sapota (*Achrassapota*) on pala (*Manilkarahexandra*)

Graft incompatibility

- The ability of two different plants when grafted together to produce a successful union and also to develop satisfactorily into one composite plant is termed as compatibility
- The inability of two different plants to do so when grafted together is often defined as **incompatibility or graft incompatibility**
- The distinction between a compatible and an incompatible graft union is not clear cut. On one

hand, stocks and scions of closely related plants unite readily and grow as one plant

- On the other hand, stocks and scions of closely unrelated plants when grafted together are likely to **fail completely in union**
- Many graft combination lie between these extreme viz., compatible to incompatible and therefore the characterization of incompatibility is not distinct
- **Partial incompatibility** Where the **stock outgrows the scion** has been reported in certain fruit crops. For instance, mandarin when grafted onto trifoliate stock, the stocks outgrew the scion but the tree grew well and produced plenty of fruits of good quality
- Incompatibility may be classified as **translocated incompatibility** and **localized incompatibility**
- The former type refers those cases in which the incompatible condition cannot be overcome by the insertion of a mutually **compatible interstock**.
- This is due to apparently some labile influence moving across it. This type involves phloem degeneration and development of a brown line or necrotic, are in the bark.
- **Hale's Early peach develops incompatibility when grafted on Myrobolan-B plus rootstock.** But when a mutually compatible interstock **'BromptonPlus'is** introduced, the incompatibility still persists indicating that the incompatibility is due to some factors translocated from the rootstock to the scion through the phloem causing phloem degeneration
- The second type viz., **localized incompatibility** includes a combination in which the incompatibility reaction apparently depends upon **actual contact between stock and scion**.
- Introduction of a mutually compatible interstock will normally overcome the incompatibility.
- Symptoms of this kind of incompatibility are that the graft is often **mechanically weak with discontinuity in cambium and vascular tissue**.
- A typical example of this kind of incompatibility is that when **Barlett pear is grafted directly on quince stock**, it is incompatible. When **Old Home interstock** is introduced in between these combination, the three part combination is completely compatible and it grows satisfactorily.
- Another example is that when **Eureka lemon is grafted on trifoliate rootstocks**, it proved to be incompatible, due to a toxic substance produced by the scion damaging the conducting tissues of the stock. When the **interstock, Valencia orange** was introduced, the combination proved successful.
- In some cases, the stock-scion combination grows in an apparently normal fashion for varying periods of times-perhaps for many years and then difficulties arise. This is called as **delayed**

incompatibility.

- A good example of the above phenomenon is the black line of walnut which occurs in certain **Persian walnut orchards in California and France**.
- When cultivars of ***Juglens regia*** are grafted on seedling rootstocks of ***J. hindsii*** **or paradox rootstocks (*J. hindsii x Juglens regia*)** the trees grow satisfactorily for 15 to 20 years or even more years of age, thereafter the trouble starts. A thin-layer of cambium and phloem and the dead tissue develop at one point and gradually extend around the tree at the graft union until the trees become girdled. The vertical width of the dead area may reach 30 cm.
- Such girdling may kill the plants above the graft union but the stock remains alive and sprout.
- Another example is that **sapota on *Bassialongifolia* stocks**.
- In compatibility is manifested by overgrowing of scion resulting in pronounced distortion at the bud joint and the graft dies prematurely.
- **Delayed incompatibility** has been also reported in many **citrus species** as indicated

Symptoms of incompatibility

Graft union malformation resulting from incompatibility usually expresses the following external symptoms *viz.*,

1. Failure to form a successful graft or bud union with a high percentage of success
2. Yellowing of leaves in the latter part of the growing season followed by early defoliation accompanied by decline in vegetative growth, appearance of shoot die back and general ill health of the tree.
3. Premature death of the trees which may live only a year or two in the nursery
4. Marked differences in the growth rate or vigor of scion and stock
5. Over growth at, above or below the graft union.

Causes of graft incompatibility

1. **Virus infection:** One component of the graft combination may carry a virus and be symptomless, but the other component may be susceptible to it. For example, when **Barlett pear is grafted on *Pyrus pyrifolia***, the **tree declines due to virus infection of the susceptible rootstock** while **Bartlett on *P. communis* remains healthy**, because
   ***P. communis* is a virus – resistant variety**
2. **Growth differences:** In certain graft combination, the differences in the time of resumption of cambium activity of the stock and scion or differential growth characteristics of the stock and scion are reported to be a causes for graft incompatibility

3. **Physiological causes:** Physiological incompatibility is due to the inability of the stock or the scion to supply the other components with necessary amount or quality or materials for normal functioning. There is some evidence that in certain graft combinations one component (Scion or stock) produces chemicals that are toxic to the other, killing the entire plant, eg. When **pear is grafted onto quince rootstock**, a **cyanogenicglucoside, prunasin**, **normally found in quince is translocated into the phloem of the pear** where it gets **broken down inthe region of the graft union into hydrocyanic acid**. The presence of this acid leads to lack of cambial activity at the graft union, leading to graft incompatibility.

Stock-scion relationships

- A grafted or budded plant can produce unusual growth patterns which may be different from what would have occurred if each component part of a graftage viz., rootstock and scion was grown separately or when it is grafted or budded in other types of rootstocks
- Some of these have major horticultural value
- This varying aspect of rootstocks in the performance of a scion cultivar or vice versa is known as stock-scion relationship

Effect of stocks on scion cultivars

1. **Size and growth habit**:
    - In apple, rootstocks, can be classified as dwarf, semi-dwarf, vigorous and very vigorous rootstocks based on their effect on a scion cultivar.
    - If a scion is grafted on dwarf rootstocks eg. **Malling IX**, the scion grows less vigorously and remain dwarf only.
    - On the other hand if the same scion is grafted on a very vigorous rootstock eg. **Malling II** the scion grows very vigorously.
    - In **citrus, trifoliate orange** is considered to be the **most dwarfing rootstock** for **grapefruit and sweet oranges**.
    - On the other hand, in **mango**, all plants of a given variety are known to have the same characteristic canopy shape of the variety despite the rootstocks being of seedling origin. But recently, **rootstocks of Kalapade, Olour** have been found to impart **dwarfness in the scion cultivars of mango**.
    - Guava cultivars grafted on ***P. sidiumpumilum*** are found to be dwarf in stature.
2. **Precocity in flowering and fruiting**:
    - The time taken from planting to fruiting i.e., **precocity is influenced by rootstocks**.
    - Generally fruiting precocity is associated with dwarfing rootstocks and slowness to

start rootstocks are precocious than those grafted on sweet orange or sour orange or acid lime rootstocks

3. **Fruitset and yield**:
    - The rootstocks directly influence on the production of flower and setting fruits in oriental **Persimmon (*Diospyrous kaki cv. Hichiya*)**.
    - When it is **grafted on *D. lotus***, it **produces more flowers but few only mature** but when ***D. kaki* is used as the rootstock, the fruitset is more**.
    - The influence of rootstock on the yield performance of cultivar has been well documented in many fruit crops.
    - **Acid limes budded on rough lemon** register nearly **70 percent increased yield than those budded on troyercitrange, Rangpur lime or its own rootstock**.
    - **Sweet orange var. Sathugudi budded on Kichili rootstock gave higher yield** that on Jambhari or on its own seedling.
4. **Fruit size quality**:
    - **Sathugudi sweet oranges grafted on Gajanimma rootstocks produced large but poor quality fruits** while on its own roots they produced fruits with high juice content and quality.
    - The physiological disorder **'granulation' in sweet orange is very low if grafted on Cleopartra mandarin seedlings**, on the other hand **rough lemon seedlings stocks induced maximum granulation**.
    - The physiological disorder **black end in Bartlett Pear did not appear if *Pyrus communis* was used as the rootstock**. When *P. pyrifolia* was used as the rootstock, this disorder appeared, affecting fruit quality.

5. **Nutrient status of scion**:
    - Roost stocks do influence the nutrient status of scion also. **Sathugudi orange trees have a better nutrient status** of all nutrients in the leaves when it is budded on ***C. volkarimariana*** rootstock than on its own rootstock or Cleopatra mandarin stocks
6. **Winter hardiness**:
    - Young grape fruit trees on **Rangpur lime withstand winter injury better than on rough lemon or sour orange**.
    - **Sweet oranges and mandarins on trifoliate stocks were more cold hardy**.

7. **Disease resistance**:
    - In **citrus** considerable variability exists among the rootstocks in their response to diseases and nematodes.
    - For instance, **rough lemon rootstock is tolerant to tristesa, xyloporosis and execortis but is susceptible to gummosis and nematode**.
    - On the other hand, **treyer citrange is tolerant to gummosis but susceptible to execortis virus disease**.
    - Similarly, **guava** varieties grafted on **Chinese guava** (*Psidium friedrichsthalianum*) **resist wilt diseases and nematodes**
8. **Ability to resist soil adverse conditions**:
    - Among the **citrus rootstocks**, trifoliate orange exhibits poor ability, while sweet oranges, sour orange, Rangpur lime rootstocks exhibit moderate ability to resist excess salts in the soil.

B. Effect of scion on rootstock

1. **Vigorous of the rootstocks**:
    - In **apple**, it has been found that if apple seedlings were budded with **the 'Red Astrochan' apple**.
    - The rootstock produced a very fibrous root system with few tap roots.On the other hand, if scion **'Golden burg'** was budded on the seedlings, they produced two or three pronged deep roots without fibrous root system.
    - In citrus, if the scion cultivar is less vigorous than the rootstock cultivar the rate of growth and the ultimate size of the tree is more determined by the scion rather than the rootstocks.
2. **Cold hardiness of the rootstock**:
    - **Cold hardiness of citrus roots** is affected by the scion cultivar
    - **Sour orange seedlings budded to 'Eureka' lemon** suffered much more from winter injury than the unbudded seedlings.
3. **Precocity in flowering**:
    - Young **mango rootstock seedlings** (6 months to one year old) were found to put forth inflorescence when the branches from old trees are inarched which can be attributed to the influence of scion on the rootstock.

Factors influencing the heeling of graft union:

1. **Incompatibility**: Certain rootstocks and scions are incompatible, therefore, the graft union between these two will not normally take place.
2. **Kind of plant**: Some species like oaks are difficult to graft, but apple and pears are very easy in producing a successful grant union.
3. **Environmental factors during and following grafting**: There are certain environmental requirements which must be met for callus tissue to develop and heel the graft union.

4. Planning, Layout and Establishment of an Orchard and Soil Types Suited for Horticultural Crop Production

Orchard – area where cultivating fruit trees in larger area

For maximum production, the following factors to be considered carefully

i. Selection of proper location and site

ii. Layout of an orchard

iii. Planting system and distance

iv. Choosing the varieties

Planning of an Orchard

1. Optimum spacing – accommodating more trees per unit area
2. Stores and office building – at the centre of an orchard – proper supervision
3. Wells – in convenient place – **one well for 2 to 4 hectares**
4. Pollinators – **deciduous fruits**
5. Irrigation channel – every 30 m length – 7.5 cm slope
6. **Live fencing** – drought tolerant, should stand severe pruning and should be thorny – eg. **Agave, *Prosopis juliflora, Pithecolobium dulce*** and **Thevetia**
7. **Wind breaks** – to resist wind velocity – double row of tall trees alternately placed – should be erect, tall and quick growing, hardy and drought resistant and mechanically strong and dense to offer maximum resistant to wind – eg. ***Casuarina equisetifolia, Pterospermum acerifolium, Polyalthia longifolia, Eucalyptus globulus, Grevillea robusta, Azadirachta indica****, etc.,*

Planting season

- ✓ **Monsoon** (June-August) – best for evergreen trees like Citrus, Mango, Sapota and Guava
- ✓ **Spring** (February – March)
- ✓ Deciduous trees – planted during the dormant period

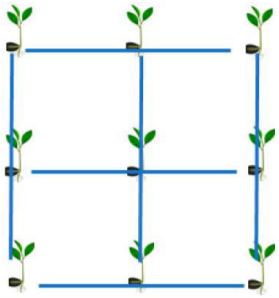
There are different systems of planting of fruit crop which could accommodate a maximum number of trees in an efficient manner

- ✓ Vertical row plant system
- ✓ Alternate row plant system

We can select any one of the above systems of plant depending upon the slop of the selected area, purpose of utilizing the orchard, availability of space, water, convenience etc.,

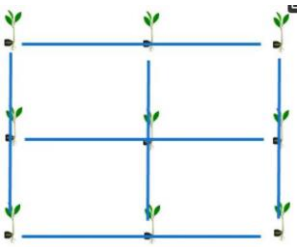
1. Vertical row plant system

- **Square system:**
  - ✓ Simple system of planting
  - ✓ In this system of planting, **equal spacing is given all the trees**.
  - ✓ In this system, the plot is divided into square shape and trees are planted at four corners of the square in straight rows at right angle. Intercrops can be cultivated



- **Advantages**
  - ➢ Most easy and popular one.
  - ➢ In this row to row and plant to plant distance is kept similar.
  - ➢ Plants are exactly at right angle to each other.
  - ➢ Interculture operations can be done in both the directions
  - ➢ Adequate space for inter-cultivation of remunerative crops like vegetables

- **Rectangular system:**
  - ✓ Here also, trees are planted on **each corner of a rectangle**.
  - ✓ The distance between any two rows is more than the distance between any two trees in a row.
  - ✓ Like in square system, raining intercrops is also possible in this system.
  - ✓ The only difference in this system is, more plants can be accommodated in the row, keeping more space between the rows.



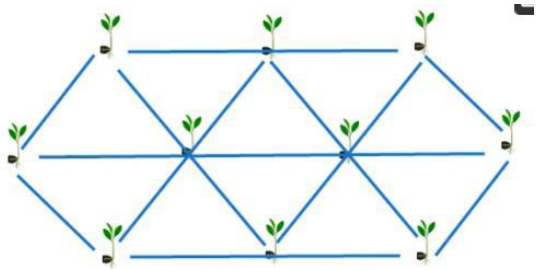
❖ **Advantages**

- Lay out in rectangular shape.
- More space between row to row.
- Inter-cultural operations can be done in both the ways.
- Plants get proper space and sunlight.

2. Alternate row plant system

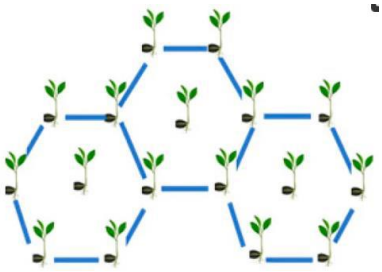
❖ **Triangular shape:**

- ✓ The trees are planted as in square system but the difference being that those in the even-numbered rows are mid-way between those in the odd rows instead of opposite to them.
- ✓ It accommodates **11% less number of trees than the square system**.
- ✓ It is difficult both to layout and cultivate trees in this system.
- ✓ Only advantage of this system is, more open space is available for the spread of the trees and intercrops



❖ **Hexagonal system:**

- ✓ In this system, trees are planted in each corner of an **equilateral triangle**.
- ✓ Here six trees form a hexagon with the 7th tree at the centre. Therefore this system is also called as **'septule'**.
- ✓ This system follows alternate row planting pattern as no tree in a row is perpendicular to a tree in the adjacent row.
- ✓ This system can be followed when there is ample supply of water in a highly fertile, valued land and **accommodates 15% more trees than square system**.

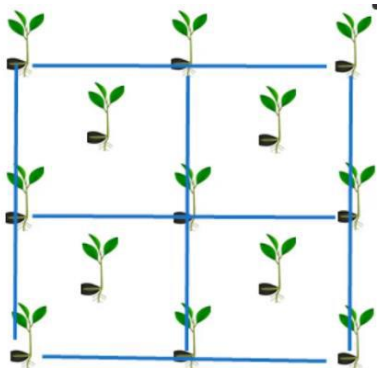


❖ **Advantages**

- Accommodates 15 % more plants than the square system.
- Plants are planted at the corner of equilateral triangle.
- Six trees are planted making a hexagon.
- The seventh tree is planted in the centre and called septule.
- This requires fertile land.

❖ **Quincunx or diagonal system:**

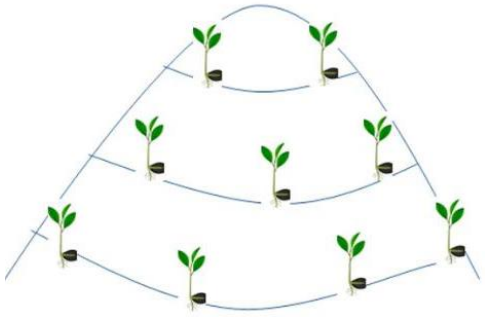
✓ This is nothing but the square system with plants in the centre of the square. Even though t his system of planting **accommodates double the number of plants**, does not provide equal spacing between plants.



- ✓ The central 5th tree, actually a **filler tree**, is quick and erect growing and early maturing, like **banana, pomegranate, papaya** which would be removed as soon as themain trees planted at the corners come to bearing.

❖ **Contour system:**

- ✓ This system of planting is followed mainly in the **hills with slopes**, where the land is with undulating topography and greater damage of erosion and difficulty of irrigation persist.
- ✓ On undulated lands, generally bench terracing may be done after the trees are planted. Trees can be planted on terraces or along contours.
- ✓ As the tree position can be decided only on the spot, the trees will not be equal-distant. This type of system is good for shallow soils where terracing will expose rocky or poor sub soil.
- ✓ Irrigation and cultivation can be done along tree rows only.i. Contour system ii. Terrace system



❖ **Fixing the base line:**

- ✓ Base line is a straight line marked at a determined space from a particular point, like road, fence, and channel *etc*.
- ✓ It is the first row accommodating trees. It is at a distance equal to half the spacing to be given between the trees. Generally, it is 2 to 5 m from the road.

High Density Plantation

- ➢ Planting of fruit trees rather **closed spacing than recommended spacing**
- ➢ Obtaining **maximum productivity per unit area**
- ➢ Technique was first established in **apple in Europe**
- ➢ Planting density in general depends on kind of fruit tree, its growth habit, rootstock utilized, pruning and training needs and rainfall of the area and soil type.

Different planting densities are recognized

- ✓ Low HDP – less than 250 trees per ha
- ✓ Moderate HDP – 250 – 500 trees per ha
- ✓ High HDP – 500- 1250 trees per ha
- ✓ Ultra HDP – more than 1250 trees per ha
- ✓ Super HDP – 20000 trees per ha in apple
- ✓ Meadow orchard – 70000 trees per

Fruit	Variety	Spacing	System of planting	Number of plants
Mango	Amrapali	2.5 x 2.5 m	Triangular system	1600
	Dashehari	3.0 x 2.5 m	Rectangular	1333
Banana	Cavendish group	1.2 x 1.2 m	Square System	6944
		1.0 x 1.0 x 2.0 m	Paired row system	6666

Characteristics of HDP

- Should have maximum no. of fruiting branches and minimum no. of structural branches
- Training – Central leader system
- The height should be – one and half times its diameter at the base

HDP is achieved by

- Use of dwarfing rootstock (**Apple** - MM 106, 109, 111, **Pear** – Quince A, Adam and Quince C)
- Polyembryony rootstocks in Mango – **Vellaikolamban**- imparts compactness to the scion
- Use spur type scion
- Training and pruning methods – to induce dwarfness
- Mechanical – Chemical – to control size eg. **Daminozide, Ethepon, Chlormequat** and **Paclobutrazol**

5. Manures and Manuring of Horticultural Crops

- Manures are substances of organic or inorganic nature which are capable of supplying the nutrients to the plants when applied to the soil.
- In general, manures are divided into **organic** and **inorganic manures**.
- **Organic manures:** derived from living organisms
- Organic manures includes cattle manure or farm yard manure, night soil, guana, bones, oil cakes, leaf mould, wood ash, coir compost and vermin-compost.
- **Inorganic manures:** derived from non-living material

Role of organic manures

- ✓ To serve as a good source of major and minor nutrients.
- ✓ To build up soil organic matter and maintain fertility.
- ✓ To improve physical, chemical and biological properties of the soil.
- ✓ To have residual effect.
- ✓ To control pest and diseases.
- ✓ To improve the quality of the crop.
- ✓ To act as a chelating agent.

The soil organic matter can be increased by the addition of farm yard manure which is popularly called as **compost**. Compost is defined as the material resulting from the decomposition of plant residues under the action of bacteria and fungi.

Green manure

- The soil organic matter can be increased by cultivating green manure crop or green leaf manures.
- The green manure crops are generally leguminous plants, raised in the field for the purpose of serving as manure.
- Eg. Sunhemp (*Crotolariajuncea*), Daincha (*Sesbaniaaculeata),* Pillipesara*(Sesbaniaspeciosa)*.

Green leaf manure

- Green leaf manuring refers to the incorporation of the green leaves and other tender parts of the plants collected from the shrubs and trees grown outside the field and also collected from the waste lands and nearby forests into the soil.
- Eg. Gliricidia (*Gliricidia maculata)*, Sesbania (*Sesbania speciosa)* and Pungam (*Pungamia pinnata).*

Organic manures:

Cattle manure or Farm Yard Manure (FYM)	• Manures produced by horse cattles or other animals. • They contain 0**.6% N, 0.35% P** and **0.6% K.**
Night soil	• Excreta of human • Rich in nitrogen ie. 5.5% N, 4.4% P and 2.0% K.
Guana	• Excreta of sea birds. • Used in Coast of Peru and South America. • 10.15% N, 9.82% P
Bone	• Steamed bone meal • 3.5% N, 23% Phosphoric acid also contain lime
Oil cakes	• Residues left after the oil extracted from the seeds of groundnut, castor, gingelly, pongamia*etc*. • 3 – 5% N, 1.5 – 2% P.
Leaf mould	• Withered and dry leaves and garden sweepings are used after decomposition. • Rich in humus.
Wood ash	• Rich in potash
Coir compost	• Coir pith obtained from coir industry are decomposed by a fungus *Pleurotus sojar caju*. • C/N Ratio **25 : 1** • 1.4% N, 0.06% P and 1.2% K.
Vermi-compost	• Organic waste materials and animal dungs when fed with certain species of earthworm. • The excrement of worms are called `**Vermi-compost'**

Inorganic Fertilizers

Nitrogenous fertilizer

- ❖ These fertilizers supply nitrogen to the crops when applied to the soil. Eg. Urea, ammonium sulphate, ammonium nitrate, sodium nitrate etc.

Phosphate fertilizers

- ❖ These fertilizers supply phosphorus to the crops when applied to the soils.

- Eg. **Super phosphate** (16-18% water soluble phosphate), **basic slag** (8-18% phosphoric acid) and **rock phosphate** (30-40 % P_2O_5, 3-4% Fluorine and various amount of lime).

Potassic fertilizers

- These fertilizers supply potassium to the crops when applied to the soils.
- Eg. **Muriate of potash** (potassium chloride – 48-62% K_2O and 35-47% Chloriine) and **potassium sulphate** (50% K_2O).

Mixed fertilizers

- It is a mixture of more than one straight fertilizers which can supply more than one plant nutrient elements.
- Eg. 17:17:17 complex.

Advantage of mixed fertilizers

- ✓ Saving in time and labour in application.
- ✓ Saving from transport of too many straight fertilizers from too many places.

Disadvantages

- ✓ Specific needs of crops and individual nutrient element cannot be satisfied.
- ✓ Unit cost of mixed fertilizer is higher than unit cost of straight fertilizers.

Biofertilizers or bio-inoculants

- Bio-fertilizers are carrier based preparations containing beneficial microorganisms in a viable state intended for seed or soil application and designed to improve soil fertility and help plant growth by increasing the number and biological activity of desired microorganisms in the root environment.
- Three types of bio-inoculants are used to increase the growth and production of horticultural crops.
    - ✓ Inoculants of biological **nitrogen fixing micro-organisms.** Eg. *Azotobacter, Rhizobium* and *Azospirillum.*
    - ✓ **Phosphobacterial** inoculants. Eg. *Bacillus sp. Pseudomonas sp. (*Bacteria), *Pencillium sp.* and *Aspergillus sp.* (fungi) and Phosphobacteria.
    - ✓ **Mycorrhizal** inoculants eg. (VAM) Vasicular Arbuscular Mycorrhizal fungi.
    - ✓ The fertilizer nitrogen can be reduced to the tune of 20-25%

Time of application

- The manures are applied to supply the nutrients which are not present in sufficient quantities in the soil.
- Yield is increased when they are applied at proper time and at proper place.

- There are certain factors which decide the time of application of fertilizers and manures after choosing the fertilizers to be used.
    - ✓ **Nitrogen** is required throughout the crop growth and all nitrogenous fertilizers are readily soluble in water and loss is found to occur. So it is better to supply nitrogenous fertilizers in split doses. ie. Basal and top dressing.
    - ✓ **Phosphorus** is required in large amounts in the early stages of growth. All phosphate fertilizers are found to be slow acting and fixed in the soil and hence the entire quantity of these fertilizers are applied as basal.
    - ✓ **Potassium** is required throughout the crop growth but the release of this nutrient is slow and hence entire quantity is applied as basal dressing.

Method of application

Broadcasting

- The fertilizer is sprinkled uniformly over the cultivated surface.
- It may be done before last ploughing or planting or sowing of seeds as basal dressing.
- For top dressing, fertilizers are applied when crop is in field.

Liquid fertilizers

Starter solution

- It is a solution containing water soluble nitrogenous, phosphatic and potassic fertilizers in small quantities (0.05%) which are used for the establishment of young plants, this solution is called starter solution. Eg. Tomato.

Foliar application

- Many nutrients are absorbed through the leaves of the plants.
- When compared to soil application plants require less quantity of nutrients if supplied through foliar application. 2 or 3 trace elements can be combined and applied.
- Eg. Urea spray in brinjal and bhendi. Concentration used for foliar spraying should be correct otherwise it creates many problems to the crop plants.

Good agricultural practices (GAP)

- Good agricultural practices (GAP) are "Practices that address environmental, economic and social sustainability for on-farm processes and result in safe and quality food and non-food agricultural products".
- **HACCP:** Hazard Analysis and Critical Control Point
- **Codex Alimentarius:** Leading food safety agencies developed by FAO and WHO in 1963
- International organization for standardization (ISO), Geneva, Switzerland

- ISO 9000 – concerned with quality management
- ISO 14000 – Environmental management

GMP (Good Manufacturing Practices)

- It is a system for ensuring that products are consistently produced and controlled according to quality standards.
- It is regulations require a quality approach to manufacturing, design to minimize or eliminate instances of contamination and errors.
- This in turn, protects the consumer from purchasing a product.

Hazard Analysis Critical Control Point (HACCP)

- HACCP is a systematic approach to the identification, evaluation, and control of food safety hazards. Preventing problems from occurring is the paramount goal underlying any HACCP system.
- The Hazard Analysis and Critical Control Points (HACCP) System is a logical, scientific approach to controlling safety problems in food production.
- While adopts HACCP, puts controls in place at each point in the production system where safety problems could occur from biological, chemical, or physical hazards.

6. Methods of Irrigation including Fertigation

- The water relations of plant are of extreme importance both for vegetative growth and for fruit production.
- It is necessary for rapid growth and satisfactory crops and to maintain turgor in cells for maximum photosynthetic activity.
- In arid and semi-arid zones, irrigation is a very important cultural practice. Even in humid areas where distribution of rainfall is not satisfactory, irrigation is essential during the droughtperiod.

The need for irrigation and also the amount of water that should be supplied are influenced by the following factors.

1. **Annual precipitation:**
   - ✓ If rainfall is high or low but irrigation facilities are available, intensive cropping can be followed.
   - ✓ If irrigation facilities are not available and the rainfall is also poor, extensive cropping with drought tolerant crops can be followed.
2. **Period of moisture shortage:**
   - ✓ In south India, the period from December – March is totally free of rainfall and during this period, irrigation is a must even to perennial crops.
3. **Stage of the crop:**
   - ✓ Irrigation requirements sometimes depend upon stage of growth the crop.
   - ✓ For instance, fruit bearing mango trees are to be regularly irrigated at 10-15 days interval during the fruit development stage ie. From fruitset to full development stage.
4. **Type of crops and cropping:**
   - ✓ Most horticultural crops have high moisture requirements.
   - ✓ Some fruit trees have deeper root system and hence, during the period of drought, they suffer very little or not at all if the subsoil moisture is at a high level.

The frequency of irrigation is determined by the following factors

1. The nature of soil:

- ✓ **Fine texture soil hold moisture longer** than soil of coarse texture.
- ✓ **Deep soils hold larger quantities** of water than shallow soil.
- ✓ Presence of organic matter content also increases the same.
- ✓ When the water holding capacity of soil is increased the interval between irrigation can be extended.

2. Rate of absorption by plants:

- ✓ Transpiration rate of crop plants affects the rate of absorption of water and consequently influences the frequency of irrigation.
- ✓ Those plants with large leaf surface require more water than those with reduced leaf surface.

3. The root system of the crop:

- ✓ A shallow rooted crop requires more frequent watering than a deep rooted crop.
- ✓ There is no absolute method for determining when it is time to irrigate.
- ✓ Some growers can tell based on the external symptoms.
- ✓ The immediate symptoms of lack of water are wilting, drooping of leaves, curling of leaves, shrinkage of fruit etc.
- ✓ Since the feel test is difficult to describe and requires considerable skill, soil moisture meters like **irritometers** and **Bouyoucos moisture meter** are available which measure the moisture content of soil

Systems of irrigation

A. Surface irrigation

- ❖ Supplying water to the soil without aerial application is known as surface irrigation. It depends on gravity for spread of water over the area.
- ❖ These systems generally use more quantity of water.

Different systems of surface irrigation are:

- ❖ **Flooding**: This is followed in wet lands mostly for banana. This is a wasteful method which will lead to stagnation of water and help weed growth.
- ❖ **Check**: Check bunds for large areas enclosing a number of trees are provided with channels between two row. This is more economical than flood system.
- ❖ **Basins**: This is widely practiced. The basins should be square or circular and should be sloping from the trunk to periphery. Useful in young orchards, light sandy and alkaline soils.
- ❖ **Ring**: In this system, small ring bund will be provided around the trees or one single irrigation channel connecting all trees will be formed and around each tree, the channel is widened to form basin.
- ❖ **Bed**: This is adopted in heavy soils for fruit crops like banana, wherein 3-4 plants are enclosed in a bed and is irrigated by opening on one side of the bed.
- ❖ **Furrow**: This is most widely followed for vegetable crops like tomato, onion, brinjal*etc*. All the above different systems of surface irrigation do not ensure uniform distribution of water. It may be more in areas near channels and less in areas away from the channels.

B. Sub Irrigation

- ❖ This method supplies water from below soil through underground pipes or by ditches on one side.
- ❖ This is useful for green houses. Pipes are laid 45-60 cm deep and 6m apart. Pipes will have holes at regular intervals.
- ❖ This method is costly and deep cultivation is not possible. But, evaporation of moisture is prevented to a great extent.

Special irrigation methods

1. Overhead irrigation

- ✓ Overhead irrigation is by the use of sprinklers.
- ✓ Most widely used overhead system.
- ✓ In this systems, the initial cost of installation is rather high but there are several advantages. There is saving in labour cost and water.
- ✓ More uniform wetting of soil is possible and erosion will be eliminated.
- ✓ This method is best for step and terraced lands. This is more widely adopted in Plantations.

2. Drip irrigation

- ✓ Drip irrigation is known by various names like 'trickle irrigation or high frequency irrigation daily flower irrigation'.
- ✓ This is a method of watering plants at a rate equivalent to its consumptive on so that plants would not experience any stress during the growing phase.
- ✓ In this the water is conveyed from a source under low pressure to the root zone of the crop only.

It has the following components

1. Water supply pump at the source of water
2. Filters, fertilizer mixing tank,
3. Control system
4. Pressure regulators,
5. Monitor valve/water meter,
6. Headlines or main lines for conveying water from pump set to the field where water is to be delivered.
7. Laterals to carry water to plant rows and
8. The emitters/dripper through which water is finally released at a distance of 5 to 25 cm from the plant base.

Advantages

- ✓ **Water saving –** Water is applied directly to the root zone, eliminating wastage. 30 to 70 percent water saving
- ✓ **Labour saving** – This is eliminates the need for constructing borders, bunds and labour intensive works associated with conventional irrigation techniques, thereby saving about to 60 to 90%
- ✓ **Use of lower quality water** – Water is applied continuously and the root zone is kept wet constantly.
- ✓ **Increased yield and plant vigor** – It maintains soil moisture at optimum level eliminating water stress resulting in greater vigour, better establishment and high productivity.
- ✓ **Reduced weed growth** – Since water is applied to the restricted area, wide spread weed growth is inhibited due to restricted water supply
- ✓ **Saving of nutrients** – Nutrients are directly applied to the root zone along with water. Leaching losses are minimized. Saving upto 30 to 60%

Disadvantages

- ✓ Higher initial investment
- ✓ Clogging of drippers due to oxidants, bi oxides and algae

Fertigation

- ❖ Fertigation is a new technique of applying fertilizers particularly soluble fertilizers along with irrigation water, through drip system.
- ❖ Optimum use of fertilizers, water and land is the need of hour which is easily achieved through fertigation.
- ❖ The inputs applied are more efficiently utilized than in any other system.

I. System components

- ✓ Pump
- ✓ Filtration system – sand filters/disk filters/screen filters
- ✓ Injectors-venture/dosatron/closer pump/bladder tanks/fertilizer tanks/bulk injection systems
- ✓ Back flow prevention equipment

II. Types of fertilizers for fertigation

- ✓ Water soluble fertilizers (WSF)
- ✓ Liquid fertilizers (LF)

III. Nutrient sources

- ✓ N- Urea, ammonium nitrate solutions, ammonium nitrate, calcium nitrate and KNO3
- ✓ K-KCL, K2SO4 and KNO3
- ✓ P-The choice of phosphorus products is more limited. Phosphoric acid and ammonium phosphate solution are used most commonly.

IV. Prerequisites for fertigation

Soil nutrient status, nutrient requirement of the crop, water properties, experienced personalities for installation and execution, availability of specialty fertilizers (WSF or LF) crop and site specific nutrient requirement, crop nutrient demand specific to each stage of the crop

7. Horticultural Cropping Systems – Inter Cropping Cover Cropping

Orchard cultivation refers to the careful management of orchard soil in such a way that the soil is maintained in good conditions suitable to the needs of the tree with least expenses. This involves maintenance of physical condition of soil, its moisture and nutrient content. A good system of orchard cultivation should ensure.

- ✓ weed control and saving in moisture and nutrients
- ✓ Very little disturbance to soil and preventing soil erosion and
- ✓ Reduced cost of cultivation

Methods of soil management practices

I. Clean culture

This type of cultivation is extensively followed in India. This involves regular ploughing and removal of weeds. The clean culture has many disadvantages

- ✓ Humus will be completely depleted rapidly due to frequent cultivation.
- ✓ Frequent cultivation causes injury to the feeding roots and the trees may be short lived or stunted in growth.
- ✓ Clean cultivation aids in more aeration leading to the depletion of nitrogen
- ✓ Hard pan is created in the soil
- ✓ Frequent cultivation causes more soil erosion

The above mentioned defects in clean cultivation can be minimized by avoiding deep and frequent cultivation and also cultivation when the soil is too wet.

2. Clean culture with cover crops

- ✓ This type of soil management involves raising of a cover crop or green manure after removing the weeds.
- ✓ If clean cultivation is attempted during the rains, considerable erosion is almost sure to occur.
- ✓ It is probably best to plant a green manure crop between the trees early in the rains and plough it into the soil towards the end of monsoon season.
- ✓ In India, green manure crops like **sun hemp, cowpea, daincha, lupin** etc. are more commonly used.
- ✓ Legume cover cropping in grape, mango, guava and other fruit crops is becoming a common practice in the management of orchards.

Intercropping

- In young orchards, there is a greater scope for utilization of vacant space.
- If the trees are properly spaced, there will be considerable land which will not be used by the permanent trees for several years.
- Similarly, in the case of other long duration horticultural crop like tapioca, turmeric, ginger and banana, some area between adjacent plants will be remaining unoccupied by the main crop for few months.
- It naturally appeals to the grower to get some return from this vacant land especially when he is getting no return in the early periods.
    - ✓ Intercrops should not be occupy the area where the roots of the fruit trees are concerned.
    - ✓ Soil fertility should be maintained or improved when intercrops are grown/Water requirement of the intercrops should not clash with those of the main fruit trees.
    - ✓ The intercrop may require an irrigation at a time when it would be detrimental to the trees
    - ✓ Intercrops should be selected with reference to their effect on soil moisture.
    - ✓ Grain crops remove excessive moisture to the detriment of fruit trees.
    - ✓ The intercrops selected should not exhaust the soil water and nutrients and should not demand more water than is allowed for fruit trees.

Vegetables are the best intercrops when compared to millets. The intercropping should be stopped when trees occupy the entire orchard space. Many growers prefer some quick growing fruit trees to grow as intercrops. Short-lived trees are known as **'fillers' eg. Papaya.**

Mixed cropping

- It refers to the practice of growing certain perennial crops in the alley spaces of the main perennial crops.
- The main advantage is the effective utilization of available area and increase in the net income of the farm per unit area
- **Increase in yield (upto10%)** is obtained in the main crop due to the synergistic effect of the crop combinations arising out of beneficial microorganisms in the rhizosphere and the more availability of major nutrients in the active root zone of the crop mix as compared to the pure stand.
    - ✓ Mango up to 7 years leguminous, vegetable, papaya
    - ✓ Grapes upto 8 months snake gourd or bitter gourd

- ✓ Apple upto 5 years potato of cabbage
- ✓ Banana upto 4 months sun hemp,onion
- ✓ Tapioca upto 3 months small onion, coriander
- ✓ Turmeric upto 3 months small onion, coriander
- ✓ Arecanut upto 10 years pineapple
- ✓ Coconut upto 3 years banana, tapioca, vegetables

MULTITIER CROPPING – MULCHING

Mulching

- ❖ This is one of the important soil management practices adopted in certain countries.
- ❖ Crop residues like straw, cotton stalks, leaves, saw dust, pine needle, coir dust and other materials like polythene films or certain special kinds of paper are spread in the tree basins and in inner spaces between trees.
- ❖ Main objective of mulching is to conserve soil moisture and to control weed growth.

The other advantages

- ✓ Keep soil cool in day; warm at night hours
- ✓ Reduces surface run-off
- ✓ Add humus to the soil
- ✓ Prevents soil erosion
- ✓ Fruits are protected and kept clean since they fall on the mulches
- ✓ It allows the absorption of more rain water and
- ✓ It reduces irrigation frequency.

The following are some of the disadvantages

- ✓ Dry materials used as mulches encourage the risk of fire and consequent damage to trees
- ✓ Thick mulches may act as places for mice and rodents to live and multiply.
- ✓ They may cause damage to tree trunks and roots by eating the bark and burrowing to the land.

Sod

- ❖ In this method, **permanent cover of grass is raised in the orchard and not tillage** is given.
- ❖ This type of orchard cultivation is followed in USA and Europe. This may be useful in sloppy lands for preventing soil erosion.
- ❖ But they compete for soil moisture and available nitrogen.
- ❖ The drawbacks of this system are the need for increased manuring and water application.
- ❖ They are harmful to shallow rooted trees.

Sod mulch

- This is similar to sod and the only difference is that the **vegetation is cut frequently** and the **cut material is allowed to remain on the ground**.
- This is slightly better than the previous one, as the moisture loss is not so great as in sod – in both sod and sod mulch, more nitrogen should be applied to the fruit trees than usual application because the vegetation utilizes more soil nitrogen.

Multitier system of cropping

- Certain horticultural plants like coconut and arecanut are grown for about 50 years in a particular land.
- It takes nearly 4 to 7 years for the above trees to reach the bearing stage.
- Adequate alley spaces (nearly 75%) are available in between these trees and being the palm trees, their root system will not also spread beyond one meter in diameter.

Tier	Crop
First (Top)	Coconut or Arecanut
Second	Pepper trained over the trunk of coconut or Arecanut trees
Third	Cocoa or cloves planted at the centre of four arecanut or coconut
Fourth (ground)	Pineapple, ginger and dwarf coffee

8. Protected Cultivation – Controlled Environment

In West, the climate is extremely adverse for most of the year. For most part of the year, the temperature would be below 10 degree Celsius ruling out open cultivation of any crops. Hence greenhouses are the only means of cultivation in such countries. A green house is a structure which has enclosed frame work with provisions for heating, enrichment of CO2, micro irrigation, fertigation, automated or semi-automated light, humidity and temperature regulation.

Green house

Framed structures, covered with transparent (or) translucent materials, large enough to grow crops, under partial (or) fully controlled environment, to get greater productivity of the highest quality.

- ✓ High value. Low volume crops – Slogan of greenhouse cultivation.
- ✓ India – 300 to 350 ha. area under cover.
- ✓ Green house cultivation is commercial in 750 countries.

Advantages

- ✓ Crops grown throughout the year.
- ✓ High yields of excellent quality.
- ✓ Easy to control pests & diseases.
- ✓ Labour& water requirement are minimum.
- ✓ Control of environment results in higher productions is well proved.

Draw backs

- ✓ High cost.
- ✓ Non-availability of various components

Lay out

- ➢ Type, design & construction depend on climate.
- ➢ A thorough knowledge of climate viz. maximum & minimum temperature, relative humidity, wind velocity, rainfall, sunshine hours, type of crops – necessary as essential.
- ➢ In North India Kashmir & New Delhi Mean & Maximum 0°C & 40°C – So, cool in summer; heat in winter.
- ➢ In **South India** – Mean & Maximum 12°C & 36°C, No heating required in winter, natural ventilation (30 – 40%).

Crops grown

- ✓ Tomato (off season), Capsicum, Cucumber.
- ✓ Roses, Chrysanthemums, Carnation & Gerbera.
- ✓ Vegetable seedlings, planting material, hardening of tissue cultured plants.
- ✓ Tomatoes can be grown throughout the year – **300 to 400 t/ha/year**.
- ✓ Labour requirement heavy – 10 men/ha.
- ✓ Open cultivation – 1 man / ha.

Potentials

- ✓ Supply of fresh produce to cities – off season production of vegetables.
- ✓ Export of agricultural produce – cultivation near lifting points and facilitate this.
- ✓ Cultivation of rare medicinal, aromatic & ornamental species – conservation, cultivation & exploitation.
- ✓ Green house technology a base for other biotechs like hydroponics, nutrient film technique etc.
- ✓ Cultivation in problematic regions & extreme climates – (75 million ha of barren & uncultivable land in India)

Roof Shading

- ✓ Solar energy – intensity reduced by applying opaque materials directly to glazing.

Fan & Pad system

- ✓ Fan – exhausts out hot air – A vacuum is created enters fresh cool air through pad. Green house has to be maintained airtight.
- ✓ All access, openings and door have to remain closed.

Green house heating

- ✓ Necessary in cold environments.
- ✓ Energy is used as heat.
- ✓ Heat supplied by burning fossil fuels, geothermal& hydroelectric source. Artificial lighting is also practiced.

Shading

- ✓ Application of shading paint to glazing.
- ✓ White paint is less expensive in general.

Cultivation of Horticultural Crops in Green House – Operation and Maintenance

- ❖ States have sizable area under greenhouse Karnataka, Tamil Nadu, Andhra Pradesh, West Bengal, Maharashtra, Rajasthan, Utter Pradesh, Delhi & Haryana.

- ❖ Green house area in India 200 ha. It may increase to 500 ha in future.Crops grown – Roses, carnation, chrysanthemum, gerbera, anthuriums, liliums, and orchids.

Operation and maintenance

- ✓ A thorough knowledge of the environment on crop growth is essential.
- ✓ Light, temperature, relative humidity, CO_2 and soil root medium are important.
- ✓ Light – intensity, quality – many physiological process affected. – Duration influences flowering & fruiting.

Classification

- ✓ **Photoperiod insensitive** (or) day neutral. Eg. Tomato, Brinjal, Pepper, Cucurbits.
- ✓ **Short day** & long night plants. Eg. Potato, Sweet Potato, Soybean, Chrysanthemum.
- ✓ **Long day** & short night – Eg. Chinese Cabbage, Radish, Spinach, Peppermint.

Temperature

- ✓ Quality & maturity rate affected.
- ✓ Photosynthesis, transpiration & respiration increase with temperature.
- ✓ Low temperature – active growth – low respiration – influences initiation & development of organs.
- ✓ High temperature – higher senescence.

Relative humidity

- ✓ Plants in humid – large sized fleshy leaves, stems & flowers.
- ✓ Low humidity – injury to leaf margins, tips, petals, wilting and senescence. – Leaves & flowers weak & distorted.
- ✓ Plants under high humidity continuously – soft, mushy & rotting.

CO_2

- ✓ Main source for biomass production.
- ✓ High CO_2 – high growth rate – short time for flowering.

Cultivation & management

- ✓ Crops grown in ground beds – various soil & soil less media.
- ✓ Physical & chemical properties adjusted.

Soil

- ✓ Common media
- ✓ Amended with org. manure, compost, peat & others – nutrients, physical structure.

Soilless media – Peat, sand, gravel, perlite, vermiculite, rockwool.

9. Training and Pruning

- Horticultural plants are grown for their produce like fruits, vegetable, flowers, medicinal components, spices (oleoresins), aromatic (essential oils) etc.
- In manipulation of plant development, training and pruning are important for which our knowledge about plant development and its phenology has to be complete.
- These practices are important in fruit crops.

Training - Definition:

- Physical techniques that control the shape, size and direction of plant growth are known as training **or** in other words training in effect is orientation of plant in space through techniques like tying, fastening, staking, supporting over a trellis or pergola in a certain fashion or pruning of some parts.

Objectives:

- To improve appearance and usefulness of plant/tree through providing different shapes and securing balanceddistribution.
- To ease cultural practices including intercultivation, plant protection andharvesting.
- To improve performance like planting at an angle of 45° and horizontal orientation of branches make them fruitingbetter.

Methods of Training

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

Training in herbaceous annuals and biennials:

- These plants are usually grown without any attempt to alter their growth patterns because even if useful not practical being in large number in field. However, for some of ornamental value and creeping nature following types of training is affected.
- **Staking or supporting** of vine like plants.
- Training on pergola or trellis of vine type fruit plants or even indeterminate type tomatoes.
- **Nipping** of apices for encouraging lateral growth to give bushy appearance or fulsome appearance in pot plants like aster, marigold andchrysanthemum.
- **De-shooting** or removal of lateral buds for making single stem for large flowers as in chrysanthemum and Dahlia.
- **Staking** with bamboo sticks and tying together various shoots in pottedchrysanthemum.

Training of woody perennials

- **Open centre system (Vase shaped):**
  - ✓ In this system the main stem is allowed to grow to a certain height and the leader is cut to encourage lateral scaffold from near the ground giving a vase shaped plant.
  - ✓ This is common in peaches, apricots and ber.
- **Central leader system (Closed centre):**
  - ✓ In this system the central axis of plant is allowed to grow unhindered permitting branches all around.
  - ✓ This system is also known as **closed centre system** and common in use in apple, pear, mango and sapota.
- **Modified leader system**
  - ✓ This system is in between open centre and central leader system wherein central axis is allowed to grow unhindered up to 4—5 years and then the central stem is headed back and laterals are permitted .It is common in apple, pear, cherry, plum, guava.
- **Cordon system:**
  - ✓ This is a system wherein espalier is allowed with the help of training on wires.
  - ✓ This system is followed in vines incapable of standing on their stem.
  - ✓ This can be trained in single cordon or double cordon and commonly followed in crops like grape and passion fruit
- **Training on pergola:**
  - ✓ To support perennial vine crops pergola is developed by a network of crisscross wires supported by RCC/angle iron poles on which vines are trained.
  - ✓ This is common for crops like grape, passion fruit, small gourd, pointed gourd and even peaches.

Training in different shapes:

- ✓ Generally ornamental bushes are trained in different shapes for the purpose of enhancing beauty of places.
- ✓ These shapes could be vase, cone, cylindrical and rectangular.

Details of Training:

Height of the head: This is the height from ground to first branching orscaffolding.

Depending on the height the trees could be divided in three groups.

- ✓ **Low head**: 0.7—0.9 m. This is common in windy areas. Such plants are easy tomaintain.
- ✓ **Medium head**: 0.9—1.2 m. This is the most common height which combines both effects,

ability to stand against wind and easymanagement.

- ✓ **High head:** More than 1.2 m. Common in tropics in wind free areas. Operations under the canopy are easy toperform.

Number of scaffold branches:

- ✓ It refers to allowing of number of scaffolds on the primary axis of the tree which vary from 2 to 15 but extremes are undesirable.
- ✓ In fruit trees 5 to 8 scaffolds are preferred to make the tree mechanically strong and open enough to facilitate cultural operations.

Distribution of scaffolds:

- ✓ Scaffolds should be distributed in all the directions spaced at 45- 60 cm allowing strong crotches through wide angles of emergence.

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

Pruning - Definition:

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

Objectives:

- ✓ To control plant size and form.
- ✓ For plant performance like
- ✓ Establishment of transplant where leaves/shoots are pruned to strike a balance between roots and shoot so that plants lose less water against restricted root system lost during lifting of plants.
- ✓ Improvement in productivity and quality by regulating the load of the crop and extent of flowering.
- ✓ For flower and fruit quality.
- ✓ Elimination of non-productive vegetative growth like water sprouts, suckers, dead and diseased wood.
- ✓ In case of forest trees production of knot freetimber.

Types of pruning:

Basically there are three types of pruning with definite purposes.

- ✓ **Framepruning**
- ✓ **Maintenancepruning**

- ✓ **Renewal pruning**

Frame pruning:

- ❖ This pruning is done to provide shape and form to a plant in its formative years so that tree develops strong framework and a shape for ease of operations.
- ❖ This process begins from nursery itself and continues up to fruiting stage.
- ❖ This is done continuously irrespective of the season.

Maintenance pruning:

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

Renewal pruning:

- ❖ This pruning is done in old trees like mangoes which shows decline.
- ❖ In this case severe pruning is required.

10. Plant Growth Regulators

- These are organic compounds other than nutrients, which in small amounts promote, inhibit or otherwise modify any physiological process in plant.
- It may be defined as any organic compounds which are active at low concentrations (1-10 ml) in promoting, inhibiting or modifying growth and development in plants.
- The naturally occurring (endogenous) growth substances are commonly known as **plant hormones**, while the synthetic ones are called **growth regulators.**

Plant hormones

- It is an organic compound synthesized in one part of plant and translocated to another part, wherein very low concentration causes a physiological response.
- The plant hormones are identified as **promoters** (auxins, gibberellin, cytokinins), inhibitors (abscisic acid and ethylene) and other **hypothetical growth substances** (Florigen, death hormone, etc.).

Auxins

- Auxins are the first identified hormones of which **IAA** seems to be the major naturally occurring endogenous Auxin in plants and crops.
- Besides IAA, plants contain three other compounds which are structurally similar and elicit many of the same response as that of IAA, 4, Chloroindole acetic acid (CIAA), Phenylacetic acid (PAA), Indole butyric acid(IBA).

Site of Auxin synthesis:

- Auxins are synthesized in **stem tips** and in **young tissues** and **move mainly down stem** (**Basipetal movement**) i.e from shoot tip to root.

Synthetic compounds are classified into five major categories

- ✓ Indole acids
- ✓ Napthalene acids
- ✓ Chlorophenoxyacid
- ✓ Picolinicacid.
- ✓ Derivatives.

Role of Auxin

- ✓ **Cell division and enlargement:** IAA + GA, example - cambial growth in diameter.
- ✓ **Tissue culture:** Shoot multiplications (IBA and BAP), callus growth (2, 4-D), root multiplication IAA and IBA (1-2mg).

- ✓ Breaking dormancy and apical dominance (inhibition of lateral buds): **NAA**
- ✓ **Shortening internodes:** Apple trees (NAA) dwarf branch fruit.
- ✓ **Rooting of cutting:** (10-1000 ppm-NAA, IAA, Phenyl acetic acid)
- ✓ **Prevent lodging:** NAA develop woody and erect stem.
- ✓ **Prevent abscission:** premature leaf, fruit and flower fall (NAA, IAA and2,4-D).
- ✓ **Parthenocarpic fruit:** Grapes, Banana and Orange (IAA).
- ✓ **Flower initiations:** Pineapple uniform flowering and fruit ripening (NAA) and delay flowering (2,4-D).
- ✓ **Weed eradication:** 2,4-D.

Gibberellins:

- ❖ It is the active principle isolated from the soil borne fungus ***Gibberella fujikuroi*.**
- ❖ The concentration of GA_3 is usually highest in **immature seeds**, reaching up to 18 mg/kg fresh weight in Phaseolus species, but it decreases rapidly as the seeds mature.
- ❖ In general, roots contain higher amounts of GA_3 than shoots.
- ❖ Gibberellins have also been found effective in overcoming both kinds of dormancy in buds as well as seeds.

Role of Gibberellins

- ✓ GA: Synthesis in leaf and induce shoot elongation (IAA + GA_3), by effecting cell elongation or cell division orboth.
- ✓ **Enhance metabolic activity:** Mobilization of reserved food material, promote growth and height, increase root activity and kinetin production in root- translocate to growing bud.
- ✓ **Shoot elongation:** GA_3 spray increases height of seedlings.
- ✓ **Delay senescence:** Increase photosynthetic and protein synthesis so decreaseabscission.
- ✓ **Increase cambial growth and differentiation:** Induce flower and fruit set (IAA+GA_3).
- ✓ **Dwarf plant (genetically) to normal height:** GA_3.
- ✓ **Promote flowering in Long Day Plants**: Substitute for long day condition and cold treatment (vernalization).
- ✓ **Induction of parthenocarpy in grapes**: Three physiological events: Rachis cell elongation, flower thinning and berry enlargement.
- ✓ Breaking dormancy (in potato) and leaf expansion.

Cytokinins:

- ❖ First endogenous cytokinin was isolated from maize kernels named as **zeatin.**
- ❖ Germinating seeds, roots, sap streams, developing fruits and tumor tissues are rich in

cytokinins.

- ❖ Cytokinins imbibed seeds germinate better in dark than unimbibed lettuce seeds.
- ❖ Similarly cytokinins together with gibberellins effectively **break the photodormancy of celery (*Apium graveolens*) seeds**.

Synthetic Cytokinins:

- ✓ Kinetin, Benzyladenine and Ethoxyethyladenine.
- ✓ **Kinetin** - induces transport of soluble nitrogen fromintact leaves tolocalise areas of other leaves

Role of Cytokinin:

- ✓ Cell division, elongation and enlargement.
- ✓ Tissue culture morphogenesis.
- ✓ Induction of flowering and fruit development.
- ✓ Parthenocarpy.
- ✓ Apical dominance overcoming.
- ✓ Breaking dormancy.
- ✓ Delay senescence.
- ✓ Improves N_2 metabolism

Growth retardant

- ❖ The term growth retarding chemical or growth retardant is that chemical slows cell division and cell elongation of shoot tissues and regulate plant height physiologically without formative effects.
- ❖ **E.g**: AMO 1618, Phosphon-D, CCC, Chloromequat and Alar.
- ❖ These do not occur naturally in plants and acts in retardation of stem elongation, preventing cell division.
- ❖ Plant growth retardants are defined as synthetic organic chemicals that cause a retardation of cell division steps in pathways of hormone biosynthesis without evoking substantial growth distortions.
- ❖ **Inhibitors:** These suppress the growth of plants. There are phenolic inhibitors and synthetic inhibitors and abscisic acid (ABA).
- ❖ **Phenolic inhibitors:** E.g. Benzoic acid, Salicylic acid, Coumaric acid and Chlorogenic acid.

Various uses of plant growth regulators

Propagation of plants

- ❖ A number of plants are propagated by stem, leaf cutting and by layering.

- For promotion of rooting, the most commonly utilized hormone is IBA followed by NAA. Gibberllic acid causes inhibition of root formation in cutting.
- Cytokinins also help in quick and profuse root formation in cuttings and layers.
- By use of auxins, profuse root formation is observed in cuttings of guava, fig, pomegranate, crotons, rose, hibiscus, etc.

Seedgermination

- Many seeds have natural dormancy which can be got over by dipping the seeds in auxins.
- Soaking seeds of french beans and peas in 10-20ppm solution of GA for 12 hours before sowing, significantly improves the yield and quality.
- Dipping sweet potatoes in 5ppm GA solution for 5minutes before sowing increases sprouting and yield of potatoes.

Control of plant size

- In fruits and vegetables, application of higher doses of nitrogenous fertilizers spraying cycocel (growth retardant), the superfluous growth of leaves is checked.
- By spraying 10ppm solution of morphactin in potato, the growth of plant is reduced and thereby the size of tubers is increased.
- The growth retardants are useful in checking the growth of hedges in ornamental gardens there by reducing the cost of trimming the hedges.

Regulation offlowering

- In **Pineapple**, due to later flowering the fruit get ready in rainy season.
- This deteriorates the quality of the fruit.
- This difficulty can be overcome by spraying **5-10 ppm solution of NAA** before flowering.
- Application of 100-200 ppm GA in Dahlia plants induces early flowering.
- Sometimes, it is necessary to delay flowering. E.g. crossing of varieties which do not flower simultaneously. Hence, the crossing becomes difficult.

Control of Sex expression

- In number of cucurbits, such as ridgegourd, bittergourd, watermelon, cucmber and pumpkins which have proportion of male flowers is more than female flowers.
- For better yield, it is necessary to increase the number of female flowers.
- This can be achieved by application of auxins which increases the number of female flowers and decreases the number of male flower.
- The commonly used auxins (NAA) and ethrel.

Control of fruit set and growth of fruit

- Spraying NAA, TIBA, and PCPA on flowers increases the fruit set.
- **Dipping of grape bunches** (young fruits) in GA solution increases the berry size in Thompson seedless grape.

Control of fruit drop

- In Nagpur Santra, the fruit drop can be controlled by spraying 10-20 ppm NAA or 10 ppm 2,4-D after fruit set.
- The fruit drop in mango can be controlled by these two auxins.

Thinning offruits

- Sometimes it is necessary to thin the fruits so as to bring a balance between the supply of nutrients and development of fruit.
- In such cases spraying with mild solution of ethrel or morphactin reduces the fruit load by 25-30 per cent.

Early ripening and development of fruitcolour

- Many seeds have natural dormancy which can be got over by dipping the seeds in auxins.
- Soaking seeds of french beans and peas in 10-20ppm solution of GA for 12 hours before sowing, significantly improves the yield and quality.
- Dipping **sweet potatoes in 5ppm GA solution for 5 minutes** before sowing increases sprouting and yield of potatoes.
- Application of ethrel at the tapping panel increases the **flow of latex in rubber**

Prevention of sprouting

- In potatoes and onions, after harvest, in storage, the buds start sprouting which makes them unfit for cooking.
- Spraying of **malic hydrazide (MH) solution before storing prevents sprouting** and these can be stored safely for 6 months.

Control of weeds

- The conventional method of controlling the weeds is to remove them by uprooting manually.
- Successful control of weeds is obtained by spraying 2,4-D in many crops.

11. Flowering, Pollination and Fruit Set in Horticultural Crops

- Pollination refers to **transfer of pollen grains from anther to stigmatic surface**.
- It is of two types viz., self-pollination and cross-pollination.
- If the transfer is from stamen to stigma of the same flower or to the stigma of another flower on the same plant or to the stigma of a flower on any plant of the same clonal variety, then this type of pollination is known as '**self-pollination'**.
- If it is effected without the aid of any outside agency, such as wind or insect, then this process is known as **'autogamy'**
- If the pollen is to be transferred to the flower of another individual or in the case of homological varieties, to the flower of another variety, this process in known as **'cross- pollination'**.

Cross-pollination may be required for a number of reasons in Horticultural crops.

- ✓ Due to the **dioeciously nature** (eg. Papaya, Datepalm, Nutmeg) or monoecious nature (Cucurbits)
- ✓ Due to the **peculiar flower structure**, (eg. Brinjal, Delicious apples, Vanilla)
- ✓ Due to the **dichogamy nature** (Onion, Carrot, Sapota)
- ✓ Due to the **behaviour of bisexual flowers as functionally unisexual** (eg. Avocado and Allspice)
- ✓ Due to **self-incompatibility or self-sterility** factors (eg. Apple).

- The pollen may be transferred from the anther to the stigma in a variety of ways. In most plants, pollen is shed at or after anthesis and is transferred to the stigmas by insects or by mechanical means primarily the wind.
- In majority of the horticultural crops, pollination is effected by insects and pollination by wind is not a common one.
- Fruit crops like sapota, jack and amla and nutcrops like walnut, chestnut and pecans are reported to be **pollinated by winds**.
- They normally produce large quantity of pollen grams which are light in weight so that they can be carried to distance places. In these nutcrops, the stigma is also feathery to facilitate wind pollination.
- **Honey bees,** ants and many insects aid in cross-pollination. Their activity is greatly affected by weather conditions especially low temperature and rain which sharply curtail their activity. Hence, honey bee keeping is important.

- In apple orchards, each honey bee usually forages 2-3 trees and visits 50-100 flowers per trip. Thus in a day, it visits about 50000 flowers. Hence, 10-12 colonies per hectare at. a distance of 150 meter are ideal for temperate fruit orchards.
- Recently, a chemical substance (proprietary product Name: Bee-Q) is used to attract the bees so as to increase the fruit set. It has been estimated that nearly double the number of flowers are pollinated in cardamom if such chemical is used at the time of early and mid-flowering phases.

Artificial pollination

- Self-incompatibility is common in apple and pear. This has been recently overcome with the 'recognition' or 'mentor pollen' technique.
- In this technique, pollination is effected with a 2:1 mixture of Methanol killed or irradiated compatible pollen and self-pollens which results in seed set.
- It is believed that the regualtory sub stance from the mentor pollen to the in compatible/incongruent pollen helps to overcome the crossing barriers.
- Another technique viz, `**pioneer pollen'** is also reported to increase the seed set in such fruit crops.
- In this method, pollination twice with compatible pollen with an interval of 1-2 days is done. It appears that the first applied pollens promote the activities of the pollens in the second application, hence the first applied pollen is called **'pioneer pollen'**.
- In emergent situations, when adverse weather conditions prevail or the orchard has inadequate pollinizers, hand pollination can be resorted to.
- This is much helpful in temperate fruit orchards and is being practiced in European countries and not yet in India.

The following are some of the methods by which artificial pollination is done.

- ✓ Artificially collecting the pollens, mixing it with spores of ***Lycopodium*** (fern) and applying to flowers *w*ith a soft brush.
- ✓ **Placement of bouquets** - in this method, branches of flowers of pollinizers are hung in the trees to be pollinated.

Fruit set

- In an orchard, all the fruit trees do not bear equally or regularly. Sometimes one fails to bear and at the same time, another tree of the kind under similar conditions produces a heavy crop.
- This problem may be due to failure to set the fruits, unfruitfulness and sterility.

- The following terminologies are useful in understanding the problem of unfruitfulness.
- Fruit setting refers to the initial setting of fruit at or just after the time of blossoming and to its remaining on the plant until maturity.
- A plant is said to be fruitful which not only blossoms and sets fruit but carries it through to maturity. Plants which are unable to do this are also known as **'unfruitful'** or **'barren'**.
- **Fertility'** on the other hand refers to the ability of the plant not only to set and mature fruits but to develop viable seeds.
- Inability of a plant to do this is known as **'infertility'** or ***'*sterility'.**
- Fertile plants are necessarily he fruitful and all the fruitful plants need not be **'f*e*rtil*e*'.**
- **'Self fruitfulness**" indicates the ability of the plant to mature fruit without the aid of pollen from some other flower (or) plant and those plants are. known as **'self fruitful plants'**
- In **Ber**, Fruit set can be increased by the application of **GA_3 @ 20 ppm**

12. Bearing Habits of Horticultural Crops

Bearing habits

- **Fruit trees** may bear fruits either terminally on a long or short growth, laterally on current or past season growth or adventitiously from any point of the trunk.
- The relative position of a fruit with reference to its potential bud giving rise to flower or inflorescence in the shoot is often known as bearing habit.
- A knowledge on the baring habit is a pre-requisite before resorting to pruning in any fruit crop.
- The position of flower or inflorescence on the shoot in relation to the growth of current season is characteristic of a species or variety.
- Position of fruit bunds bears a relationship with the growth habit and the trees are rather compact when compared to plants having lateral fruit bud bearing habit since they force the development of laterals below rather than beyond the flowers or flower clusters.

Different kinds of flower bearing shoots

Based on the position of fruit bud and the kind of flower bearing shoots they produce, fruit trees can be classified into the following groups.

Group 1 : Fruit buds borne **terminally** which unfold to produce inflorescence without leaves **e.g. Mango**.

Group 2 : Fruit buds borne **terminally** which unfold to produce leafy shoots that terminate in flower clusters **e.g. apples.**

Group 3 : Fruit buds borne **terminally** unfolding to produce leafy shoots with flowers or flower clusters in the leaf axils **e.g. guava.**

Group 4 : Fruit buds borne **laterally** unfolding to produce flower parts only without any leaves **e.g. citrus, coconut, papaya, coffee**.

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

Group 6 : Fruit buds borne **laterally** unfolding to produce leafy shoots with flower clusters in the leaf axils, e.g**. avocado.**

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

Group 8 : Fruit buds always borne **adventitiously** in old trunk or shoots. E.g., **jack, cocoa, Indian star gooseberry** (Cauliflorus bearing)

FRUIT DROP – CAUSES AND PREVENTION

Fruit drop

- ❖ Fruit trees usually bear a large number of flowers and only a small percentage of which are enough to give a normal yield.
- ❖ For instance, a single inflorescence of mango contains as many as 5000 flowers and an average of 5 fruits per inflorescence would provide a good and heavy crop, however, the actual percentage of fruit set will be much lesser.
- ❖ When the fruit set is much more that the tree can normally carry to maturity, there will be drop of fruits at various stage of fruit development as an adjustment by the tree to its resources.

First drop

- ✓ It occurs a **fortnight later than the first drop**.
- ✓ Usually flowers with **aborted pistils drop off** at this stage.
- ✓ **Lack of pollination**, low stigmatic receptivity, defective flowers, poor pollen transference and occurrence of incompatibility are some of the causes attributed for this drop.

Second drop

- ✓ It occurs a **fortnight later than the first drop**.
- ✓ This drop includes unfertilized flowers and some fertilized flowers.
- ✓ Fertilized flowers also drop off at this stage as a result of adjustment in the trees between nutritional factors and fruit set.

Third drop

- ✓ This drop occurs when the fruits are of '**marble size'** due to the formation of abscission layers in the young fruit stalks.
- ✓ This drop generally occurs in most deciduous fruit and as it coincides with the **month of June**, this drop is also known as '**June drop'.**

Pre-harvest drop

- ✓ Another kind of fruit drop which is a loss to the grower is referred as 'pre-harvest' drop.
- ✓ In this case, dropping or shedding of fruits occurs before harvest.
- ✓ At this stage, half-developed and three-fourth developed fruits are shed due to many causes.
- ✓ This is a loss to a growers and is a serious problem confronted by them especially in apples, pear mango and citrus fruits
- ➢ The pre-harvest drop of pome fruits can be reduced by spraying – **NAA**
- ➢ Pre harvest fruit drop in **apple** can be prevented by spraying of – **NAA @ 10ppm**

Causes of fruit drop

- Mechanical – Wind and hailstorm cause fruit drop
- **Climatic factors** – Climatic factors such as high temperature, low humidity and very low temperature hasten the formation of abscission layers and consequently the fruits drop. It has been observed in South India that shedding of fruits in mango will be more if the temperature is high and humidity is low
- **Physiological factors** – Abnormal fluctuations of soil moisture favour heavy fruit drop
- Nutritional – Lack of available nitrogen and other nutritional factors may causes fruit drop. The shed is more in weak shoots than in strong ones and also more in young trees than in medium or old trees.
- **Cultural practices** – Deep digging or deep ploughing during the fruit development phase will injure the roots and cause the fruit to be shed. Drought or lack or irrigation especially in mango during the third drop stage increases the dropping percent.
- **Pathological causes** – Incidence of pests and diseases will cause more shedding of fruits. For instance, high incidence of diseases like powdery mildew and anthracnose and pests like hopper and mealy bugs in mango favour more fruit drop
- **Varietal factor** – Within a kind of fruit, the varieties differ among themselves in the extent of fruit drop. In one study, it has been found that under similar conditions, the extent of shed varied form **0.9% in Willard variety to 32.5% Jahangir** variety of mango

Prevention

- The pre-harvest drop may be reduced by controlling the causes to a certain extent.
- Proper and timely culture such as irrigation and manuring.
- Plant protection, provision of pollinizers and wind breaks will help to prevent or reduce the amount of fruit drop
- A define relationship between the auxin content and the abscission of fruits during various stages of development has been established is apple fruits.
- In the final stages of fruit growth, a rapid decline in auxin content is correlated to degeneration of endosperm causing pre-harvest fruit drop.
- The possibility of reducing the pre-harvest drop by means of plant regulator sprays has been well established in many fruit crops.
- **Naphthalene Acetic acid** and its related compounds are very effective in reducing the drop of fruits in pome fruits such as apple and pears.

12. Pre-harvest Operations for Horticultural Crops

- The quality of a crop at harvest can have a major effect on its post-harvest life. There are numerous factors involved and these frequently interact.
- Giving complex inter relationships. In tree crops, fruit produced on the same tree and harvested at the same time may behave differently.
- The factors which influence quality include obvious things such as harvest maturity and cultivar or variety, but also the climate and soil in which it was grown, chemicals which have been applied to the crop, and its water status.

Temperature

- The temperature in which a crop is grown can affect its quality and post-harvest life.
- For eg. **Oranges** grown in the tropics tend to have a higher sugar and total solids content than those grown in the subtropics.
- However, tropical-grown oranges tend to be less orange in colour and peel less easily.

Nutritional status of crop at harvest

- ✓ Excess of deficiency of certain elements from the crop can affect its quality and its post-harvest life.
- ✓ Crops which contain high levels of nitrogen have poorer keeping qualities that the same variety of crop with lowers levels.
- ✓ High rate of nitrogen fertilizer to apple trees can adversely affect the flavour of the fruit.
- ✓ Nitrogen fertilizer increase their susceptibility to physiological disorders and decrease fruit colour.
- ✓ Eg. **Apples called 'bitter pit'**. It is principally associated with calcium deficiency and influenced also by the dynamic balance of minerals in different parts of the fruit, as well as the storage temperature and levels of oxygen and carbon dioxide in the store.
- ✓ **Strawberries are called 'albinism'**
- ✓ The ratio of K : Ca and N : Ca was found to be greater in such fruit than in red fruit.
- ✓ Imbalance of fertilizers can result in the physiological disorder of watermelon called blossom end rot.

Flowering

- ✓ A physiological disorder of mangoes called '**jelly-seed'** can develop during storage, **Tommy atkins** is associated with flowering time delaying flowering by removing all the inflorescences

from the tree greatly reduced jelly- seed in fruit which develops from the subsequent flowering.

- ✓ These fruits were larger than those produces from trees where the inflorescences had not been removed but the number of fruit per tree was reduced.

Light

- ✓ Fruits on the parts of trees which are constantly exposed to sun may be of different quality and have different post-harvest characteristics from those on the shady side of the tree or those shaded by leaves.
- ✓ **Citrus and mango fruits** produced in full sun generally had a thinner skin, a lower average weight, lower juice content and a lower level of acidity but higher total and soluble solids content.

Day length

- ✓ This is related to number of hours of light in each 24 hour cycle.
- ✓ Certain crop species and varieties have evolved or been bred to require certain day lengths in which to mature.
- ✓ If this requirement is not met then the crop may still be immature at harvest. Eg. **Onion**

Water relations

- ❖ Crops which have higher moisture content generally have poorer storage characteristics. Some varieties of crop naturally have high moisture content.
- ❖ eg. Hybrid onion cultivars-a high yield of bulbs with a low dry matter content and very short storage life.
- ❖ If bananas are allowed to mature fully before harvest and harvesting is shortly after rainfall or irrigation the fruit can easily split during handling operations, allowing microorganisms infection and post-harvest rotting.
- ❖ The incidence of damage in carrots – heavy irrigation during the first 90 days after drilling resulted in up to 20% growth splitting, while minimal irrigation for the first 120 days followed by heavy irrigation resulted in virtually split-free carrot with a better skin colour.
- ❖ In leaf vegetables too much rain or irrigation can result in the leaves becoming more hard and brittle.
- ❖ Susceptible to damage and decay during handling and transport.

Chemical treatment

- Besides fertilizers, which are applied to the soil and sometimes to the growing crop. Chemicals are applied for other purposes.
- The control of pests and diseases in commonly achieved by spraying chemicals directly onto the crop.
- These chemicals, particularly fungicides, can have a considerable effect on the post-harvest life of the crop.
- Generally, if a fruit has suffered an infection during development, its storage or marketable life may be adversely affected.
- **Bananas** which suffer a severe infection with diseases such as leaf spot may ripen prematurely or abnormally after harvest.
- Chemicals may also be applied to certain crops in the field to prevent then sprouting during storage and thus to extend their storage period.
- Growth regulating chemicals have been applied to trees to increase fruit quality and yield. Daminozide applied to **Cox's Orange Pippin apples at 2500 ppm** in late June and mid-August caused more red colour in the skin and firmer apples than unsprayed fruits.

Pre-harvest infection or infestation

- Frequently crops are infected with microorganisms or infested with invertebrate pests during production.
- Field infestation of yam tubers with parasitic nematodes was shown to increase when the tubers were stored in tropical ambient conditions, resulting in areas of necrotic tissue.
- However, when the tubers were **stored at 13^{o}C,** there was no increase in nematode population and no increase in necrosis.
- The potato tuber moth may infest tubers during growth if they are exposed above the soil.
- **Mealy bugs on pineapples** occur in the marketing chain from field infestation.

Pre-harvest fungicidal sprays for post-harvest disease control

- Many post-harvest diseases of fresh fruits and vegetables begin during production.
- The time between infection and the symptoms of the disease developing may be lengthy, for example **anthracnose (*Colletotrichium musae*)** in bananas can take over 5 months.
- Fungal and bacterial infections can occur through mechanical injuries and cut surfaces of the crop, growth cracks or pest or disease damage.
- They also occur through natural openings in the surface tissue of the crop, such as stomata, lenticels and hydrathodes. Eg. **Mangoes – anthracnose diseases**

- Preharvest sprays with chemical fungicides have been shown to reduce post-harvest disease but the effects have not always been consistent.
- In UK, single sprays of apples with 0.025% benomyl in June, July or August controlled rots caused by infection with *Gloeosprorium spp*. which developed in subsequent storage from September onwards at 3.3^{o}C in unsprayed fruit.
- The control of anthracnose in papaya also caused by *C. gloeosporiodes*, was achieved by pre-harvest sprays copper oxychloride 50% wettable powder at 400 g 100 litres^{-1} water applied at 7-10 day intervals.

MATURITY INDICES – HARVESTING – HANDLING OF HORTICULTURAL CROPS

- ✓ Climacteric fruits
- ✓ Non-Climacteric fruits

Methods to determine the proper time to pick the fruits

1. Maturity tests

Following are the rough but ready maturity tests of fruits employed to pick the well matured fruits

- **Colour changes**
  - ✓ The changing of colour is one of the criteria to judge the maturity of fruits.
  - ✓ The **change of peel colour** from green to yellow is the main criterion to test maturity in mangoes.
  - ✓ Similarly in **papaya changes of colour at apical end of the fruit indicates** the full maturity stage.
  - ✓ In the case of **pineapples nearly 25% of the fruit surface** should have turned to yellow colour.
- Increasing in size
- Softening of the tissue of the fruits eg. **Figs and Grapes**
- Ease of detachment from the stalk. eg. **Sapota and Annona**
- Shrivelling of fruit stalk eg. **Watermelon**
- Time elapsed from the date of flowering to picking maturity.
- **Sound by tapping:** Jack and watermelon when ripe produce hollow and dull sound on tapping but produce metallic sound if unripe
  - ✓ Drying of foliage or top
  - ✓ Flowering/Bolting can generally include be taken as maturity indices

2. Accurate tests

- **Colour charts**
  - ✓ Charts are prepared for indicating colour on different stages of maturity.
  - ✓ By referring to this ready chart, one can easily judge the correct stage of maturity.
- **Penetrometer**
  - ✓ It is an installment which indicates or measures the softening of tissues as an index of maturity.
  - ✓ It chiefly helps in determining when fruits are too soft and ripe to storage rather than when picking should begin.
  - ✓ **Firmness of the flesh** can be assessed by removing a thin slice of the skin and flesh with a knife and using a special hand operated tester which records the kilogram of pressure for the plunger to penetrate the flesh.
- **Sugar/acid or Brix/acid ratio**
  - ✓ This is based on the principle that acid content reduces and sugar increases on ripening.

Tomato: The maturity standards of tomato are grouped as follows.

- ✓ **Immature:** Before seeds have fully developed and jelly like substance surrounding the seeds have formed. Fruits are not suitable for consumption
- ✓ **Mature green:** Fully mature, light green at bloom end and yellowish green in all other areas. Seeds are surrounded by jelly like substance, filling the seed cavity. This kind of fruits are artificially ripened and become suitable for long distance market.
- ✓ **Pink**: 3/4th surface shows pink colour
- ✓ **Hard ripe**: Nearly all the areas are red or pink but flesh is firm
- ✓ **Over ripe**: fully red coloured and soft
- ✓ This is suitable for processing as it possesses good quality and colour development

Onion:

- ✓ Bulbs are considered mature when the **neck tissue begin to soften** and tops are about to abscise and decolorize.

Okra:

- ✓ Development of **crude fibre** is used to determine the optimum stage of maturity

French beans:

- ✓ Seed size, percent seed, dry matter content, distribution of seeds are some of the reliable maturity indices.

- ✓ Tender and fleshy pods can be harvested for vegetable purpose.

Peas:

- ✓ In peas, pod colour changes from dark green to light green with well filled grains/seeds at full maturity

Tapioca:

- ✓ In tapioca, maturity is indicated by the cracks formed in the soil, yellowing and falling leaves.

Sweet potato:

- ✓ When the leaves turn yellow and begin to shed, tubers can be harvested.
- ✓ The tubers can also be cut and judged.
- ✓ In immature tuber, cut surface show dark greenish colour while the colour will be milky white in fully mature tubers.

Dioscorea and amorphophallus:

- ✓ In these crops, maturity is indicated by yellowing, drying and then dropping of leaves.

Brinjal and cucumber:

- ✓ Tenderness is the main structure is the indication of maturity for harvesting.

Musk melon:

- ✓ Development of net like structure is the indication of maturity for harvesting

Chillies:

- ✓ Development of uniform red colour is treated as maturity index.

II Harvesting

- ❖ Harvesting of vegetables at optimal maturity and careful handling constitute the very key to their successful long storage life.
- ❖ Harvesting is done in two way viz., by hand, with or without mechanical aids or gadgets and mechanical harvesting.
- ❖ In India, most the vegetables are harvested manually.

Root crops:

- ✓ Beet root, Carrot, Radish, Turnip and tubers like Potato, Tapioca and Sweet potato are easily harvested by digging into the soil below the roots or tubers.
- ✓ Then it is levered upwards so as to loosen the soil and to reduce the possibility of mechanical damage.
- ✓ In Punjab, tractor drawn potato diggers are used for harvesting potato.

Leaf vegetables:

- ✓ In spinach and methi, the lateral buds and they snapped off by hand.

Cabbage, cauliflower, knolkhol and lettuce:

- ✓ Here, the main stem is cut off with a sharp knife.

Bulbous crops:

- ✓ Green onions and leeks can be easily pulled out by hand from the moist soil whereas for harvesting of fully mature onions and garlic bulbs, soil is loosened first with a fork or how.
- ✓ Simple tractor drawn implements are also available for loosening the soil in onion and garlic like crops. Onion could be harvested.
- ✓ Harvesting of immature bulbs cause **shriveling and rotting**.
- ✓ **Delay in harvest cause splitting and bolting**

Tomato:

- ✓ Harvesting the **fruits at breaker stage** is recommended for long shelf life and optimum quality.
- ✓ Harvesting during evening hours in summer keeps the fruit firm and uniform ripening is affected.

Okra:

- ✓ Immature, green, tender fruits should be picked from **3rd -5th day** of first pod formation.

Brinjal:

- ✓ Brinjal is harvested at tender stage ie. 15-20 days after fruit-set when the seeds are immature.

The fruit growers should bestow more attention and considerable care during the picking **season to reduce to a minimum level of careless handling of fruits by pickers**

- ❖ Picking must be commenced from the lower branches of tree advancing towards the top in order to reduce dropping of fruits to the minimum
- ❖ As far as possible, dropping of fruits from the tree should be avoided to avoid any possible physical damage.
- ❖ During picking, care must be taken to avoid any possible damages to the branches especially to the spurs as the subsequent cropping depends upon them
- ❖ Picking early in the morning is always best. Picked fruits should be kept in shade and excluded from sun. After picking, the fruits must be kept in the coolest place available which is well ventilated to arrest respiration and break down as much as possible
- ❖ There should not be any bruises in the fruits while picking as it will lower the marketable quality
- ❖ If picking is done in mid-day or hot weather, fruits should be kept in a shed overnight to cool.

Handling

- Handling includes all process from picking to deliver or disposal at the consumer point.
- This includes the treatments given for getting the fruits ready for the market viz., **packaging and wrapping, ripening and storage.**
- One of the important treatment is the dipping the fruit in antiseptic solutions like **1-2%caustic soda to remove the dust** and infestation of scale insects and washing with **1-15% of Hydrochloric acid** to remove any spray residue and to improve the appearance.

Pre-cooling:

- It refers to the rapid removal of the field heat from the freshly harvested fruits and vegetables in order to sow ripening and reduces deterioration prior to storage and shipments.
- Different methods are adopted to precool the fruits, the important ones are
  - ✓ **Air cooling** in which the fruits and vegetables in a cold room
  - ✓ **Hydro cooling**: dipping of the fruits in cold water or by spraying cold water on the fruits
  - ✓ **Vacuum cooling**: a costlier technique in which the atmospheric pressure is reduced so as to reduce the pressure of water vapour in chamber which results in evaporation of water from fruits which bring down the temperature.
  - ✓ Vacuum cooling about **1% weight loss in the produce.**

Grading

- Grades or grading refers to the assortment of the fruits into different groups based on certain characters.
- This includes colour, condition to firmness and soundness and free form blemishes and also size of the fruit.
- Grading is a good market practice which improves the mutual confidence of salesman and consumer

Agriculture prescribes the following grades to apples in the USA

1. US Extra fancy
2. US Fancy
3. US No.1
4. US commercial

In India, grading of fruits like apple plum, pear and **mango varieties like alphonso, rumani, bangalora** and **sathugudi is done by AGMARK** mainly based on size only.

Wrapping

- Covering the fruits after harvest with any material in order to improve its post-harvest life is known as wrapping.
- The materials commonly employed as wrappers are tissue papers, waxed paper, pliofilm, cellophane paper, aluminiumfoils and alkathene paper etc.
- Wrapping has the following advantages.
    - ✓ It minimizes the loss of moisture in shriveling
    - ✓ It protects against the spread of diseases from one to the other
    - ✓ It reduces bruises.
    - ✓ It reduces damage during transport or in storage and
    - ✓ Itmakes the fruit more attractive
- Care must be taken to see the wrap is not too impervious to the passage of oxygen and carbon-di-oxide.
- **Pre-packing of banana** fruits is done in **100 gauge polythene bags** under room temperature and cold storage.

Waxing

- Another treatment given to the fruits during handling is waxing.
- Waxing of fruits helps in reducing the moisture loss, improving the appearance of fruits and reduces the incidence of storage diseases.
- **Wax emulsion** is prepared by **melting microcrystalline paraffin or carnauba wax** along with emulsifiers.
- Boiling water free from hardness is slowly added to the molten ingredients and thoroughly stirred in order to make a stable emulsion.
- The harvested fruits are dipped in dilute wax emulsion for a minute and then these are completely dried for 10-15 minutes.

Packaging and packing:

- The term packaging encompasses both the direct or primary packaging around the product and the secondary and tertiary packaging, the over packaging such as over warts, cartons and crates etc.
- Proper packaging is essential otherwise the spoilage of fruits and vegetable are more in our country.
- A packaging material should be sturdy and it should protect the fruits in transport, more specifically it must be economical.

- The materials that are generally used in India for construction of a package of fruits and vegetables are bamboo, wood, gunny bags, plastic, films, fibre and plastic corrugated boards etc.
- **Bamboo baskets and wooden crates** of different shapes and sizes are used for a number of perishable commodities.
- **Mud pots, gunny bags and palmyrah mats** are also used for a variety of purposes.
- **Bamboo baskets** are though relatively cheaper, they have many disadvantages like the low dimensional stability and inability to withstand stacking load they are not strong enough to withstand rough handling.
- **Packaging of grapes in mud pots** is quite common in south India. It is often observed that during transport, the mud pots break and the contents get damaged.
- Though the mud pot has its own advantages as a container for grapes and such other fruits, it has to be handled very carefully thus affecting the speed of handling.
- In some cases like **mango, pine apple, banana** etc. A straight load is practiced in certain regions.
- For example, banana in bunches are loaded without any packaging into the railway wagons or trucks and transported from Maharashtra to Delhi. S
- imilarly, mangoes are transported from South to North and pineapples are shipped form North East India and Kerala to different regions.
- In these cases, it has been observed that the losses due to spoilage are considerable.

Cushioning materials

The cushioning materials used for packaging fruits and vegetables are dry grasses, paddy straw, leaves saw dust, paper shavings etc.