HOR.111 Fundamentals of Horticulture (1 + 1)

Theory

The term Horticulture first appeared in the writings of 17th century. The word is derived from the Latin word '**Hortus**' meaning garden an **cultura** meaning 'cultivation'. According to the modern world, horticulture is defined as the crop science which deals with the production, utilization and improvement of fruits, vegetables, ornamental plants, spices and plantation crops, medicinal and aromatic plants. Horticultural science can be distinguished from agricultural or forestry science in one or more of the following factors

- Horticulture produces are utilized in the fresh state and are highly perishable. In contrast, agricultural field crops are often utilized in the dried state of are usually high in dry matter content.
- Horticultural crops generally require intensive cultivation warranting a large input, capital, labor and technology per unit area of land.
- Cultural operations such as propagation, fertilization, training pruning, harvesting and marketing are skilled operations and are specific to each and every horticulture crops.
- Horticulture crops are rich in sources of vitamins and minerals where as agricultural crops are generally rich in carbohydrates or protein.
- Aesthetic sense is an exclusive phenomenon for horticulture science.

Divisions of Horticulture

1.Pomology

Pomology is the study of fruit crops and science.
Woody Plants Evergreen – Acid lime, Litchi, Mango
Decid – Apple, pear
Herbaceous perennial – Strawberry, Banana, Pineapple

2. Olericulture

Olericulture is the branch of horticulture which deals on Vegetables like leafy vegetables, root, tuber, cole crops etc.

3. Floriculture

Floriculture is another branch of horticulture which deals on commercial Floriculture, landscaping and cut flowers.
Arboriculture: Growing of trees for aesthetic/scientific/educational purpose
Landscape gardening
Ornamental floriculture
Indoor garden and Outdoor garden

4. **Spices, Plantation, Medicinal and Aromatic crops**

Spices – used for food flavoring to aroma and flavour pepper, cardamom, clove, nutmeg
Condiments – plants used to add taste only (coriander, cumin)
Plantation crops – Arecanut, Tea, Coffee, Rubber, grown extensive area
Medicinal plants – Senna, periwinkle, Aswagandha
Aroma crops – Eucalyptus, Palmarosa, Citronella

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.

Fruits and Vegetables

i 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.

ii 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 (Vit A) 1.2-2.0 mg thiamine, 1-2.2 mg riboflavin, 16-26 mg nicotinic acid, 50mg ascorbic acid.

iii 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.

iv But the per capital availability works to 30g fruits 92 g vegetables only.

AREA AND PRODUCTION, IMPORTS AND EXPORTS OF HORTICULTURAL CROPS TAMIL NADU (1996-97)

FRUIT CROPS

MAJOR DISTRICTS	CROPS	AREA (HA)	PRODUCTION (Ton)	PRODUCTIVITY
DPI, Vellore, MDU, Theni, DGL.	Mango	85,009	4,13,900	4.87
CBE, Erode, Tuti, NV, TVM, Vellore	Banana	79,314	31,17,780	39.31
MDU, DGL	Guava	8,269	95,040	11.49
DGL, TNV	Lime	6,693	10,450	1.56
Salem, Namakal, DGL	Orange	3,376	18,240	5.40
K.K.D.DGL, CUD	Jack	2,547	75,440	29.62
CBE, DPI, Theni, TNV, DGL	Grapes	2,209	47,420	21.47
DGL	Pear	1,411	29,631	21.00
DGL, Namakkal	Pine apple	471	10,570	22.44
TOTAL		1,94,987	38,55,827	19.77

VEGETABLES – TAMIL NADU (1997-98)

	AREA (HA)	PRODUCTION (Te)	PRODUCTIVITY (M.To./ha)
Tapioca	85,240	29,83,400	35.00
Tomato	25,120	3,76,800	15.00
Onion	25,230	4,54,140	18.00
Brinjal	8,120	1,62,400	20.00
Ladies finger	4,750	47,500	10.00
Potato	4,675	1,02,850	22.00
Carrot	4,475	89,500	20.00
Greens	2,300	34,500	15.00
Beans	1,700	13,600	8.00
Sweet potato	1,250	31,250	25.00
Yam	1,370	34,250	25.00
Cabbage	1,750	1,83,750	105.00
Beet root	1,100	25,300	23.00
Pumpkin	610	13,420	22.00
Other veg.	8,850	2,38,950	27.00
TOTAL	**1,76,540**	**47,91,610**	**27.14**

SPICES AND CONDIMENTS

Sl. No.	Particulars	AREA (HA)	PRODUCTION (Te)	PRODUCTIVITY (M.Te./ha)
1.	Chillies	80,240	56,168	0.70
2.	Coriander	38,850	15,540	0.40
3.	Tamarind	18,900	66,150	3.50
4.	Turmeric	16,850	1,01,100	6.00
5.	Cardamom	5,520	519	0.09
6.	Pepper	3,550	1,065	0.30
7.	Garlic	1,260	7,560	6.00
8.	Clove	700	700	1.00
9.	Ginger	600	15,000	25.00
10.	Other spices	1,350	2,700	2.00
	Total	**1,67,820**	**2,66,502**	**1.59**

PLANTATION CROPS

Sl. No.	Particulars	AREA (HA)	PRODUCTION (Te)	PRODUCTIVITY (M.Te./ha)
1.	Cashew	84,200	37,890	0.45
2.	Tea	63,400	5,07,200	8.00
3.	Coffee	32,400	19,440	0.60
4.	Betelvine	3,380	76,050	22.50
5.	Arecanut	2,650	4,505	1.70
	Total	**1,86,030**	**6,45,085**	**3.67**
	Flower crops	**16,745**	**1,42,333**	**8.50**

ABSTRACT

Particulars	AREA (HA)	PRODUCTION (Te)	PRODUCTIVITY (M.Te./ha)
Fruits	2,06,850	50,05,940	24.201
Vegetables	1,76,540	47,91,610	27.142
Spices & condiments	1,67,820	2,66,502	1.588
Plantation crops	1,86,030	6,45,085	3.468
Flowers	16,745	1,42,333	8.500
Total	**7,53,985**	**1,08,51,470**	**14.392**

SPECIAL FEATURES OF HORTICULTURAL CROPS GROWN IN INDIA

Horticultural crops

1. Utilised in fresh state - Highly perishable
2. Require intensive cultivation - Input, capital, labour, technology per unit area
3. Practices like propagation, fertilization, training, pruning, harvesting & marketing - Skilled & specific to hort crops
4. Rich sources of vit.B & minerals - Field crops are rich in CHO & proteins
5. Aesthetic sense - Exclusive to horticulture
6. Horticulture therapy: a recent science fast developing western countries.

EXPORT

Fresh banana
1994-95

Quantity - 966.08 MTs.
Value - 89.56 lakhs rupees
Chief importing countries - Nepal, Netherland, Qatar, Russia

Guava Export (Fresh (or) dried)
1994-95

Quantity	-	16,813.40 MTs.
Value	-	4048.98 lakh Rs.
Importers	-	Bangaladesh, Hong Kong, Kuwait, Netherlands, UAE, UK, Saudi

Dried Grapes
1994-95

Quantity	-	63.55 MTs.
Value	-	35.81 lakh Rs.

Fresh Mangoes
1994-95

Quantity	-	25,414.36 MTs
Value	-	4,502.73 lakh Rs.
Importers	-	UAE, Bangladesh, Saudi, UK, Kuwait

Mango Pulp
1994-95

Quantity	-	34,460 MTs.
Value	-	80.71 Crore Rs.

Mango slices
1994-95

Quantity	-	1,095.95 MTs.
Value	-	227.52 lakh Rs.

Mango Juice
1994-95

Quantity	-	793.96 MTs.
Value	-	198.75 lakh Rs.

Mango Pickles & Chutneys
1994-95

Quantity	-	7,935.28 MTs.
Value	-	2323.66 lakh Rs.

Papaya-Fresh
1994-95

Quantity	-	320.87 MTs.
Value	-	44.90 lakh Rs.

CLIMATIC ZONES OF INDIA FOR HORT.CROP PRODUCTION

Advantages of classification

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

1. **Temperate Northern region**

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

2. **North Western arid region**

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

3. **North Easter sub-tropical-humid region**

    Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland & Tripura
    Crops: Banana, P.Apple, Citrus, Jack fruit, Tea & Cardmom

4. **North Central sub-tropical region**

    Parts of U.P., Bihar, entire M.P., and part of Maharastra
    Crops: Mango, sapota, sweet oranges & guava.

5. **South Central tropical region**

    Western & easter ghats of T.N., A.P., Karnatak & part of Maharashtra
    Crops: Mango, guava, sapota, P.Apple, turmeric

6. **Coastal tropical humid region**

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

7. **Southern hilly zone**

    Western & Eastern ghat above 800 M MSL.
    Crops: Coffee, Tea, cardamom, pepper, oranges, P.apple

AGROCLIMATIC ZONES OF TAMIL NADU

1. **Geographic location**

    Southern most, 8, ^{o}5’ and 13^{o} 10 North Lat. & 76^{o} 15’ and 80^{o} 20^{o}’ East. A coastal line of about 1000km in east & south.

2. **Physical characters**

    a Coastal plaints, b.Eastern ghats, c.Central plains and d.Western ghats.

3. **Climate**

    Semi-arid (Thorthwaite and Mather)

4. **Rainfall**

    Mean – 937 mm.
    Seasons – Winter, Summer, South west and north east.
    Variation exists between regions

5. **Temperature**

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

Questions

1. Mention the major disciplines of horticulture
2. What are different agro climatic zone sin India and Tamil Nadu
3. Mention the nutritional uses of fruit and vegetable crops

FACTORS LIMITING HORTICULTURAL CROP PRODUCTION

I	**Biotic**	-	a. Diseases b. Pests c. Nematodes d. other microbes e. plant genetic make up
II	**Abiotic**	-	Soil Climate – light, temperature, sunshine, wind speed, rainfall, evaporation Cultural practices Water Inputs – manures & fertilizers, Hormones & other chemicals

I. BIOTIC

a. Diseases

Banana	-	Bunchy top, Panama wilt, sigatoka leaf spot
Grapes	-	misdews, 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 veg.

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

a) Soil
b) Climate
c) Cultural practice
d) Water
e) Inputs-manures & fertilizers, hormones & other chemicals

a) Soil

i) Soil type

a) Sandy soil – coarse, large pore space, poor water & nutrient holding, suits ppgn 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 org.manure. It has better water & nutrient holding capacity
d) Organic soils (High org.matter – 20%)
   Microorganism – enzymatic digestion.
   (organic matter – plant & animal waste)
   Green manure cropping
   found in swamps, bogs, lake bottom & river beds.
   Peet – 50-90% org.matter – High water holding capacity – crops-tuber, root cole crops)

   Muck – 20-50% org.matter – low water holding capacity

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 (mg. sulphate) to acidic soils
- Alkalaine soils –sodicity is dangerous

- Knoledge on soil salinity is important.

Classification of soils based on salinity tolerance.

Tolerant	-	8m.mhos. (eg.-Dates, Guava, Fig, Grapes)
Moderate	-	3-6 m.mhos (Pome, grape fruit, apple, pear & plum)
Sensitive	-	1.5-3 m.mhos (orange, peach, avocado, strawberry)

iv Soil depth

A depth of 2.0 m is essential for fruit crops
No hard & compact subsoil layers like Cankar, 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

b.Climate

i) Temperature

- Specific temperature is recommended 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 – tropical
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. – dessication

ii) Light
  Intensity
  Quality
  Duration
Influences all activities

Photoperiodism – Duration of light and dark hours in a day. It also affects sex of plants
  eg. cucurbits – LD-Male Flowers
    SD-Female Flowers

Coffee, Cardamon, Cocoa	Filtered shade
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
  Quantum
  Distribution

- The requirement varies with crop
- 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-April-Panicle initiation
- Grape-rainy season crop-poor quality

Rainfall

1.	Mango	025 to 250 cm/year
2.	Pepper	125 to 200 cm/year
3.	Cadamon	200 to 250 cm/year
4.	Rubber	200 to 250 cm/year
5.	Dates	015 to 025 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 effected by black tip disorder since they were located 1.5 km from brick kiln.
- CO_2, So_2 and acetylene are responsible

vii) **Frost**

- Thin layer of formation 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 fruitset.

xi) **Altitude**

- Critical factor deciding climate particularly temperature
- For every warm temperature fruits require 1800m.msl. 100m elevation-1oc. To 2oc decrease is noticed
- Humid zone fruits & plantation crops -100-1800m
- Tropical fruits requires <1000m.
- Coconut at 1000-1200m 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.

Questions

1. What are the factors limiting horticultural production
2. How climate influences production of horticultural crops
3. Temperate and arid zone horticulture- Differentiate

Methods of propagation of horticultural crops and their advantages and disadvantages

ASEXUAL PROPAGATION

Asexual propagation is the method of multiplication of a plant from a tissue 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

1. Root cutting – Red raspberry, Bread fruit etc.,
2. Stem cuttings
   a. Hardwood –fig, grape, gooseberry, rose etc.,
   b. Semi hard wood – coleus, geranium, sweet potato etc.,
   c. Softwood-lilac, jasmine etc.,
   d. Herbaceous – coleus, geranium, sweet potato etc.,
3. Leaf cutting
   Begonica, Bryophyllum, Sansevieria etc.,
4. Leaf bud cuttings – eg. Hydrangea

B) Layering

a) Ground layering

1. Tip layering : Black berry
2. Simple layering: Guava, Pomegranate, crotons etc.,
3. Mound layering : Goose berry, apple etc.
4. Compound layering : Grape, Honey suckle etc.,
5. Trench layering : Etiolation method eg. Cherry

b) Air layering (Gootee (or) marcotage) : Litchi, guava, crotons etc.

c) Grafting

1) Root grafting
   a) Whip graft-apple and pear

2) Crown grafting
   a) Whip and tongue graft – Persian walnut, apple
   b) Cleft graft – camellia, plums
   c) Side graft - Narrow leaved evergreen, mango

3) Top grafting
   a) Cleft – various fruit trees
   b) Notch graft
   c) Bark graft
   d) Side graft
   e) Whip and tongue graft

f) Veneer grafting

D) Budding

a) T budding (Shield budding) – Pomefruits, rose, ber etc.
b) Patch budding – Citrus
c) Ring budding – Walnut and pecan
d) Flute budding – Walnut and pecan
e) Chip budding – citrus

E) Tissue culture

F) Other special 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

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 etc.,

6) Crowns – Pineapple

7) Tuberous roots

Plants produce thickened under ground 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 make up (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.in 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 are not seed borne. When propagated vegetatively the virus are carried to the next generation eg. ‘Katte’ disease of cardamom.

Genetic variation in sexual 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, Bougain villeas.

Kinds of Chimeras

1) Sectorial Chimeras	- growing point of the stem is found with two types of tissues. - the leaves & lateral buds are also mutated
2) 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
3) Mericlinal	- similar to periclinal - the outer of mutated cells does not surround fully - it occupies as a segment of the whole part only

Budsport

- Budsport is one where a branch of a tree alone is found with genetic change from the rest of the part
- The characters of budsport are inheritable
- They can be vegetatively propagated
- Eg. Apple – varieties –‘star kind’ and Richa Red ar ebudsports from ‘Delicious apple’

Seed propagation dormancy methods of breaking the dormancy

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

There are 3 factors which are associated with germination of seeds

i. Seed must be viable viz., embryo should alive
ii. Seed should be subjected to favourable environmental condition
iii. 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.

1) **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

1) Nature of seed and its covering
2) 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

2) **Temperature**

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

a) **Low temperature**

Here, seeds will germinate only at relatively low temperature eg. Alpine. For cool season plants, it is 4.5^{o}C and for warm season plants, it is 10-15^o C. These are the lower critical levels. Below these temperature ranges, seeds fail to germinate or chilling injury can occur.

b**) 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 is between 80 ^{o}F (30c) and 104^{o}F (40c). over and above, heat injury will occur.

c) **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^{o}c-35^{o}c

3. **Oxygen**

Seed gets O_2 through respiration. It is a must to produce energy.

Sugar + Oxygen = Carbon dioxide + Water + Energy

$C_6H_{12}O_6 + CO_2 = 6CO_2 + 6\ H_2O + 673$ 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 an 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

4. **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 translocated 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

1. Gibberellins – control of food mobilizing system
2. Cytokinins – Natural endogenous hormones will also control germination through DNA to RNA transcription system
3. 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

a) Hard seed covering, impermeable to moisture. Eg. Leguminoceae, Malvaceae
b) Hard seed covering resistant to embryo expansion eg. Walnut
c) 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 integumental layer. There are three groups in this category.

a**) 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, Kinetine, Potassium nitrate may be used to over come.

b) **Physiologically intermediate dormancy**

Moisture chilling stimulate germination. This is found in conifers and in woody plants. Temperature just above freezing (2 to 7^{o}c) are generally most effective to break dormancy.

c**) 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.

Pre-conditioning of seeds or breaking dormancy

1) 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

2) Acid scarification

Concentrated sulphuric acid is used to modify hard or impermeable seed covering

Dry seeds are placed in glass or earther 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. This may vary from 10 minutes for some sp. to as much as 6 hours for other sp.

At the end of treatment , the acid is poured off and the seeds are washed with copious amount of water.

3) 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 gradullay cooling water for 12 to 24 hours. Following this, unswollen seeds can be separated from the swollen ones.

4. Stratification : (Moist chilling)

Here, seeds are exposed to low temperature. It permits physiological changes to occur in the embry. Temperature range is from 0oc to 10oc. 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 2oc to 7oc. 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.

5. Chemical stimulants

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 12000 ppm. This will improve seed germination.

Cytokinin (Kinetin)

Commercial preparation of kinetin are available. A common synthetic cytokinin is Benzyl Adenine. Seeds are soaked in 100 ppm kinetine 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.

Ethylene

When ethylene was applid 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.

Potassium nitrate

Freshly harvested dormant seeds germinate better after soaking in potassium nitrate solution. Potassium nitrate solution of 0.2% concentration will improve seed germination in Kentucky bluegrass.

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.

Seed invigouration

In most of the species, as the seed ages, it slowly looses the germination capacity due to a number of factors like accumulation of inhibitors etc., These aged seeds when treated with specific chemicals like potassium dihydrogen orthophosphate (KH_2 PO_4) sodium dihydrogen orthophosphate (NaH2 PO4), dipotassium hydrogen phosphate (K_2HPO_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.

APOMIXIS

It is the occurance of an asexual reproductive process in place of normal sexual reproductive process of reduction division and fertilization. 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)

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

Nonrecurrent apomixes

Here embryo arises from the egg nucleus without fertilization. Since the egg is haploid, the resulting embryo will also he haploid. The case is very rare.

Vegetative apomixes

In some cases, vegetative buds or bulbils are produced in the inflorescence in place of flowers eg. Agave and grass species

Polyembryony

The phenomenon in which two or more embryos are present within a single seed is called polyembryony (Nucellar embryony)

Significance of apomixes

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

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 semihard 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 3to6”. 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 (Geranium, Coleus, Alternanthra and Sweet potato) Length of cuttings is 3-5” with leaves

Leaf cuttings

Leaf blade are utilized in starting a new plant. Advantitious roots and an adventitious shoot form at the base of leaf. (eg.) Sansevieria, Begonia & Bryophyllum

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.Lemon, 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

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.

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

Principles and methods of propagation by layering

It is a propagation method by which adventitious roots are caused to form on a stem while it is till 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

a) Air layering or Gootee

b) Ground layering

1) Simple layering
2) Compound layering
3) Mound (Stool) layering

Air layering

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.

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

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 are propagated by this method.

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

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

Initiation of root primordia in herbaceous plants

1. Origin is usually just outside and between the vascular bundles (from cmbium)
2. 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)
3. 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 'understock' 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 is not successful in perpetuating a clone, eg.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-sterile trees
5. For fancy purposes, different types of scion may be grafted in the same plant
6. To modify the growth of the plant as dearf 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.

Questions

1. Mention difference between sexual and asexual propagation
2. What are specialized **plant propagules**

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-varital 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 (*Prunus salicina*) is grafted commercially on peach (*Prunus persica*)
4. **Intergeneric grafting:** when the plants to be grafted together are in different genera but in the same family the chanes of union are more remote. But successful union has been reported in the following cases
   Citrus spp. on trifoliate orange (Poncirus trifoliatat)
   Sathugud (Citrus sinensis) on wood apple (Ferronia elephantum)
   Sapota (Achras sapota) on pala (Manilkara hexandra)

Graft incompatibility

The ability of two different plant 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 an 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. 'Brompton Plus'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 is 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 Bassia longifolia 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 in Table 15.3

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 syceptible 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 cyanogenic glucoside, prunasin, normally found in quince is translocated into the phloem of the pear where it gets broken down in the 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. <u>Size and growth habit</u>: 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 Psidium pumilum 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 troyer citrange, 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 alnutrients 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. Im pome fruits, similarly, ariation exists among rootstocks to resist excess soil moisture or excess boron in the soilyrobolan plum rootstocks

generally tolerate excess boron and moisture than Mananna plum root or other rootstocks viz., peach, apricot or almond.

B.Effect of scion on rootstock

1. Vigous 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 hariness 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: Yound mango rootstock seedlings (6 months to one year old) were found to putforth 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 an 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

a) Temperature has a pronounced effect on the proeducation of callus tissues. An optimum temperature is essential for production of callus tissues. In most of the temperature fruit crops callus production is retarded.

Mist chamber constuction use and maintenance

For successful propagation of plants, plant propagating structure or nursery structure are often used, because certain plants have special requirement for light temperature of humidity for germination of seeds or rooting of cuttings. The outdoor conditions may not be suitable for growing young plants. There are several kinds of plant growing structure, the most important ones are green house, mist units and shade hours.

The greenhouse is mainly used for providing controlled environment either for germination of seeds or rooting in 'difficult to root' plants and also to harden the propagated plants, whereas the shade house is used for hardening of young plants before they are transplanted to a permanent location.

Mist propagating beds are useful propagating units for the rooting of cuttings, especially those, which are difficult to root. Mist beds are constructed usually within the green house. A fine mist is sprayed over the cuttings intermittently usually during the day: During night, it is not necessary.

The lay out of the jest, which form the mist, is very important. All the hades (jest) should be at the same level. They may either be suspended from the roof of the glass-house above the beds or be fixed on stand – pipes attached to the beds. the jets are arranged in such a manner that each corner of the bed received mist spray equally and uniformly. This can be early achieved when sprays of two jest overlap.

There must be continuous supply of water for misting. Installation of a pressure tank and pump ensures consistent pressure for misting. The water for misting should be clean and uncontaminated. In hard-water areas, it is better to use rain water or install water treatment equipments, which remove dissolved salts from the water.

Guidelines for effective functioning of mist chamber

i The rooting medium should be pathogen-free and well drained

ii The water used for misting should not be alkaline in reaction.

iii Hygiene and cleanliness should be maintained inside the mist chamber.

iv The missing interval and time of interval should be decided on the basis of species an variety and avoid misting during night.

v Continuous mist is undesirable and harmful to rooting in several plant species and varieties.

vi The nutrients can also be applied if it is felt necessary.

vii Shade is to be provided against intense sunlight without interrupting sufficient sunlight falling on plants essential for full photosynthetic activity during rooting period.

viii During rooting period, air should not be allowed to stand still inside the mist chamber. Therefore cross ventilation should be provided

ix Keep mist propagation equipments clean and under workable condition and provide centrifugal pump with 1-2 HP motor

x The capacity of the motor is decided based on the size of the mist chamber. Water should be allowed to get filtered before being pumped into the mist chamber.

Pressure tank – It is a thick walled airtight metallic chamber. Water is filled automatically when pressure drops below the limit.

Time clock set (Timer) – It controls the mist spray at regular intervals

Nozzles – there are various types of nozzles. Deflection type of nozzles is best suited to mist chamber of medium size. Prior to installation of mist propagation, selection of site is important. In temperature region, it is essential to select the site which is in the open sun whereas in tropical and subtropical regions, where summer is very hot, the mist house should be installed either nearer to a building or large trees which could provide partial shade. A temporary structure can be made with polythene sheets.

Propagation by specialised plant parts

Certain plants posses specialized vegetative structure whose primary functions are storage of food and vegetative reproduction. If such structures are naturally detachable for propagation, this procedure is termed as 'separation' On the other hand such structure are to be can into sections for ht purpose of propagation, then this process is called as 'division' the following specialized vegetative structure are used in propagation

1. Bulb

A bulb is a specialized under ground organ consisting of a short, fleshy, usually vertical stem axis bearing at its apex a growing point or a flower primondium enclosed by thick flesh scales. The outer bulb scales are generally fleshy and contain reserve food materials whereas the scales towards the inner contain relatively less food materials an dare more leaf-like. Bulbs possessing dry and membranous outer scales are tunicate bulbs and bulbs which lack this cover is non-tunicate

2. Corm

A corm is the swollen base of a stem axis enclosed by the dry, scale-like leaves. It is solid stem structure with distinct nodes and internodes. the propagation of cormous plants is principally by the natural increase of new corms. the development of miniature corms between the old and the new corms is termed cormels.

3. Tuber

A tuber is modified stem structure which develops below ground as a result of th swelling of the subapical portion of a stolon and sub-sequent accumulation of reserve materials. A tuber has all the parts of a typical stem. Certain plants produce aerial tubers in the axils of leaves which are known as tubercles.

4.Tuberous roots and stem

In certain plants, the adventitious roots become thickened and they do have external and internal structures of roots nodes and internodes. These are known as tuberous roots. In other plants such as tuberous Begonia, Cyclamen or Gloxinia, they have thickened structures which have arisen from enlarged hypocotyls tissue. They have a vertical arrangement and may show features of stems. Propagation of platn with such tuberous roots or stem consists of division of such materials.

5. Rhizome
It refers to a specialized stem structure in which the main axis of the plant grows horizontally at or just below the ground surface. A rhizome consists of nodes and internodes having leaf scars on the node. In determinate types of rhizomes each clump ends in a flowering stalk and growth continues only from lateral branches.

6. Runner
Runner is a specialized stem which develops from the axis of a leaf at the crown of a plant and grows horizontally along the ground and forms a new plant at one of the nodes

7. Offset
It refers to a special types of lateral shoot or branch which develops from the main stem in certain plants and is characterized by shortened, thickened stem of rosette-like appearance. Offsets which produce sufficient roots can be removed by cutting them close to the main stem with a sharp knife and used for propagation

8. Suckers
A sucker is a shoot which arises on a plant from below ground usually from an adventitious bud on a root. Suckers are further known as root suckers, ground suckers and shoot suckers if they arise respectively from root, near the ground and stem of the plant

9. Crown
The term crown designates that part of a plant at the surface of the ground from which new shoots are produced. This kind of crown is observed in herbaceous perennials like strawberry, pyrethrum, Gerbera or African violet wherein the stem is a short and thickened structure from which the leaves are produced in a rosette like arrangement

Certain plants do have one or more of the above mentioned specialized structures useful for propagation. But particular structure is preferred for commercial propagation for obvious reasons. Strawberry can be propagated both by runners and splits from crown.

Questions

1. How root stocks influence the growth of scion
2. Graft incompatibility- Discuss

PRINCIPLES OF MICROPROPAGATION AND ITS ADVANTAGES

Micro propagation or in vitro propagation refers to the development of new plant in an artificial medium under aseptic conditions from very small pieces of plant, such as embryos, seeds, stems, shoot tips, root tips, callus, single cells and pollen grains. This technique has been put into various applications in the discipline of agriculture, horticulture and forestry ever. The various applications of micro propagation are as follows

1. Rapid rate of multiplication of a plant clonally.
2. Production of disease-free and disease resistant plants.
3. Induction of mutant and selection of mutants.
4. Production of haploids through anther culture
5. Wide hybridization through excised embryo and ovule culture
6. Somatic hybrids and cybrids through protoplast fusion
7. Transformation through uptake of foreign genome
8. Nitrogen fixation
9. Cryopreservation of germplasm types

Requirements for micro propagation

1. Laminar air flower chamber – It is useful to perform all operation in aseptic culture
2. Auto-clave or pressure cooker – It is used to sterilize the media, containers, petridishes and the various accessories required in the transfer operation.
3. Alcohol lamps, disinfectant and sterile water are also required
4. Culture medium – A medium consists of mineral salts, carbon and energy source, vitamins, plant growth regulators and other organic components

Procedure for micro propagation

1. **Collection of explant:** The small piece of plant used to begin a culture is referred to as an explant. The size, age and type of explant affect the success of *in vitro* propagation.
2. **Surface sterilization:** Explants so collection from field grown plants harbor numberous fungi and bacteria, which when inoculated into a nutrient medium contaminates the entire in vitro system. Hence, surface sterilization is resorted to prior inoculation of explants. The efficacy of the sterilants used are found to vary depending upon the type of chemical, concentration used, time of exposure etc., A few drops of teepol are also added to facilitate better contact between the explants and the sterilant.
3. **Inoculation:** Transfer of the explant into the culture medium is known as inoculation. This must be done in an aseptic condition. This is achieved by

surface sterilization of the working table of the laminar air flower chamber with absolute alcohol followed by UV light for 30 minutes.

4. **Sub-culturing:** After inoculation, the explant increases in volume or it proliferate. At this stage, it is divided into different components or parts and transferred into a fresh medium under above mentioned aseptic sterile condition. This process is known under above mentioned aseptic sterile condition. This sub cultured mass should produce a shoot and root system which is dependent upon the type of growth regulator and its concentration used in the medium. It is generally observed that if the concentration of cytokinins is high relative to auxin in a medium, shoots are induced and on the hand, when the concentration of cytokines is low to auxin, roots are induced and at intermediate concentration, the tissue grows as undifferentiated callus.

Various methods of culturing plant tissues and organs

There are five classes of plant tissues culture

1. **Callus culture:** A piece of sterile plant tissue with living cells is transferred to a culture medium to induce callus proliferation. Subculturing is then done onto a medium with or without altered growth regulator concentration, ultimately resulting in the induction of adventitious organs or embryos.
2. **Cell culture:** Cells are maintained in suspension cultures so as to produce free cells and are then subcultured to regenerate complete plants from single cells. This technique is now useful to induce variability in plant cells and slowly exposed to select desirable cell variants and regenerate complete plants from these variants.
3. **Meristem culture:** This technique involves aseptic culture of shoot meristems on nutrient medium so as to produce complete plants. Most important application of meristem culture is the production of virus free plant from these variants.
4. **Embryo culture:** involves aseptic excision of the embryo and its transfer to a suitable medium for development under optimum culture conditions. After the embryo has grown into a plantlet in vitro, it is transferred to sterile soild or vermiculite and grown to maturity in a green house
5. **Protoplast culture:** From different sources, protoplasts, the plant cells without any rigid cellulose wall but with plasma membrane only, is allowed to fuse to form a somatic hybrid. These are cultured in suitable media to regenerate the cell wall and are again cultured in suitable medium for differentiation and morphogenesis.

Hardening

The plant lets developed in the culture tubes are acclimatized to a specific environment having a high humidity, a low light level and a constant temperature.

Besides, the roots developed in vitro are hairless and hence delicate, requiring care during transfer from culture medium. To have better survival rate, the plantlets may be transferred to container kept in mist chamber where relative humidity is maintained at higher order. Once new growth is seen, the plants may be slowly transferred to outside by exposing to increased light intensity in stages.

Questions

1. What is micro propagation
2. Mention few horticultural crops propagated by tissue culture
3. What is sub-culturing

PLANNING, LAYOUT AND ESTABLISHMENT OF AN ORCHARD AND SOIL TYPES SUITED FOR HORTICULTURAL CROP PRODUCTION

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

1. Vertical row plant system, 2.Alternate row plant system, 3.Traiangular system, 4.Hexagonal system, 5.Quincunx system, 6.contour 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. **Square system:** This system is considered as the simples of all the system of planting and followed widely. In this system of planting, equal spacing is given fir 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.
2. **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 intercrop's 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.
3. **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 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
4. **Hexagonal system:** In this system, trees are planted in each corner of an equilateral triangle. Here six trees form a hexagon with the 7^{th} tree at the centre. 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.
5. **Quincunx or diagonal system:** This is nothing but the square system with plants in the centre of the square. Eventhough this system of planting accommodates double the number of plants, it does not provide equal spacing between plants. the central 5^{th} tree, actually a filler tree, is quick and erect growing and early maturing, like banana, pomegranate, papaya which would be removed as soon as the main trees planted at the corners come to bearing.
6. **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.

7. **Fixing the base line:** Base line is a straight line marked at a determined space from a particular point, like road, fence, 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.

Questions

1. What are different systems of planting of orchard crops
2. Elaborate on HDP planting in mango

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 includes cattle manure or farm yard manure, night soil, guana, bones, oil cakes, leaf mould, wood ash, coir compost and vermicompost.

ROLE OF ORGANIC MANURES

1. To serve as a good source of major and minor nutrients.
2. To build up soil organic matter and maintain fertility.
3. To improve physical, chemical and biological properties of the soil.
4. To have residual effect.
5. To control pest and diseases.
6. To improve the quality of the crop.
7. 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 (*Crotolaria juncea*), Daincha (*Sesbania aculeata)*, Pillipesara *(Sesbania speciosa)*.

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).*

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% Phoshoric 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 sojarcaju*.
- C/N Ratio 25 : 1
- 1.4% N, 0.06% P and 1.2% K.

Vermicompost

- Organic waste materials and animal dungs when fed with certain species of earthworm.
- The exrements of worms are called **`Vermicompost'**

INORGANIC FERTILIZERS

1. Nitrogenous fertilizer

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

2. Phosphate fertilizers

These fertilizers supply phosphorus to the crops when applied to the soils. Eg. Super phosphate, basic slag and rock phosphate.

3. Potassic fertilizers

These fertilizers supply potassium to the crops when applied to the soils. Eg. Muriate of potash (potassium chloride) and potassium sulphate.

4. 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

1. Saving in time and labour in application.
2. Saving from transport of too many straight fertilizers from too many places.

Disadvantages

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

Biofertlizers or bio-inoculants

Bio-fertilizers are carrier based preparations containing beneficial micro organisms 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.

1. Inoculants of biological nitrogen fixing micro-organisms. Eg. *Azotobacter, Rhizobium* and *Azospirillum.*
2. Phosphobacterial inoculants. Eg. *Bacillus sp. Pseudomonas sp. (*Bacteria), *Pencillium sp.* And *Aspergillus sp.* (fungi) and Phosphobacteria.
3. Mycorrhizal inoculants eg. (VAM) Vasicular Arbuscular Mycorrhizal fungi.

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.

1. 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.
2. Phosphorus is required in large amounts in the early stages of growth. All phosphatic fertilizers are found to be slow acting and fixed in the soil and hence the entire quantity of these fertilizers are applied as basal.
3. 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

1. 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

1. 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.

2. Foliar application

Many nutrietns 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.

Questions

1. What are different nutrients required for plant growth
2. Name some inorganic nitrogenous fertilizers
3. Mention about organic farming

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 drought period.

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.

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.

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. This system 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

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 over head 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 growin 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. head lines or main lines for conveying water from pumpset 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

1. Water saving – water is applied directly to the root zone, eliminating wastage. 30 to 70 percent water saving
2. Labour saving – This is eliminates the need for constructing borders, bunds and labour intensive works associated with conventional irrigation techniques, there by saving about to 60to90%
3. Use of lower quality water – water is applied continuously and the root zone is kept wet constantly.
4. Increased yield and plant vigor – It maintains soil moisture at optimum level eliminating water stress resulting in greater vigour, better establishment and high productivity.
5. Reduced weed growth – Since water is applied to the restricted area, wide spread weed growth is inhibited due to restricted water supply
6. Saving of nutrients – nutrients are directly applied to the root zone along with water. Leaching losses are minimized. saving upto 30 to 60%

Disadvantages

1. Higher initial investment
2. 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

1. pump
2. Filtration system – sand filters/disk filters/screen filters
3. Injectors-venture/dosatron/closer pump/bladder tanks/fertilizer tanks/bulk injection systems
4. Back flow prevention equipment

II Types of fertilizers for fertigation

1. Water soluble fertilizers (WSF)
2. Liquid fertilizers (LF)

III Nutrient sources

N- urea, ammonium nitrate solutions, ammonium nitrate, calcium nitrate and KNO3
K-KCL, K2SO4 potassium thiosulphate, 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 speciality fertilizers (WSF or LF) crop and site specific nutrient requirement, crop nutrient demand specific to each stage of the crop

Questions

1. Name different irrigation methods
2. Advantage of micro irrigation
3. Mention about fertigation

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 a 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.

1. weed control and saving in moisture and nutrients
2. Very little disturbance to soil and preventing soil erosion and
3. 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

1. Humus will be completely depleted rapidly due to frequent cultivation.
2. Frequent cultivation causes injury to the feeding roots and the trees may be short lived or stunted in growth.
3. Clean cultivation aids in more aeration leading to the depletion of nitrogen
4. Hard pan is created in the soil
5. 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 manurecrops like sunnhemp, 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.

1. Intercrops should not be occupy the area where the roots of the fruit trees are concerned.
2. Soil fertility should be maintained or improved when intercrops are grown/
3. 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
4. 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.

The recommended intercrops for some important horticultural crops are given

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 are. Increase in yield (upto10%) is obtained in the main crop due to the synergistic effect of the crop combinations arising out of beneficial micro organisms 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 upto 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 sunnhemp,onion
Tapioca upto 3 months small onion, coriander
Turmeric upto 3 months small onion, coriander
Areacanut 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

1. Keep soil cool in day; warm at night hours
2. Reduces surface run-off
3. Add humus to the soil
4. Prevents soil erosion
5. Fruits are protected and kept clean since they fall on the mulches
6. It allows the absorption of more rain water and
7. 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.

Questions

What is intercropping

Mention about soil mulching

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 green house cultivation.
India – 300 to 350 ha. area under cover.
Green house cultivation is commercial in 750 countries.

Advantages

a. Crops grown through out the year.
b. High yields of excellent quality.
c. Easy to control pests & diseases.
d. Labour & water requirement are minimum.
e. Control of environment results in higher productions is well proved.

Draw backs - 1. High cost.
2. 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

1. Tomato (off season), capsicum, cucumber.
2. Roses, chrysanthemums, carnation & gerbera.
3. Vegetable seedlings, planting material, hardening of tissue cultured plants.

Growing a crops anytime in a year Same crop throughout the year	Possible in green house

Tomatoes can be grown throughout the year – 300 to 400 t/ha/year.
Labour requirement heavy – 10 men/ha.
Open cultivation – 1 man / ha.

Green house farming is always

1. Capital intensive venture.
2. Construction
3. Equipping.

Potentials

Production of plant material	Range can be increased Production can be increased Quality can be increased

1. Supply of fresh produce to cities – off season production of vegetables.

2. Export of agricultural produce – cultivation near lifting points and facilitate this.

3. Cultivation of rare medicinal, aromatic & ornamental species – conservation, cultivation & exploitation.

4. Green house technology a base for other biotechs like hydroponics, nutrient film technique etc.

5. Cultivation in problematic regions & extreme climates – (75 million ha of barren & uncultivable land in India)

Temperature, light shade management

Temperature affects other factors alos.

Green house designed & positioned to collect maximum sunlight for maximum plant growth – leads to heating problems in summer sometimes.

Green house to be cooled when temperature crosses upper limit. If not, partial (or) total crop failure occurs.

Methods of cooling → Natural ventilation / Forced ventilation

Ventilation - Open circuit ventilation
Close circuit ventilation

Hybrid ventilation system.

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 thro' 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 fues, feothermal & hydroelectric source. Artificial lighting is also practised.

Shading

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

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CULTIVATION OF HORTICULTURAL CROPS IN GREEN HOUSE – OPERATION AND MAINTENANCE

States have sizable area under green house 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, cornation, chrysanthemum, gerbera, anthuriums, liliums, orchids. Rose – 700 – 750 budded plants/100 m^2 area. Average yield 250 flowers / m^2/year – (7 plants/m^2). So, Rs.50,000/- will be the gross return for 100 m^2 area.

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

a. Photoperiod insensitive (or) day neutral. Eg. Tomato, brinjal, pepper, cucurbits.

b. Short day & long night plants. Eg. Potato, sweet potato, soybean, chrysanthemum.

c. 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 rep. 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 adjused.

Soil **-** Common media

Amended with org. manure, compost, peat & others – nutrients, physical structure.

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

Ground beds

- Amended with range of materials – physico chemicals – nutrient availability – good aeration & drainage.
- Sterilized – nematodes & disease.
- Mulching – water & temp. of soil altered – soil borne disease fusarium – evaporation reduced – humidity reduced.
- No heavy soils – poor rooting – poor aeration – poor growth – high disease.

Containers

Sterilized media – polybags – placed on poly sheets – rooting inside the soil prevented.

Water management & Fertigation

Free from impurities – Ca, Na other salts – Ec influences absorption of nutrients.

Soil moisture – at field capacity.

Drip system – better.

Sediment free water for drip – filters.

Fertigation

Only water soluble fertilizer – N, P & K at required concentrations.

Spacing of crops – good air movement – ventilation – reduce – competition – light, water & nutrients.

Training – Tall growing plants – trained on strings.

Pruning - Pruned to single stem-remove few fruits & flowers to avoid collapsing – old senescent leaves to be removed.

Productivity of cropping sequence

- Cropping sequence round the year.
- Normally three
- Sweet pepper – Sweet pepper – okra 1052.9 quintals/ha/yr. –open field – 385.1 quintals/ha/yr

Pollination : Light tapping of flower clusters – good fruit set. Strings also help – use parthenocarpic types.

Pest & diseases Warm Temp. + humidity + still wind – timely control necessary.

Questions

1. What is green house
2. Mention different types of green houses in abroad
3. Difference between a shade net house and a green house

FLOWERING, POLLINATION AND FRUIT SET IN HORTICVLTURAL 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 ofpomological_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.

1. Due to the dioeciously nature (eg. Papaya, Datepalm, Nutmeg) or monoecious nature (Cucurbits)
2. Due to the peculiar flo\ver structure, (eg. Brinjal, Delicious apples, Vanilla)
3. Due to the dichogamy nature (Onion, Carrot, Sapota)
4. Due to the behaviour of bisexual flowers as functionally unisexual (eg. Avocado and Allspice)
5. 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 metre 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 pollinaion can be resorted to.

- This is much helpful in temperate fruit orchards and is being practised in European countries and not yet in India.

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

1. Artificially collecting the pollens, mixing it with spores of *Lycopodium* (fern) and applying to flowers *w*ith a soft brush.

2. 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 **'fertile'.**
- **'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'**

Questions

1. How pollination occurs in horticultural crops
2. Mention different pollinating **agents**

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 know 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 occur 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

Causes of fruit drop

1. Mechanical – Wind and hailstorm cause fruit drop
2. 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

3. Physiological factors – Abnormal fluctuations of soil moisture favour heavy fruit drop
4. 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.
5. 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.
6. 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
7. 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% Jehangir 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 pollinisers 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 preharvest fruit drop. This led to the thought that high concentration of auxins supplied exogeneously may inhibit fruit drop

The possibility of reducing the preharvest drop by means of plant regulator sprays has been well established in many fruit crops. Napthalene Acetic acid and its related compounds are very effective in reducing the drop of fruits in pome fruits such as apple and pears.

Questions

1. Mention different flower bearing habits in horticulture crops
2. How flower drop can be prevented

PREHARVEST 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 interrelationships. 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 lower levels.
- High rate of nitrogen fertilizer to apple trees can adversely affect the flavour of the fruit.
- Nitrogen fertilizer in crease their susceptibility to physiological disorders and decrease fruit colour.
- Eg.Apples called 'bitterpit'. 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, a lower juice content and a lower level of acidity but a 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 a 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 upto 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 and finish 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 some times 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 suffers a severe infection with diseases such as leafspot 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°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.

Preharvest 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°C in unsprayed fruit. The control of anthracnose in papaya also caused by C.gloeosporiodes, was achieved by preharvest sprays copper oxychloride 50% wettable powder at 400 g 100 litres^{-1} water applied at 7-10 day intervals.

Questions

1. Mention different preharvest sprays in horticultural crops
2. How the post harvest diseases in mango can be controlled

MATURITY INDICES – HARVESTING – HANDLING OF HORTICULTURAL CROPS

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

a. 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.
b. Increasing in size
c. Softening of the tissue of the fruits eg. Figs and grapes
d. Ease of detachment from the stalk. eg. sapota and annona
e. Shrivelling of fruit stalk eg. Watermelon
f. Time elapsed from the date of flowering to picking maturity.
g. Sound by tapping-jack and watermelon when ripe produce hollow and dull sound on tapping but produce metallic sound if unripe
   i) Drying of foliage or top
   ii) Flowering/Bolting can generally included be taken as maturity indices

2. Accurate tests

a. 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.
b. Penetrometer – It is an instalment 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 testder which records the kilogram of pressure for the plunger to penetrate the flesh.
c. 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.

i Immature: Before seeds have fully developed and jelly like substance surrounding the seeds have formed. Fruits are not suitable for consumption

ii Mahuv 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.

iii Pink : 3/4th surface shows pink colour

iv Hard ripe : Nearly all the areas are red or pink but flesh is firm

v Over ripe: fully red coloured and soft vi 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 abcise and decolourise.
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 og 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 effected.
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

i Picking must be commenced from the lower branches of tree advancing towards the top in order to reduce dropping of fruits to the minimum
ii As far as possible, dropping of fruits from the tree should be avoided to avoid any possible physical damage.
iii 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
iv 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
v There should not be any bruises in the fruits while picking as it will lower the marketable quality
vi 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

1. Air cooling in which the fruits and vegetables in a cold room
2. hydro cooling-dipping of the fruits in cold water or by spraying cold water on the fruits and
3. 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, aluminium foils and alkathene paper etc. Wrapping has the following advantages.

1. it minimizes the loss of moisture in shriveling
2. it protects against the spread of diseases from one to the other.
3. it reduces bruises.
4. it reduces damage during transport or in storage and
5. it makes 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 cranaube 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 plast 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 (1) the low dimensional stability and inability to withstand stacking load (2) 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. Similarly, mangoes are transported form 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 loss 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.

Questions

1. Mention different package material used for packing mango
2. Mention the maturity standards for mango and sapota