Orchard Management

HPH 203

5. Orchard Management (HPH 203) 2(1+1)

Orchard management, importance, objectives, merits and demerits, clean cultivation, sod culture, Sod mulch, herbicides and inorganic and organic mulches. Tropical, sub-tropical and temperate horticultural systems, competitive and complimentary effect of root and shoot systems. Biological efficiency of cropping systems in horticulture, systems of irrigation. Soil management in relation to nutrient and water uptake and their effect on soil environment, moisture, organisms and soil properties. Integrated nutrient and pest management. Utilization of resources constraints in existing systems. Crop model and crop regulation in relation to cropping systems.

Practical: *Layout of different systems of orchard soil management, clean, inter, cover and mixed cropping, fillers. Use of mulch materials, organic and inorganic, moisture conservation, weed control. Layout of various irrigation systems.*

LECTURE – 1

ORCHARD MANAGEMENT-IMPORTANCE, OBJECTIVES

Objectives: To understand the purpose of maintaining orchards and to get acquaintance with different orchard floor management practices

Orchard:

- An orchard is one where different fruit crops have been planted in an orderly manner and are managed for production of successive yield for economic return.
- Depending upon the purpose for which, they are maintained, orchards are of different types, namely.

I. Commercial orchard:

- Those orchards maintained by fruit growers mainly for commercial purpose i.e. selling the produce for making money.
- Commercial orchards may be of different types such as low density orchard, high density orchard, dry orchard etc.

1. **Low density orchard:**
    - Plants on this type of orchard are raised on standard rootstocks, which are vigorous and therefore require more spacing.
    - The number of trees per unit is less and thus named as low density orchard.
2. **High density orchard**:
    - High density orcharding with dwarfing rootstock is another innovation. Greater number of plants is planted per unit area in certain fruit crops like mango, apple, citrus, pear, walnut and others.
    - These plants are dwarfened by adopting different horticultural techniques like use of dwarfing rootstocks, genetically dwarf scion varieties, by adopting special systems of training and pruning, use of plant growth retardants, and other such other practices.
    - These dwarf trees are more productive, easily to handled and the income of the growers can be maintained steady.
    - This system has a few disadvantages like high initial investment, short life span of trees and the adverse effect of rootstock on fruit quality if proper selection has not been done.
3. **Dry Orchard.**
    - Dry orcharding is a technology where hardy type of fruit crops like mango, pear, sapota, ber, bael, guava, custard apple, cashew, jamun and others may be planted by adopting some moisture conservation methods like contour (Fig. 13.1) or terrace planting (Fig. 13.2), crescent bunding (Plate 15.1), mulching etc.

- These methods facilitate in the initial establishment of the transplant and also water needs of bearing orchards under rain-fed conditions.

II. Progeny orchard:

- Orchards maintained by nurserymen mainly for maintaining the superior types of fruit trees with all the desirable characters mainly for the purpose of propagation.
- The plants maintained in these orchards are known as mother plants.
- The disadvantages of this type of orchard are; difficulty involved in the management of fruit crops which differ in their cultural requirements, spacing, fertilizer and water mix; the whole of the orchard may not come to harvest at one time and it may be difficult to meet the cultural need of different varieties.
- The plants maintained in these orchards are known as mother plants.

III. Home orchard:

- Orchards maintained at the backyard of a residential area to meet the fruit needs of the family.
- These are maintained mostly in rural and sub-urban homes.
- Selection of fruit plants will be according to convenience and one's own taste.

IV. Experimental orchard:

- Orchards maintained in colleges and research institutions with the main aim of conducting different experimental trails for the benefit of the fruit growers /farmers in scientifically in very systematic manner (Plate 1.1).

Plate 1.1: Experimental orchard of apricot at Fruit Research Station, Kandaghat, Solan.

Management:

- A good management should aim at knowing the basic needs considering all the resources and providing them all basic inputs in optimum level in order to get more returns with maximum efficiency.
- Any good orchard management should have proper planning right from the beginning i.e., these methods facilitate easy establishment of the transplants in the orchard.

➢ **Orchard floor management** refers to the management of the orchard soil in such a manner that the fruit trees give higher yield of quality fruits in successive years for sustainable economic returns (Plate 1.2 & 1.3).

- The decision about how the orchard will be managed should always be taken before an orchard is planted. Management practices for orchard management should be executed in a timely manner during the lifetime of the orchard.
- Several systems of managing the orchard are available, each with advantages and disadvantages to consider before choosing a particular programme for an orchard.
- An efficient orchard management program always ensures higher return to the grower.
- However, no single management practice can be recommended for all orchards. A particular program is followed depending on factors like climate, location of orchard, topography, tree spacing, planting system/ orchard design etc.
- However, it should be combined with pruning, nutrient and water management, provision for pollination, fruit thinning and disease and pest management in order to obtain desirable tree growth and vigour with the aim to promote precocity with high productivity.

Plate 1.2: Peach plantation under grass mulch with clean alleys.

Objectives:

1. To provide optimum soil moisture during the critical plant growth stages.
2. Prevent or reduce soil erosion.
3. Increase or at least maintain organic matter in soil.
4. Increase nutrients status of soil
5. Control weeds in the orchard.
6. Improve soil structure and loosen it for good aeration and water percolation.
7. To ensure additional income from the interspaces of the orchard, especially during the pre-bearing stage.
8. Enhance bio- control and improve microbial activity

Plate 1.3. An example of good ground cover

Important soil management practices usually followed are: 1) clean cultivation, 2) sod culture 3) sod mulch, 4) use of herbicides 5) mulching,) 6) inter-cropping, 7) cover crops 8) clean strips.

LECTURE – 2

CLEAN CULTIVATION, SOD CULTURE AND SOD MULCH

Objectives: To control weeds and soil erosion and to conserve soil moisture in the orchard.

Clean cultivation:

- In this management system, the inter space between the trees is kept clean by tillage and removal of weeds (Plate 2.1).
- It is commonly followed in young orchards. Clean cultivation does not provide satisfactory results especially during rainy season.

Plate 2.1: Clean cultivation in hedge-row plantation of pear

Advantages:

i. Improves soil aeration and physical conditions.

ii. Controls weeds and thus reduces competition for light, nutrients, and moisture.

iii. Eliminates or avoids alternate hosts for pests and diseases.

iv. Improves the infiltration of water through breaking the hard soil surface crust.

v. Enhances biological activity in the soil through better aeration.

Disadvantages:

i. Depletion of organic matter.

ii. Soil erosion by water and wind.

iii. Loss of nutrients due to excessive leaching.

Sod Culture:

- This practice is followed in the orchard located on sloppy land, particularly when the gradient of the slope is greater than 10 per cent.
- In this system, grasses are allowed to grow in the interspaces between the trees without tillage or mulching (Plate 2.2).
- Mixing of clovers- [red clover (*Trifolium pretense*)], white clover (*Trifolium repense*) with grasses is useful for improving soil fertility.
- The grasses are mowed periodically to reduce competition for water and nutrients with the trees. Orchard grass (*Dactylis glomerata*) is suitable for areas facing north, tall fescues (*Festuca arundinaceae*) a drought tolerant perennial grass for areas facing south, and Timothy (*Phleum pretense*) for cold temperate region.
- This system prevents soil erosion to the greatest extent; however it should not be followed in orchards of young or dwarf trees because such trees are shallow rooted and compete for nutrients and water with grasses.
- The roots of large trees on the other hand penetrate the soil to a greater depth and are less likely to suffer from such competition.
- Tree basins are kept free of weeds by tillage or application of herbicides.

Plate 2.2: Sod plus herbicidal strip in apple orchard

Advantages:

1. Controls soil erosion.
2. Maintains optimum soil moisture to ensure water and nutrients supply to trees.
3. Maintains organic matter.
4. Provides better aeration to the roots.
5. Enhances microbiological activity in the soil through better aeration
6. Avoids bruising of falling fruits.

Sod mulch:

- In this method, grasses are allowed to grow in the entire area of the orchard.
- Tree basins are mulched with straw, instead of tilling.
- The grasses are mowed down regularly and are spread to maintain the mulch in basins (Plate 2.3).
- This method is best suited in orchards on steep slopes to prevent soil erosion.

Plate 2.3: Sod mulching in olive

Advantages:

1. It has all the advantages of sod-tilled method.
2. Most suitable for orchards on slopes having greater gradient.
3. Highly effective for controlling soil erosion.
4. Conserves moisture and controls weeds in tree basins.
5. Improves fruit colouration and enhances fruit maturity.

Frequently asked questions (*F.A.Q.*):

1. What do you mean by clean cultivation?
2. What are the disadvantages of clean cultivation?
3. Differentiate between sod culture and sod mulch.
4. Name three common grasses used for sod culture.
5. What are the advantages of sod culture and sod mulch?
6. Where sod culture and sod mulch are more useful.

LECTURE 3

HERBICIDES AND THEIR APPLICATION

Objective: Control of weeds in orchard with the use of herbicides in order to reduce their competition with fruit plants for water and nutrients.

Weed: Any plant growing out of place is a weed.

- It competes with the fruit trees for water and nutrients.
- Weeds sometimes act as intermediate or alternate hosts to certain pests, diseases which cause heavy losses to the main crop.
- The weeds may be crop specific or season specific i.e. annual, biennial and perennial weeds.
- In India, yield loss due to weeds is approximately 33 per cent of total production, and on an average 30 per cent of the total production cost is spent on tillage operations alone.
- Therefore efficient weed control is necessary for profitable fruit production.

Significance of weed control in orchard:

- Fruit trees may be much larger than most weeds, but they have root systems that do not compete well with other plants.
- Where, cover crop or weeds grow the bulk of tree roots form in the second and third foot of soil.
- If competition is reduced, the trees form the highest percentage of their roots in the much more biologically active first two feet of soil depth.
- In areas with poor quality soils, the orchardist should not give the best foot of soil to the weeds.

Damages caused by weeds:

- **Increase in cost of cultivation**: Weed control may take about 30% of total cost of expenditure thereby causing reduction in the net returns.

- **Reduction in crop yield**: Weeds being hardy and resistant against unfavourable conditions complete for water and nutrition with crop plants and reduces the yield to about 60 – 70%.

- **Reduction in the quality of produce**: Certain weeds eaten by or fed to the milching animals cause undesirable flavour to the milk. Similarly, if the produces mixed with weed seeds leads to decrease in quality.

- **Harbour insect pests and diseases**: Weed may act as alternate hosts for many crop pests and diseases.

- **Check flow of water in channels:** It physically impede the easy flow of irrigation water and cause its wastage by consuming the bulk of irrigation water.

- **Some harmful secretions:** Some of the weeds (*Cyperus rotundus*) check the germination and reduce the growth of main crops.

When weeds should be controlled?

- Weed seeds remain viable for long periods.
- It is known fact that **One year seeding is seven years weeding.**
- So weeds should be controlled before they come to flowering.

Methods of weed control are:

- The area under the tree rows cannot be properly mowed, and would become a thick tangle of annual and perennial weeds if left to grow.
- Various methods have been tried over the years to cut down this growth, including mechanical tillage, mulches, and flaming.
- Each one of these alternatively work, but often are very time consuming, expensive, and are carried out, usually, by people intentionally trying to avoid the use of synthetic pesticides.

1. **Cultural method :** The tillage practice followed in specific garden and occurrence of weeds
2. **Fire:** Weeds may be burnt using a flame gun.
3. **Biological control:** Weeds may be killed by releasing suitable parasites.
4. **Smothering:** If the orchard if fully covering the soil by shade, weeds may be killed by restricting their growth by covering them with suitable mulch of suitable thickness.
5. **Chemical weed control:** One must be very cautious in using chemicals for weed control or else the crop plants also may be damaged. One should use only selective weedicides. Weedicides may be either organic or inorganic.

Inorganic compounds are: Ammonium sulphate, copper sulphate, ferrous sulphate, borax, sulphuric acid – these are not popularly used in agriculture.

Organic weedicides are:

- DNOC – Dinitro-ortho cresol
- PCP – Pentachlorophenol
- Nitrofen – 2, 4 dichlorophenyl, 4 nitro phenol ether
- Dinoseb – 2 – butyl 4, 6, dinitro phenol
- MCPA – 2 methy 4 chlorophenoxy acetic acid
- 2, 4 D – 2, 4 – Dichlorophenoxy acetic acid
- 2,4,5 – T – 2,4,5 Trichlorophenoxy, acetic acid
- 2,4 – D.B. – 2,4 dichloro butyric acid
- TCA – Trichloro acetic acid
- Dalapon – 2,2 dichloro propionic acid

- Propanil – 3, 4 – dichloropropionanilide
- Alachlor – 2, chloro, 2, 6 diethyl – N – methoxy – methyl anilide
- Diuron – 3, 4 – dichloro phenyl
- Atrazine – 2 Chloro 6 ethyl amino 4 isoprophyl – amine 1,3,5 triazine

They should not be used with most soil residual materials, or products that may injure the young tree if applied to the trunk.

Chemical weed control in orchards:

- In this method, weeds are controlled by chemicals, referred as weedicides or herbicides. This practice is based on the principle of selectivity, killing only one kind of plants.
- These chemicals may kill or may greatly inhibit growth when applied in proper dosages at pre or post- emergence stage.
- Pre emergence herbicides like diuron, atrazine, fluchloralin etc. are applied to the soil prior to emergence of weed seeds/ seedlings by broadcasting, band application, soil incorporation or spray on soil surface (Plate 3.1).
- Post emergence herbicides such as glyphosate, paraquat (Plate 3.2) are applied with the addition of surfactant, after the emergence of weeds.
- Use of herbicides to reduce weeds under the trees is simpler method that often lowers the over-all impact on the environment.

Plate 3.1: Application of pre-emergence herbicide (Note: Tree trunk is protected with black polythene covering)

Plate 3.2: Application of paraquat for weed control in apricot (Plate 3.2a); Killing of weeds 5 days after application (Plate 3.2b).

Some of the weedicides recommended for different fruit crops are:

Mango	– Diuron – 6.67 to 8.9 kg/ha – Bromacil – 6.67 to 8.9 kg/ha
Banana	– Alachlor 9 lit/ha – pre-emergence – Oxyfluofen – 600 – 800 ml/ha – pre-emergence
Citrus	– Artazine – 2.5 kg/ha – pre- emergence – Diuron – 2.4 kg/ha – pre- emergence
Grapes	– Paraquat (Gramaxone) – 1.5 lit/ha – post-emergence – Diuron – 3 – 3.5 kg/ha – pre-emergence – Atrazine – 4kg/ha – pre-emergence
Sapota	– Bromacil – 3 kg/ha – pre-emergence – Diuron – 4.0 kg/ha – pre-emergence
Pineapple	– Bromacil – 2kg/ha - pre-emergence – Alachlor – 4.5 lit/ha
Strawberry	– DCPA 8 lb + Chloroxuron 4 lb/ac – Diphenylamide 4 lb/acre

Advantages:

1. The weeds controlled or killed while the soil remains undisturbed.
2. Prevents injury to the trees caused by rodents by destroying their harboring places.
3. Prevents injuries to the plants and roots which may occur due to disking.

4. All the cultural operations can be carried out easily in absence of weeds. Harvested fruits can be collected easily.
5. Harvesting of the fruits can be done easily.

- Some varieties of apple and pear are more sensitive to mild herbicides than others. For instance, Gala and Golden Delicious apples and all pears seem to be more sensitive than other fruits to 2,4-D, which when leached into the root zone. In these examples, you should take care not to apply, then irrigate the product into the root zone within 10-14 days after application
- Cherries and other "stone fruits" are generally less tolerant of soil active herbicides, and have many fewer safe, registered product choices. Simizine can cause serious symptoms on stone fruits when applied in many north-west facing orchard soil and irrigation situations.
- The most common and serious damage occurs on young fruit trees when unprotected bark is contacted by concentrated doses of glyphosate type products. However, this is does not mean that these products cannot be used in young orchards,
- Young trees have shallow root systems, and most of their roots are under the herbicide treated area. They may become highly exposed to root active herbicides that leach into the upper foot of soil.
- Soil Factors: These are the same well-known considerations used with many herbicides and crops. Organic matter and increased binding sites that come with finer soil texture are major soil qualities that hold potentially mobile herbicides in the upper 2-4 inches of soil, controlling weeds rather than affecting the fruit tree.
- Soil residual, potentially mobile, and actively taken up by roots. These tend to be the older, cheaper, and highly effective products that are often the foundation of a weed control combination. Examples include simizine, diuron, terbacil, and, to a lesser extent, norflurazon and dichlobenil. All very good and useful herbicides, but may be slightly to highly hazardous to fruit trees.
- Soil residual, not very mobile, and not likely to be transported in significant levels into the tree. Examples of these include oryzalin, napropamide, pronamide, pendimethalin, oxyfluorfen, and isoxaben. These products are more or less effective, but often need to be used in combinations to increase the weed control spectrum. They are more likely to fail if application directions are not followed very carefully.
- Contact, systemic, not soil active. The usual list: glyphosate or sulfosate products. These tend to be an important part of the mature orchard weed control program, and very useful for the suppression of tough perennial weeds. Contact systemic, somewhat soil active: 2, 4-D.
- Contact, not very systemic, not soil active. Paraquat, which is used very effectively as a "chemical hoe" in young orchards.

Herbicides considerations:

- Read manufacturer’s instruction prior to application of herbicides for proper use (Plate 3.3).

Plate 3.3: Manufacturer,s instructions on label

Plate 3. 4: Careful application of herbicides avoiding direct drifting of spray on tree trunk.

- Herbicides must be used with care and they should be used as per recommended dose, otherwise it may cause damage to the plants (Plate 3.4).
- Use special nozzle for herbicides application to minimize spray drift and allow low pressure spraying (Plate 3.5). They come in several sizes with capabilities to apply a range of spray volume.
- Weed behaviour as affected by various crop husbandry practices, orchard management should be recorded.

Plate 3.5: Knapsack sprayer with special nozzle for herbicide application

LECTURE 4

ORGANIC AND INORGANIC MULCHES

Objective: *In-situ* conservation of water by reducing its evaporative losses from soil surface and control of weeds and soil erosion in the orchard.

Mulching:

- Mulching refers to spreading of dried leaves hay, straw, or any other organic (Plate 4.1b) and inorganic materials (Plate 4.1a) around the tree basin to cover the soil surface. Plastic mulches can be effectively used.

Plate 4.1a: Black polythene

Plate 4.1b: Dry grass

- A wide variety of materials can be used as mulches, which are broadly classified as *organic* and *inorganic* mulches.
- All the *organic residues* viz. straw, hay (Plate 4.1b), crop residue, leaves, saw dust and organic wastes viz. farm yard manure, poultry manure, spent mushroom compost etc. and *inorganic mulches* viz. black polythene can be used as mulches.
- In some arid fruit growing areas, pebbles can be used in the event of non-availability of organic material. These mulches act as a surface barrier against evaporation, conserve soil moisture, check weed growth and enrich organic matter to the soil.
- However, mulches should be removed at the onset of monsoon rain.

Advantages:

1. Conserves soil moisture by reducing evaporative losses from soil surface and controls weeds.
2. Organic mulches add organic matter and nutrients to the soil upon decomposition thus save fertilizer requirements.
3. Improves the soil structure, nutrient availability and micro flora.
4. Controls soil erosion.
5. Improves water infiltration and controls weed growth due to etiolation.

6. Reduces soil temperature fluctuation.
7. Mulch acts as a cushion for dropping fruits and thus avoiding physical injury.
8. Growth, production, colour and quality of fruits are improved.

Disadvantages:

1. Cost of mulch is high.
2. Dry grass, hay or pine needle mulches are a fire hazard.
3. Mulch may harbor insects, diseases and rodents.
4. Growth may be extended in some seasons through fall with reduction in fruit quality.

Additional benefits of organic mulches:

- Apart from the advantages listed above, organic mulches alsoImprove root growth
- Increase the infiltration of water, and
- Also improve the water-holding capacity of the soil.
- Organic mulch provides an ideal environment for earthworms and other beneficial soil organisms.
- Organic mulches are more useful for warmer climates i.e. valley areas and low and mid-hills areas of Himalayan region, as these keeps the soil temperature cooler by 2-3^{o} C in summer.

Inorganic mulches:

- Inorganic mulches are usually preferred in fruit orchards located in the high hill areas having cooler climate.
- It also helps in raising the soil temperature in summer, required for greater nutrient absorption and roots metabolic activities.
- However, inorganic mulches lack soil improving properties of organic mulches.

How to and when to apply mulch

➢ Time of application depends on what is expected to be achieved by mulching. Mulching by providing an insulating barrier between the soil and the air, moderate the soil temperature. This means a mulched (organic) soil in summer will be cooler than the adjacent non-mulched soil; while in the winter the temperature of mulched soil may not drop as deeply as otherwise it would have been.

- Around 10 cm thick hay, straw or pine needles are spread over the tree basin areas in spring immediately after completing the tillage operation and applying second dose of nitrogenous fertilizers in the basins. However, about 10-15cm area away from the tree trunk should be kept open, in order to protect the trunk from the damage of any harbouring insect-pests, rats etc.
- Among the inorganic mulches, use of black polythene sheet of 200 micron thickness around the tree basins or in strips is common, keeping sufficient vacant space for working between the rows.
- Mulches can be applied late in the winter after the temperature falls below freezing point but before the coldest temperature arrives. Applying mulches before the coldest temperature may attracts rodents looking for a warm over-

wintering site. Delayed applications of mulch should prevent this problem as, hopefully, the creatures would already have found some other place to nest.

Benefits of winter mulches:

- One of the benefits from winter mulching is the reduction in the freezing and thawing of the soil in the late winter and early spring. These repeating cycles of freezing in night and then thawing in the warmth of the sun causes many small or shallow rooted trees (e.g. young trees) to be heaved out of the soil. This leaves their root systems exposed and results in injury or death.
- Mulching helps prevent the rapid fluctuation in soil temperature.

Frequently asked questions (*F.A.Q.*):

1. Define mulching.
2. Give two examples, each of organic and inorganic mulches.
3. What are the advantages of mulching?
3. What are the demerits of mulching?
4. How mulching prevents weed growth?
5. How organic mulches improve soil organic matter and nutrient status.

LECTURE – 5

TROPICAL AND SUB-TROPICAL HORTICULTURAL SYSTEMS- COMPETITIVE AND COMPLIMENTARY EFFECT ON ROOT AND SHOOT SYSTEMS

Objectives: In tropical and sub-tropical fruits, the main aim of orchard management is to increase land use efficiency, therefore use of inter-crops, multiple crops, multi-storied crops systems are followed for obtaining maximum income from the available land. Apart from these, cover crops, sod culture, herbicides, minimum tillage etc. are also common.

Inter-cropping:

- In this, cash crops such as peas, strawberries and vegetables are grown in the vacant space between the rows of trees during the early juvenile phase, until the trees come into bearing.
- Sometimes short duration fruit crops are raised as inter crops, which are also referred as 'fillers`. Suitable inter-crops for different crops are:

Plate 5.1: Raj mash as inter-crop in orchard

Banana : Green gram, cowpea, cauliflower, cabbage, yam, elephant foot, onion, Black gram, turmeric, brinjal, colocasia, dioscorea, chilies, lady's finger

Ber : Green gram, moth, cluster bean, cowpea, cumin, chilies

Citrus : Beans, carrot, tomatoes, berseem, onion, potato, chilies, pulses, cucurbits, lady's finger, gram, peas, tomato, cabbage

Date palm : *Citrus medica*, guava, sapota

Grape : Vegetables relevant to area

Guava : Cauliflower, peach, French bean, cowpea, cluster bean, black gram, Green gram, Lady's finger, onion, turmeric, garlic, cabbage, chillies, Papaya

Litchi : Turmeric, ginger, pointed gourd, sweet potato, tomato, radish, cabbage, turnip, brinjal, cucurbits, green gram, black gram, cowpea

Mango : Phalsa, papaya, guava, banana, peach, strawberry, pineapple
Papaya : Cabbage, cauliflower, chilies, radish, tomato
Pomegranate: Berseem, Lucerne, cowpea, green pea, cucurbit, cabbage, cauliflower, bean, peas, tomato, carrot, onion, potato, brinjal
Sapota : Banana, papaya, pineapple, broad bean, tomato, brinjal, cabbage cauliflower, spider lily.

Principles of intercropping

To evaluate the effects of annual intercropped crops in fruit orchards on the productivity and sustainability of integrated fruit systems by enhancing the efficiency of both abiotic and biotic factors.

- Intercrops should occupy a secondary place in the orchard, primary consideration being given to the perennial fruit trees.
- The crops that may grow tall and have a tendency towards excessive growth should be discouraged.
- At least 120cm radius must be left from the base of the growing fruit trees for taking intercrops.
- Water requirements of the intercrops should as far as possible coincides with the requirement of fruit trees.
- Such intercrops should be selected that do not exhaust the nutrients and moisture from the soil, so essential for the growth of fruit trees.
- Perennial or exhaustive crops should be discouraged as an intercrop in the orchard.
- This may have devitalizing effect on the growing trees. For example, sugarcane, pigeonpea, maize, *jowar* should invariably be excluded from an intercropping programme in the orchard.

Advantages:

1. Generates supplementary income during the initial juvenile years of orchard plantings.
2. Increases organic matter.
3. Increases soil nutrient status by fixing atmospheric N to soil by leguminous crops.
4. Reduces weed growth.
5. Improves soil structure.

Criteria for the selection of an intercrop: Main crops should always be given proper care in order to avoid root restriction, damage and infection, undue exhaustion of the soil, perpetuation of virus, fungal and nematode infection. Intercrops should therefore, receive secondary importance and fulfil following criteria.

- Should not be tall growing and spreading type.
- Should not be exhaustive.
- Should not function as alternate host for common pest and diseases.
- Water requirement schedule should match or phenology of crop should match so that operation could be synchronized.
- Should match for climatic requirements with main plantings.
- Separate provision for nutrients should be made for inter-crop to avoid competition.
- Intercrops should be preferably legumes or shallow rooted vegetables.

Types of inter-cropping:

- **Parallel cropping:** Cultivation of such crops which have different natural habit and zero competition.
  Black gram/Green gram + maize
- **Companion cropping:** Such inter cropping where the production of both intercrops is equal to that of its solid planting.
  Mustard/Potato/Onion + Sugarcane
- **Multiple cropping/Multitier/Multilevel cropping:** It is one of the cropping systems, wherein two or more crops are grown in succession within a year.
- **Synergistic cropping:** The yields of both crops are higher than of their pure crops on unit area basis.
  Sugarcane + Potato

Cover crops:

The crops, which are raised between the tree rows during rainy season for protecting the soil from erosion, are referred as cover crops (Plate 5.2). These may or may not be turned into the soil.

- Leguminous crops like green gram, black gram, cowpeas, cluster bean, soya been during *kharif* season should be used.
- Pea, fenugreek, broad bean during *rabi* season can be preferred, as these add N to the soil by fixing atmospheric-N in their nodules.

Plate 5.2: White clover (*Trifolium repense*) provides year round orchard cover in temperate and sub-tropics regions.

Advantages:

1. Increase water retaining capacity and biological complexes of soil.
2. Increase organic matter in soil.
3. Improve soil condition.
4. Improve soil fertility.

5. Check soil erosion and thus also nutrient losses from soil.

Minimum tillage.

- The inter-space between the trees is maintained without any soil working. The method is particularly followed in uneven topography.
- In this method, sod, weeds, cover crops and any other vegetation are controlled by the use of herbicide in spring.
- The method is extremely useful in controlling weeds and moisture conservation. Besides, nutrients are slowly released from dead materials.

Multi-storyed cropping:

- Multi-storied cropping system involves the growing of crops of different height, rooting pattern, and duration simultaneously on the same piece of land.
- This is most common in coconut based cropping system in Kerala (Figure 5.1) to meet diversified needs of farming community for fodder, food and fuel, besides increasing net return per unit area, e.g. coconut+ pepper + pineapple + grass.
- Taller trees, which has greater requirement for solar light, are able to trap more solar light when grown as top story and those having requirement of lower light are raised as ground story.
- In this system, annual and perennial crops are grown side by side in different tiers by exploiting soil and vertical space more efficiently.
- Inter-cropping and mixed cropping with compatible crops in coconut plantations has been found to give increased returns to the farmers, without affecting yield of the main crop.

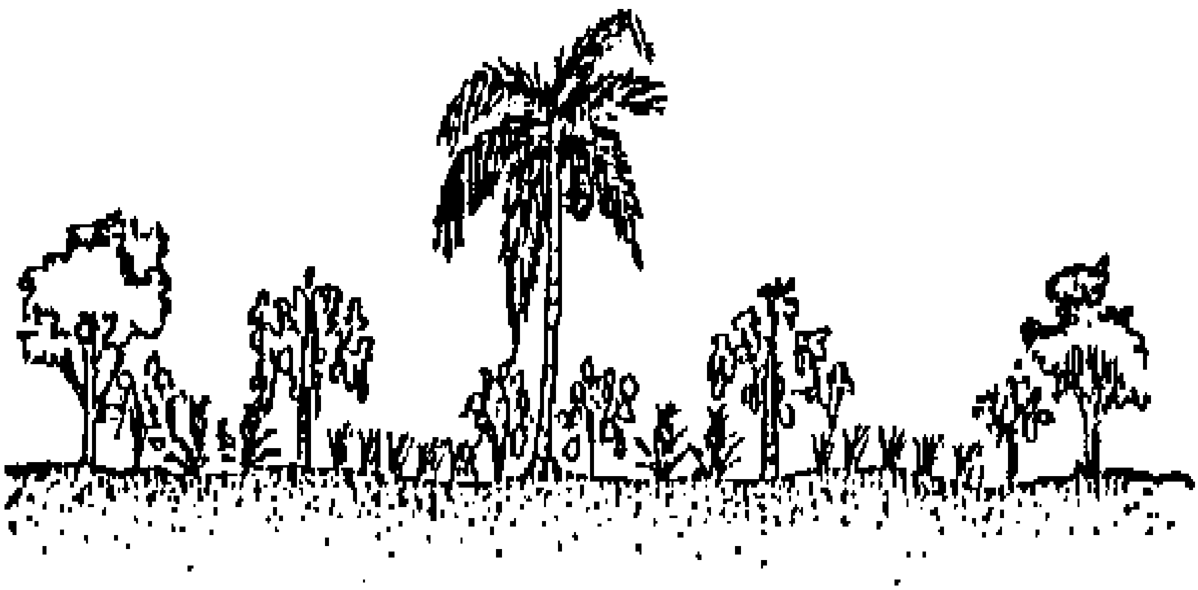


Figure 5.1: Coconut based multi-story cropping system

F.A.Q.:

1. What is inter-crop?
2. Name three important inter crops each for banana, mango, citrus and guava.
3. Differentiate between inter-crop and filler.
4. Name two fillers for mango plantations.
5. What is the major advantage of leguminous inter-crop?
6. Name four important leguminous inter-crops.
7. How exhaustive inter-crops affect the root and shoot systems of the main fruit plants.
8. In multi-storied cropping systems, why crops of variable height are grown.
9. Define cover crop.
10. What are the advantages of cover crops?
11. Give two examples of leguminous cover crops.

LECTURE – 6

TEMPERATE HORTICULTURAL SYSTEMS- COMPETITIVE AND COMPLIMENTARY EFFECT ON ROOT AND SHOOT SYSTEMS

Objectives: To sustain soil fertility, weed and soil erosion control and moisture conservation in temperate fruit orchards.

- Root and shoot systems of trees/crops may have either competitive or complimentary effects on each other depending upon the kind of management practice is followed in a particular orchard.
- The shoot/root growth of fruit trees and shrubs is influenced by external conditions like moisture, aeration, soil temperature, availability of nutrients. All these factors are greatly influenced by practices such as mulching, inter-cropping, weed management, cover crops, sod culture, fertilizer application and irrigation, which in turn affect the above ground tree growth.
- For example, use of mulch around the tree is helpful in conserving soil moisture, and thus improving root growth, nutrient uptake and consequently improving the growth of shoot system. However, roots under mulch tend to be distributed nearer to the soil surface.

- When main purpose of the orchard management is to increase land use efficiency as in case of inter cropping or multi-species cropping, losses to the main crop may occur due to competition among the crops for root growth, water, nutrients, light etc. especially if selection of inter crops and management are not planned properly before and these will have an adverse effect on the growth of shoot system of the main crop as well as that of inter crop.

➢ An efficient orchard management programme always improves the performance of fruit trees in the following ways:

- It reduces the competition of roots for light, water and nutrients and in the absence of weeds.
- it increases the availability of soil water for absorption, increases the root growth due to less soil compaction, improved soil structure, optimal soil temperature etc., which have complimentary effect on shoot system and thus the overall performance of trees.
- In multi species cropping system, complimentary interaction in plant is known as *annidation.* It augments yield and performance of both crops.

➢ In temperate fruit orchards, primary objective in their management involves sustainability of soil fertility, weed and soil erosion control and moisture conservation. These can be achieved through appropriate weed management system(s), use of mulches around the tree basins, clean cultivation, chemical weed control, sod culture etc.

- Temperate fruit orchards in India are mainly rainfed; therefore more emphasis is laid towards water conservation and its proper use during critical periods, through efficient irrigation systems.
- Judicious training and pruning are important to impart proper shape to the trees, produce high quality fruits, besides maintaining a balance between growth and fruiting.

Weed management in temperate fruit crops:

➢ Weed behaviour as affected by various crop husbandry practices included in the orchard management practices. Weeds compete with the fruit trees for water and nutrients. Therefore, there is a need to control weeds around the tree basin of both young and mature fruit trees.

- Weeds near young trees should be removed periodically as these reduce growth by competing for moisture and nutrients.
- Most weeds complete their life cycle in a shorter period in comparison to fruit trees and compete for light, water and mineral nutrients and reduce yield. Weeds sometimes act as intermediate or alternate hosts to certain pests, diseases which cause heavy losses.
- In India, yield loss due to weeds is approximately 33 per cent of total production, and on an average 30 per cent of the total production cost is spent on tillage operations alone. Therefore efficient weed control is necessary for profitable fruit production.

Weed control methods: Common weed control methods include use of mulches around the tree basins, manual weeding, and use of herbicides.

Use of mulches.

- Mulching is one of the simplest and most beneficial practices that are most commonly adopted in temperate fruit orchards (Plates 6.1 & 6.2).
- It is a recognized practice that saves soil and moisture, and is used in most orchards.
- It is simply a protective layer of a material that is spread on top of the soil (as discussed in chapter 3).

Plate 6.1: Dry grass mulching

Plate 6.2: Black polythene mulching in apple orchard

Sod culture with herbicidal strips.

- Vegetation near the tree competes for nutrients and water, resulting in reduced growth, yield and size of fruit.
- The best strategy for managing the orchard floor is to use a non-competitive *grass alley with a vegetation-free strip* in the tree row (Plate 6.3).
- The vegetation-free strip can be established and maintained with herbicides in this section.

Plate 6.3: Grass alley with a vegetation-free strip

Benefits:

- The permanent grass sod between the tree rows will minimize soil erosion, increase soil aeration and permeability, and support equipment movement through the orchard during wet weather.
- The vegetation-free strip eliminates competition for water and nutrients.
- Herbicides are directed at the soil and weeds underneath the tree.
- The vegetation-free strip method is superior to all other orchard floor management options. Vegetation under the tree competes for nutrients and water, resulting in reduced growth, yield and size of fruit.

➢ Another option is the use of organic mulches in the tree row. Examples of mulching materials include straw, wood chips, and grass residue from mowing.

Advantages:

- These mulches will suppress weed emergence.
- Mulches can improve the water-holding capacity of soils.

Some concerns regarding the use of organic mulches:

- The most significant problem is that mulches create an ideal habitat for voles.
- Additional nitrogen may be needed to support the microorganisms that aid in decomposition of organic mulches.
- In poorly drained or water-logged soils, organic mulches increase the likelihood of *Phytophthora* root rot.
- Mulches can be expensive and difficult to obtain. However, synthetic mulches made from polyethylene, or polyester can be placed in the tree row around the base of the trunk or as a narrow strip down the row. Some newer synthetic mulch allows water and air to pass through the mulch.

Herbicide Considerations:

- As discussed in chapter 3 it is advisable to read the manufacturer's instructions prior to application of any herbicide (Plate 3.3).
- Herbicides sprays are to be directed along each side of the tree row.
- While applying herbicide, ensure that tree trunk does not come in contact with spray material (Plate 3.4).
- Use special nozzles for herbicides application. Use of flat fan nozzles minimize spray drift and allow low-pressure spraying (Plate 3.5).
- It is advisable to apply white latex paint or lime to the bottom 2 to 3 feet of the tree trunk of newly planted trees before applying herbicides (Plate 6.4). Painting the tree trunks reduced the potential for winter as well as herbicide injury, especially from post emergence herbicides.

➢ As discussed in previous lecture (lecture 3), herbicides are available as pre-emergence as well as post-emergence weed control.

Pre-emergence herbicides:

- Pre-emergence herbicides are applied on the soil soon after tillage operation in spring, while post-emergence herbicides are applied two or three months later on the emerged weeds.
- Pre-emergence herbicides control germinating weeds seeds but usually do not give acceptable control of emerged weeds.
- Rain fall is needed to properly activate most herbicides; however, best control occurs when water (rain or irrigation) is added within a few days of application.
- The desired amount of time for rainfall after application varies by herbicides.

Post-emergence herbicides:

- Post emergence herbicides control emerged weeds and is most effective when applied to actively growing weeds.
- Weeds under stress from drought or mowing may not be adequately controlled by post emergence herbicides.
- If weeds are stressed from drought, delay herbicide application until after adequate rain fall when weeds are no longer wilted.
- If weeds have been mowed, wait several days to allow re growth before applying herbicides.
- Symptoms of herbicide activity may not be noticeable for up to two weeks after application of Glyphosate, Sethoxydim, clethodim, or fluazifop (Roundup, Poast, Select, or Fusillade DX, respectively).
- Effects of Glufosinate, Paraquat, and 2, 4-D are noticeable in 1 to 3 days after application.
- Some post emergence herbicides require the addition of a surfactant or crop oil to improve herbicide activity.
- Remember, surfactants and crop oil differ from another and may not be interchangeable.

Time of application of herbicides

➢ Major objectives of weed management is to reduce weed competition with the fruit crops particularly during the first 6 to 8 weeks after bud swell and keep the area under the trees weed-free through harvest. Timing of pre emergence herbicide application is important in accomplishing this goal.

- As has been discussed above, generally single application of pre-emergence herbicide is given in spring followed by post emergence herbicide application later.
- However, it can be difficult to spray underneath limbs loaded with fruit in mid and late summer.
- With appropriate pre emergence herbicide timing, post herbicide application in mid and late summer can be avoided. Several timing options have been listed below.

Fall/ Spring Split.

- One approach is to apply a nonselective burn down herbicide (Glyphosate or Paraquat) in the fall after early harvest (November).
- The fall application will generally provide pre emergence control into the early summer.
- When fall pre emergence treatment breaks and emerging weeds get 5 to 8 cm tall, another pre emergence herbicide application with a burn down herbicide should be applied.
- Fall herbicide application may be helpful in managing voles. In areas where erosion is a concern, this option may not be acceptable.

Weed scouting: It is important to scout orchards regularly to determine weeds if present. Scouting allows growers to:

- Recognize the need to control escaped weeds with a timely herbicide application and
- For early identification of difficult-to control weeds. Early identification of problem weeds can prevent them from becoming established in the orchard.
- If problem weeds are noticed for the first time in an orchard, they need to be removed before they produce seed. This can be done by hands or with a spot treatment with a nonselective post emergence herbicide like Glyphosate, paraquat.
- Scouting also gives growers an opportunity to recognize poorly controlled weeds so their weed management program can be adjusted.
- Another aspect growers should consider is the potential for infestation of weeds from around the border of the orchard. Weeds in these areas produce seeds that will find their way into the orchard.

Chemical Mowing

- Some herbicides can be used at sub-lethal doses to suppress orchard floor vegetation.
- Timing and rate will vary with the vegetation present.
- Generally, tall fescue can be used as the guiding species, because it is a major component in most orchards.
- Optimum timing for suppression is when tall fescue has 5 to 10 cm of new growth in the spring.
- Glyphosate can be recommended for this operation.
- Chemical suppression of grasses should be done only to healthy, well-established sod.

Weed management in newly planted trees

- Newly planted plants in the orchards should always be kept free from weeds as weed competition can reduce their growth and development by 50 percent.
- Newly planted trees suffer from weed competitive more severely than the well established older plantations. Moreover, young tress do not have well-developed limbs to shade the soil surface in late summer to minimize the competitiveness of late summer weeds.
- In general, pre-emergence herbicides provide effective control of annual grasses and small-seeded broadleaf weeds.

- Lower 40-50 cm of the tree trunk should be painted with a white latex paint, which paint provides a barrier to herbicides, and thus protect tender, green bark from burn injury (Plate 6.4).

Plate 6.4: Tree trunks covered with aluminium foil

Pollination, honey bees, and pesticides.

- Cross pollination (Fig. 6.1) is necessary in apple, some pears, plum, peaches, cherry, pecan nut, kiwifruits etc.
- Most of the apple cultivars grown in India are self-incompatible e.g. Delicious cultivars and require cross-pollinations with a suitable pollinizers' variety to obtain good fruit set.
- Honey bees and other native insects are the primary pollinators for apples (Plate 6.5).
- All bees are susceptible to insecticides and need to be protected during bloom and at other times.

Figure 6.1. Cross-pollination (a) is necessary for satisfactory fruit set in apples, pecan nut, kiwifruits and some cultivars of pears, plums and sweet cherries. Most peach, nectarine and sour cherry varieties are sufficiently self-fruitful to set full crops with their own pollen (b, c).

Plate 6.5: Honey bee activity during bloom in apple

- **Read carefully instructions on insecticide labels:** Most insecticide labels include a warming.

- "This product is highly toxic to bees exposed to direct treatment or residues on blooming crops or weeds.
- Don't apply this product or allow it to drift to blooming crops if bees are visiting the treatment area.
- Any apiary within $2^1/_2$ miles of the orchard is at risk from insecticide application.
- Bees are highly attracted to flowers in the ground cover. Before applying insecticides, reduce dandelion, clover, and other ground cover flowers by mowing or herbicide.

➢ The following recommendations will help to minimize bee kills;

  - Read warning statements on pesticide labels regarding honey bees and follow the instructions given.
  - Select the safest available formulation. emulsifiable concentrate (EC) formulations usually have shorter residual toxicity than powder (WP) formulations.
  - Insecticides applied during unusually low temperatures will remain toxic to bees for a much longer time than when applied in warm weather.
  - Avoid applying insecticides to blooming cover crops, and avoid insecticide drift to nearby plants are applied.
  - In case the use of an insecticide hazardous to bee must is unavoidable, apply it in the early evening to minimize risk to bees.
  - Never apply a pesticide directly over a beehive. Notify nearby beekeepers before applying pesticides toxic to bees.
  - Dispose of all unused pesticides safely so that pesticides do not end up in watering sources used by bees.

LECTURE - 7

BIOLOGICAL EFFICIENCY OF CROPPING SYSTEM IN HORTICULTURE

Objectives: Proper land use in space and time dimension to get more number of crops on the same piece of land per unit time to attain higher profit from orchard.

Introduction:

- Sustainable horticulture requires adoption of such cropping patterns, which ensure efficient use of available space, enhanced productivity and profitability. This is particularly more important for tree fruit crops, which are planted at wider spacing in the field and take longer times to come into bearing.
- Besides, vacant space between rows and trees remain unutilized during the initial years of orchard life, which leads to wastage of resources including land, water, labour etc.
- Therefore, adoption of suitable cropping system developed for a particular agro-climatic system to derive additional income and which provides opportunities for better utilization of available land, water and labour resources is required.

Cropping systems:

- Cropping patterns and its management to derive benefits from a given resource base under specific environmental condition.
  Cropping system= Cropping pattern + Management

- It changes when place and environment are changed.
- It means, cropping *system* is location specific.

- Cropping system may also be defined as "a pattern of growing a compatible crop or its combination followed on a particular farm year after year in order to get maximum utilization of land in time and space, in addition to the practices and technologies with which the crops are produced".

Advantages:

1. Better land use efficiency.
2. It ensures more efficient input utilization and generates more employments.
3. Greater interception and harvest of solar energy.
4. Decreased production cost.
5. Sustainable production and farm income.

Criteria/Considerations:

1. Soil enriching crops such as leguminous/high-biomass yielding, should be preferred.
2. Compatibility of crops in respects of light, nutrients, water, space etc. needs to be considered.
3. Optimum utilization of farm resources.
4. Maintaining fertility and productivity of soil.
5. Diverse range of production distributed on time scale.

6. High cash value and short duration crops like vegetables, fillers should be considered on priority.

Cropping Scheme:

- The plan for raising crops on individual plot of a farm should be formulated with the objective of getting the maximum returns from each crop without impairing the soil fertility.

Types of cropping systems in horticultural crops:

Mono-species orchards:

- Mono-species also referred as monoculture.
- In this, fruit trees of a single species are planted in the field.
- This system is common in modern horticulture, where trees are planted densely, using dwarf or semi-dwarf trees with modified canopy to ensure better light interception and distribution and ease of mechanization.

Advantages:

- Such orchards give early cropping, higher yield and productivity of better quality fruits.
- Orchards have lesser labour requirements.
- It gives increased returns.

Disadvantages:

- In the event of crop failure due to unfavourable climatic conditions or adversities in a particular year, growers encounter heavy losses (see unfruitfulness below).
- This system may not be suitable for small growers with marginal holding, who can afford to meet high initial cost of inputs and technologies involved.
- Mono-crop in small and marginal holding, whether with standard or close planting will neither provide sufficient employment to the family members nor give sufficient income to sustain the dependent family members.
- No efficient utilization of land and soil nutrients.

Unfruitfulness:

- Fruit growers facing situation of poor or no fruiting of trees in their orchards, though trees are mature enough to bear sizable crop.
- The studies indicate that there are various external or internal factors associated with this type of situation in the orchard.

External factors of unfruitfulness:

- Amongst the external factors, environmental conditions prevailing just before, during or at the blossoming or fruit set, may play dominant role in making the plants fruitful or unfruitful.
- Also, occurrence of pests, diseases as well as nutritional status of the trees are all important.

Figure 7.1. Use of spreader for enhancing flowering

Plate 7.1. Double "C" method of ringing of tree trunk in pear for early flowering

Internal factors of unfruitfulness:

- The internal factors of the plant itself i.e., hereditary characters, may be equally responsible for making the tree fruitful or unfruitful.
- Considering both the above mentioned factors, the orchardist shall have to manipulate his orchard management practices in such a manner that he will able to overcome them in order to make his plant fruitful.

What are C/N ratio and its relationship with fruitfulness?

- The balance between carbohydrate and nitrogen in plant is known as C/N ratio.
- The fruit bud formation, setting of fruit, and its development mainly depends on C/N ratio in the branches of the trees at certain critical stages of seasons.
- Plants with adequate nitrogen and high carbohydrate accumulation are found to make moderate growth and produce satisfactory crop.
- Plant with excess of nitrogen and moderate carbohydrates are found to grow vegetatively at the expense of fruit production.
- The accumulation of carbohydrates in the branches may be either due to their manufacture or due to less rapid utilization. In plants, which are weak in their growth, carbohydrates may be made to accumulate by supplying them more nutrients and water.
- Certain horticultural practices like branch bending (Fig. 7.1), ringing (Plate 7.1), scoring etc. increase C/N ratio in branches.

Multispecies cropping: It involves growing of large number of compatible crops in the same piece of land.

Advantages:

- This ensures maximum resource use efficiency.
- Helps to meet the diverse needs of the farm family such as food, fuel, timber, fodder
- Ensures continuous flow of cash, from a small farm holding.
- The biomass other than economic part is recycled within the system.
- This is ideally suited for smaller holdings and envisages maximum production per unit area and time, simultaneously ensuring sustainability.

Types of *multi-species cropping systems*:

i). Inter-cropping

ii). Mixed cropping

iii). Sequence/Sequential Cropping

iv). Relay cropping

v). Ratoon cropping

vi). Multi-storey cropping

i. Inter-cropping

- In plantations of fruit trees, inter-cropping is the practice of growing one or more short duration crops between interspaces of trees and rows, to get additional/supplementary income especially during the initial unproductive years of orchard life (Plate 7.2).

Advantages:

- It ensures efficient utilization of light and other resources.
- It reduces soil erosion.
- Suppresses weed growth.
- Helps to maintain greater land occupancy and thereby higher return on space and time.

Plate 7.2: Raj mash as inter-crop in apple orchard *Courtesy: Dr Kuldeep Thakur, Assoc. Prof., UHF, Solan*

Annual crops particularly legumes and high value shallow rooted vegetable crops like cabbage, cauliflower, carrot, radish, tomato, chillies, spinach, potato etc. relevant to areas are grown. In accordance with the cultivation region, some early bearing fruit crops like papaya, banana, pineapple, peach, strawberry etc., also known as ***fillers*** are grown as intercrops.

Precautions:

- The main plantation should be given priority care; otherwise serious losses may occur later as a result of
    - root restriction,
    - damage and infection,
    - undue exhaustion of soil,
    - disease infection.

Therefore, inter-crops are given secondary importance.

ii. Mixed-cropping:

- This cropping pattern is used in vegetable crops, wherein, two or more crops are grown simultaneously without a definite row pattern.
- It is generally practiced with a view to avoid risk in farming.
- It is a type of subsistence farming and ensures different needs of family.
- Mixed cropping is found in many agricultural traditions.
- In the Garhwal Himalaya of India, a practice called *baranaja* involves sowing 12 or more crops on the same plot, including various types of beans, grams, and millets, and harvesting them at different times.

- Growing of corianders on the side ridges of garlic field; sowing of radish over the ridges of potatoes; growing of pole beans between maize rows (Plate 7.3) are some other examples.

Plate 7.3: Intercropping of pole type bean and sweet corn for seed production

iii. Sequence/Sequential Cropping:

- It refers to growing of two or more crops in quick succession on the same piece of land in a farming year.
- Sequential cropping is also called non-overlapping cropping because there is no overlap between the two or more cropping.

iv. Relay cropping:

- Relay cropping is essentially a special version of double cropping, where the second crop is planted into the first crop before harvest, rather than waiting until after harvest as in true double-cropping.
- In this way, both crops share a portion of the growing season, increasing solar radiation and heat available to each. For examples:
- Sowing of corn seeds and French beans on the ridges of tomato field in June will give additional crop as the former is harvested in September after the end of tomato growing season in North-western hilly areas of the countries, while the crop of later sown for fresh vegetable matures in September-October.
- The rotation of corn grown for seed and soybean seems to be well suited to relay cropping because seed corn is harvested in mid-September (earlier than full-season field corn) and the remaining residue is not excessive.

- A winter annual crop, such as winter wheat, could be inserted into the seed corn-soybean rotation to use the solar energy and heat units available between corn harvest in September and soybean planting in May. However, winter wheat is not harvested until mid-July -- far after the optimum time to plant soybean.

Advantages

- It enables farmers to double crop their land
- Enable to produce more home-grown forage.
- It eliminates a time management bottleneck.
- It protects the environment by reducing soil erosion and impacts of manure and/or chemical fertilizer.
- It has potential to reduce nitrate leaching (wheat acts as a scavenger crop), increase carbon sequestration, and increase income for producers.

Disadvantages: Unfortunately, a relay system is not without risk.

- The soybean planting process will likely stress the wheat crop and reduce yield from what would be expected of a non-disturbed crop. Likewise, wheat harvest may stress the soybean crop. The hope is that the two crops will result in greater income (and profit) than either single crop grown without disturbance.
- Relay cropping requires a greater level of management. Wheat must be planted during the soybean and corn harvest season and planting soybean into a standing crop is a new process to most farmers. Also, pest management and control practices must account for more crops being grown in close sequence.
- The system may not allow time for herbicide carry-over levels to decline and may increase the potential for insect and disease infestations if these pests have more than one host in the crop sequence.

v. Ratoon cropping:

- A *ratoon crop* is the new cane which grows from the stubble left behind is harvesting (Plate 7.4).
- This enables the farmers to get three or four crops from these before they have to replant.
- The principles involved in ratoon cropping, a form of sequential copping, are different from other types of multiple cropping because of such factors as the presence of a well developed root system, earlier maturity, and the perennial nature of the plant.
- Although the term may be applied to perennial pasture plants, it is considered more appropriately used with respect to field crops such as sugar cane, sorghum, banana (*Musa sapientum, M.cavendishii*), cotton, kodramillet (*Paspalum scrobiculatum*), pineapple (*Ananas comosa*).

Plate 7.4. New plantlets emerging from the roots of mature banana plants

Advantages:

1. Reduced cost of production through savings in land preparation and care for the plant.
2. Reduced crop cycle: crop planted less often, so replanting cycle is longer.
3. Better use of growing season.
4. Higher yield per unit area in a given period of time.
5. Ratoon crop uses less irrigation water and fertilizer than main (original) crop because of a shorter growing period.
6. Simple and effective way to provide windbreaks for vegetable production.

Drawbacks: Ratoon cropping has a number of drawbacks, which include:

1. Later crops have lower yields than the first crop;
2. Build up of insect pests;
3. Build up of harmful weeds;
4. Increased disease problems;
5. Greater cost per unit produced;
6. Where heavy equipment is used, the soil may become hard resulting in poor drainage and subsequently cause depletion of soil oxygen level for roots;
7. Decrease in crop density (number of plants per unit of land).
8. Growth of volunteer seedlings inferior to sown variety.

vi. Multi-storied cropping: Multi-storied cropping is a practice, which is in use in plantation crops in tropical humid climates of India (Plate 7.5). This has been discussed in detail in chapter 5.

Plate 7.5. Agro-forestry experiments fodder grass in coconut garden

F.A.Q.:

1. Explain the concept of proper land use in space and time dimension in fruit production.
2. Where mono-species cropping is adopted in modern fruit production.
3. Give at least two drawbacks of mono-species cropping.
4. Name three multi-species cropping systems in horticulture.
5. What is the major advantage of inter-crop in fruit plantations?
6. What precautions should be taken in inter-cropping system.
7. Give one example of mixed-cropping.
8. Explain relay-cropping citing suitable example.
9. What are the pro and cons of relay cropping?
10. Name important fruit crops suitable for Ratoon cropping.
11. Give two advantages and disadvantages of Ratoon cropping.
12. What do you mean by multi-storied cropping?
13. Give two examples of multi-storied cropping.
14. In which parts of India multi-storied cropping system is followed?

LECTURE – 8

SYSTEMS OF IRRIGATION

Objectives: To meet water requirement of fruit crops at critical stages of growth and development.

Introduction:

- Despite the fact that nearly 75% of the total area on the earth's surface is occupied by water. This can be traced to the fact that 97.3% of the water is in oceans and seas. Only 2.47% is the fresh water. Water is a vital factor and natural resource for the growth of any living organism, and is a limiting factor for plant growth. It is the most important in supporting all forms of life.
- Plants also require water for their better growth and production.
- Where there is shortage of water, particularly during critical stages like flowering and fruiting, there can be drastic reduction in yield. Hence, the necessity of irrigation is to make up this deficiency of water. The water needs of any orchard depend upon.

1. Annual rainfall
2. Periods of water shortage
3. Types of crops and cropping
4. Expected increase in production with irrigation
5. Type of soil
6. Annual rainfall
7. Periods of water shortage
8. Types of crops and cropping
9. Expected increase in production with irrigation
10. Type of soil

- Availability of water for irrigation has an enormous impact on the success of commercial fruit growing.
- However, where rainfall is normal and well distributed, it is also feasible to grow certain fruit crops under rain-fed conditions.
- In India, temperate fruit cultivation is mostly confined to such areas, which is the main cause of low productivity.
- However, proper management of rain water by using appropriate water harvesting techniques, its judicious use and moisture conservation practices can increase water use efficiency and consequently productivity.
- Where irrigation water is available, its optimum use shall determine the tree's performance in terms of growth, vigour and yield. Therefore, water management practices such as irrigation; rain water harvesting and moisture conservation practices should be followed on scientific lines to get maximum return from the orchard.

Irrigation:

- It is defined as the artificial supply of water to support plant growth and production in absence of adequate supply of water through rainfall is known as irrigation.
- Irrigation is very important in fruit crops as sufficient moisture must be maintained in soil for obtaining yield of good quality fruits. There are three important aspects of irrigation:

  i) Time of irrigation
  ii) Quantity of water in required.
  iii) Appropriate System irrigation

Systems of Irrigation:

- Several methods of irrigation are employed in orchard depending upon age of the trees, topography of soil and availability of irrigation water. Descriptions of commonly adopted methods of irrigations are outlined below:

1. Surface irrigation: Flood system, basin, boarder method, Furrow method etc.
2. Sub-surface irrigation: Drip irrigation
3. Overhead irrigation: Sprinkler irrigation

Flood system: In this system, whole orchard area is irrigated through one head *i.e.* without sub-division of the unit area into small plots (Plate 8.1).

- Follow this method if the land is flat and levelled and plenty of water is available.
- The method is useful where intercrops or green manuring crops are grown in the orchard.
- In this system, wastage of water is more; weed growth is excessive, risk of bark diseases like collar rot or foot rot exist as the tree trunk remain in contact with water for a longer time.
- It is suitable for orchard attaining more than 8-10 year of age.

Plate 8.1: Flood irrigation in tomato field   Plate 8.2: Furrow irrigation in tomato field

Advantages:

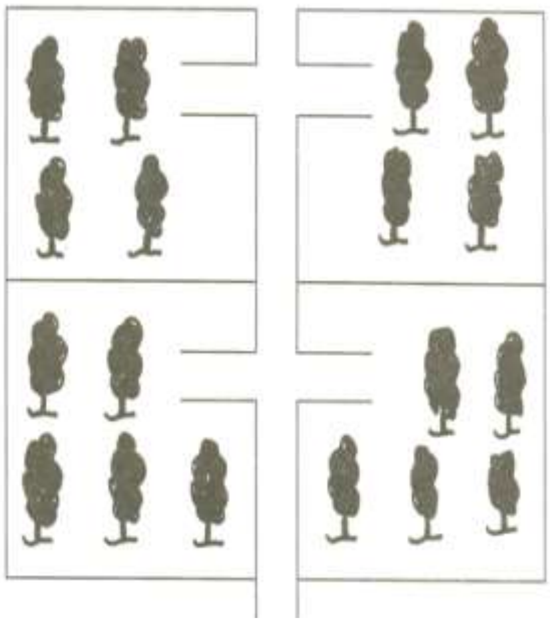
- The entire soil gets fully saturated with water without leaving any dry pocket in it.
- As involvement of labourer is less, the operational cost is also less in this method.
- Rodents are controlled to considerable extent.
- By flooding trees are well protected from frost as the latent heat of water is more.

Disadvantages:

- The orchard trees badly suffer due to over-irrigation if the irrigation water is not drained off quickly and timely.
- The method can't be used unless the land is even.

Check basin:

- Prepare basins of desired size and shape (circular, rectangular, square) around each plant depending upon age of the plant and topography of land.
- After the rains, trenches are formed between the rows of banana plants (Figure 8.1).
- In some cases (In Poovan and Monthan, in Tanjore area) 60 cm wide and 45 cm high trenches are dug between alternate rows of plants.
- Irrigation water should not directly touch the trunk as there is a risk of disease infection. In tree fruit crops (citrus), heaping of soil around the trunk should also be avoided as it keeps the wet soil in contact with scion portion leading to soil borne diseases like gummosis.
- The basins should, therefore, be made slopping downwards from the tree trunk.



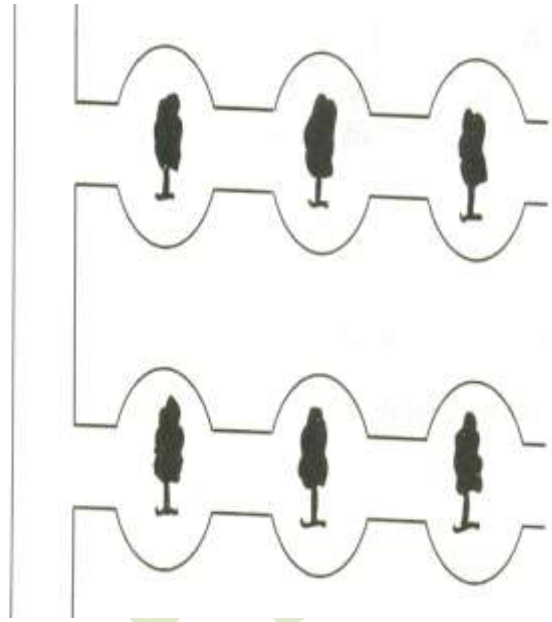


Figure 8.1: Check basin system of irrigation **Figure 8.2: Basin system of irrigation in fruit crops**

Advantages:

- The distribution of water takes place more uniformly.
- The chance of over-irrigation is less as the entry of irrigation water in the beds is regulated.
- The soil is made to saturate more evenly.

Basin system.

- In this system, basins around the trunk are linked directly with one another through strait channel (Figure 8.2).
- Water wastage and weed growth are less in this system. However, water passing through the channel touches the tree trunk directly and hence risk of spreading of bark diseases is more.
- Water flows also draw away the manure from the tree basin and deposits it at the end of channel. This system is suitable for young fruit trees.

Advantages:

- Helpful especially in loose textured soil where flooding or furrow method has limitation.
- Water stagnation in a basin dose not takes place as the excess water flows to the next basin and is finally drained off.

Disadvantages:

- The nutrients present in the soil in a basin are washed away and move to the next basin.

- The soil-borne pathogens, if exist in the soil of a basin are carried to the other basins and thereby, the soil of those basins are also contaminated.

Modified basin system.

- This is an improved system over the basin system.
- In this system, main channel runs in between the tree lines and the basins are linked independently through small sub channels.
- Attention should be paid to block the sub channels after basin has received adequate water. The size of basin is increased with the increase in tree canopy size every year.
- This is a good system of irrigation for young orchard up to 6-8 years of age and also for arid regions, having water shortage. Incidence of bark diseases are less and intercropping is possible.

Furrow method:

- This system suitable for vegetable crops (Plate 8.2) and in sloppy orchard land areas, particularly for old orchard.
- Make 20-30 cm deep furrows on either side of the tree at proper distance depending upon age and spread of the plant.
- Restrict the furrow length to 80-100 feet only to avoid wastage of irrigation water.
- In this system, the water moves slowly in furrows in the area between the rows. The trees are fed through the lateral movement of water.
- The consumption water is less in this system and there is no risk of bark diseases.
- Saturation of root zone is comparatively less. Not suitable for intercropping and green manuring.

Advantages:

- Evaporation loss of water is less.
- The irrigation water is able to reach greater depth of the soil.
- For such fruit crops which are needed to be earthed up occasionally as in banana, the method is preferable. This is because, earthing-up is done automatically while opening the furrows.
- Where the soil is of higher clay content, the method is considered to be particularly suitable.

Disadvantages:

- The method is not suitable in porous soil for high vertical percolation.
- Many feeder roots lying close to the soil surface may be damaged or cut off while opening the furrows.

Border Method:

- This method is also called as the Sara method.
- To irrigate by this method, the land is divided in to long strips by relatively broad ridges.
- Each strip is then irrigated with a water channel unless it is thoroughly saturated.

Pitcher system.

- Pitcher with a hole at the bottom is buried in the tree basin where feeder roots are confined (Figure 8.3).
- When it is filled with water, water is released slowly as droplets, which meet the water requirement of plant.
- Number of pitcher per tree depends upon the spread of the tree. However, 4 to 5 pitchers per tree are sufficient for the tree having 3 m spread.
- This system is highly a boon in the arid region where availability of water is limited.

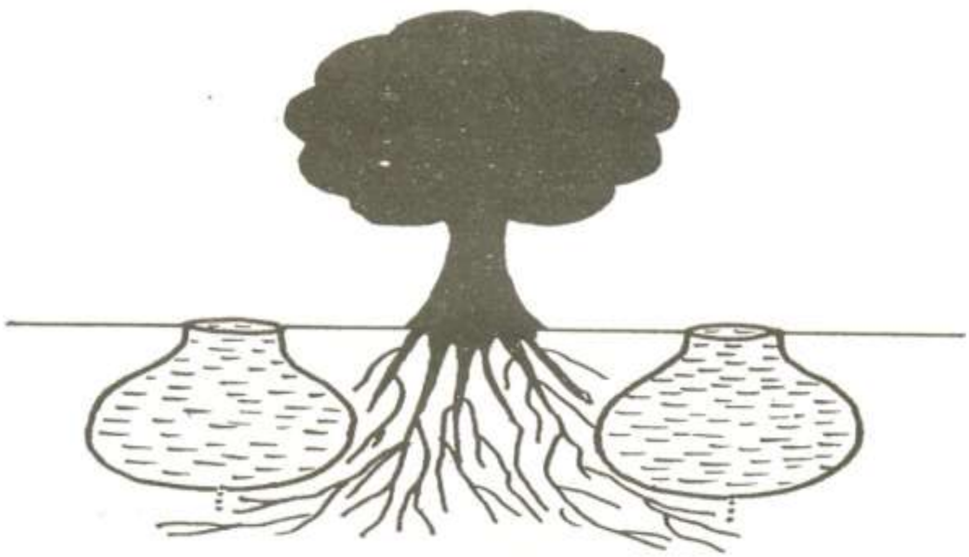


Figure 8.3: Pitcher system of irrigation for fruit crops in arid region.

Drip irrigation system.

- In this system of irrigation, water supplied to the plant is equivalent to its *consumptive use*. This is a highly *water use efficient* (WUE) system of irrigation having very less water requirement.
- This is an outstanding irrigation technique especially for arid region, where there are two basic constraints for surface irrigation, namely undulating land terrain and less water availability.

- A drip irrigation has four basic components: *suction*, *regulation*, *control* and *discharge*, which are accomplished by water lifting pump, hydro-cyclone filter, sand filter, fertilizer mixing tank, screen filter, pressure regulator, water meter, main line, lateral and dripper (Figure 8.4 & Plate 8.3).
- After lifting, the water passes through hydro cyclone filter, sand filter, fertilizer mixing tank and screen filter and ultimately through dripper.
- Coarser sand particles, relatively finer particles and very fine particles are filtered through hydro cyclone filter, sand filter and screen filter, respectively.
- These filters are essential for smooth running of water through laterals and drippers otherwise chocking of laterals may takes place.
-

Types of drip irrigation systems:.

- High pressure drip system. This operates at more than 30 psi pressure.
- Low pressure drip system. This operates at less than 30 psi pressure.

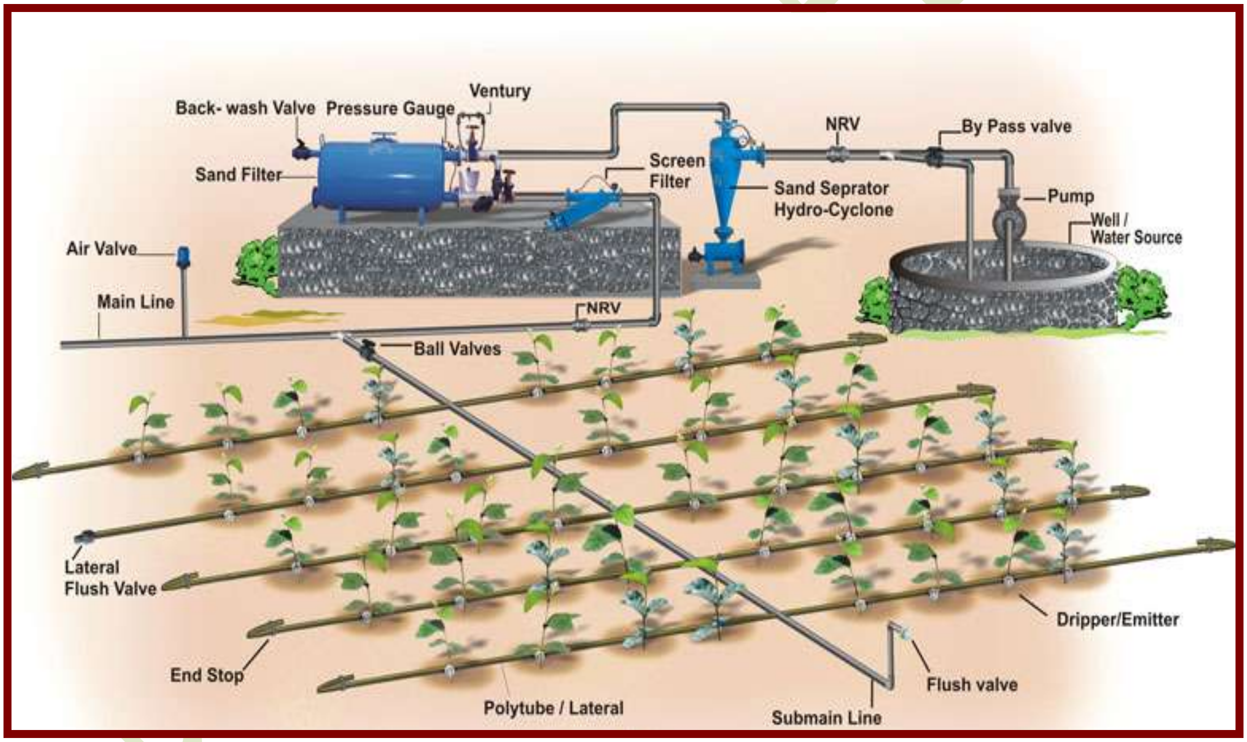


Figure 8. 4: Lay out plan for drip irrigation system for horticultural crops

Plate 8.3: Drip irrigation in papaya (left) and kiwifruits (right)

Advantages:

1. Water saving to the tune of 30 to 70 per cent.
2. Increase yield and fruit quality.
3. Higher returns per unit area and time.
4. It saves labour cost.
5. Improved water penetration.
6. Eliminate soil erosion.
7. Reduced weed growth.
8. Saving in fertilizers and chemicals (40-60%).
9. Poor quality water can be used more safely.
10. Even undulated land can be irrigated.
11. Better pest and disease management.
12. Eco-friendly technology.

Scheduling Irrigation:

- Orchard is irrigated to supplement the deficit in soil water storage.
- Proper scheduling of irrigation involves the use of soil, plant and climatic parameters, so as to achieve maximum productivity.
- It is essential to determine the field capacity and permanent wilting point of the soil by gravimetric method.

- Set up tensiometer in the field to monitor changes in moisture level to determine the time of irrigation.

Soil parameters

- Root zone soil profile moisture give fair account of the irrigation requirements.
- Moisture in the soil between FC(field capacity) and PWP (permanent wilting point)is the available water to the plant and this moisture content varies with soil texture, and structure, rooting depth and water extraction capacity of plant species.
- Depletion of available water is replenished with irrigation.

  - The appearance and feel of the soil at different profile depths also indicate its moisture status.
  - Irrigation requirement can be calculated by adding the moisture deficits of each profile and giving allowance for irrigation efficiency.
- The state of water in the soil can be more precisely expressed by its content or energy status. The moisture content can be measured by gravimetric (drying samples at 105^{o}) or volumetric (ratio of volume of water to bulk volume of soil) measurement.
- Estimation of water extraction from soil can be made from the pre-calibrated relation between the difference in evaporation from black and white atmospheres and water extraction from soil for use in irrigation practice.
  - The component forces which influence energy status and make up total soil water are:
    - ✓ gravitational (Z), Matrix (M) and osmotic (O) given by Ψ =Z+ M+ O.
  - Since osmotic potential in most normal soil is negligible, matrix potential is usually measured by techniques, such as pressure plate apparatus, pressure membrane apparatus, thermocouple psychrometer, tensiometer, electric resistance meter, neutron scattering etc.

Plant parameters

- Though wilting is the most common sign of water deficit but, at this stage, there is a significant adverse effect on the growth of plants.
- Visual plant symptoms such as change in foliage colour, leaf angle; reduced growth, etc. provide fair indication about the irrigation requirement of trees.
- However, measurement of plant water status is the most practical approach for scheduling of irrigation.
- Leaf water potential is considered a good measure of plant water status for scheduling irrigation.
- Transpiration rate from the leaves is also correlated with the plant water status.

Climatic parameters

- Climatic factors, such as rainfall, temperature, relative humidity and wind speed determine the pattern of water loss from soil through evaporation and from plant surface through transpiration.
- While the loss from the soil surface gets progressively decreased with the spread of canopy cover with the tree age, that from plant surface depends upon the crop coefficient (Kc), a ratio between evapotranspiration (ET) under a crop and the potential evapotranspiration (PET) or potential evaporation (Ep) or pan evaporation (PE).
- This evaporative demand mainly determines the amount and frequency of irrigation, keeping in view the incidental soil moisture condition.
- The PET can either be estimated by mathematical computations from weather data or can be evaluated by standard evaporimeters.
- The ET is insignificant.
- The cumulative pan evaporation (CPE) data are used for scheduling irrigation.
- Since the irrigation water depth (IW) varies with tree age, fruit crop and soils, the IW/CPE ratio is commonly used for this purpose.
  - ➢ In fruit crops, critical stages of growth/developmental stage should also be considered.
  - ➢ In full bearing fruit trees, growth flushes, fruit set and fruit developmental stages are considered critical for irrigation.

Water requirement:

WR = Wa + Ws + Wm or Wi + Wr +Ws + Wg + Wd

Where, Wa = Non avoidable losses in run-off, seepage, deep percolation, weed growth, etc.

Ws = losses through transpiration

Wm= Quantity of water needed for metabolic activity

Wi = Irrigation water

Wr = Contribution of effective rainfall

Wg = Ground water

Wd = Stem flow

- ➢ Water requirement for individual fruit crop (Table 8.1) would, thus depend on its irrigation needs besides the several factors which contribute to losses and gain of water in the orchard.
- ➢ However, optimum water requirement is that which results in maximum yield. This varies with stages of growth and development of fruit plants.

Table 8.1: Water requirement for different crops:

Sl. No.	Crops	Spacing(m)	Water requirement (ltr./pl/day	
			Minimum	Maximum
1	Mango	8.0x8.0	50	100
2	Banana	1.8x1.8	04	11
3	Coconut	8.0x8.0	55	120
4	Cashew	7.5x7.5	40	95
5	Oil Palm	7.5x7.5	40	95
6	Ber	6.0x6.0	30	70
7	Sapota	10x10	80	175
8	Citrus	5.0x5.0/6.0x6.0	20	65
9	Guava	6.0x6.0	25	70
10	Grapes	3.0x3.0	25	70
11	Pomegranate	5.0x2.0/5.0x3.0	20	65
12	Arecanut	2.7x2.7	07	18
13	Rose	0.75x0.75	01	08
14	Jasmine	1.5x1.5	03	05

For example Mango with 8.0x8.0m spacing taking 75 lit./plant/day on an average

Length of irrigation with 2 -
Drippers of 4 ltrs discharge/hr. } = $\frac{\text{Water requirement}}{\text{No. of drippers x dripper discharge}}$

ie. $\frac{75}{2x4}$ = 9.375 = 9.4 hrs.

Total water requirement per ha. = 75x 156 (No.of pl. /ha.) = 11700 lit./ha.

Maximum area that could be covered with }
a pump discharge of 10,000 ltr/hr. for 9.4 hrs.} = $\frac{\text{Pump discharge x hrs of pumping}}{\text{Water requirement / ha.}}$

= $\frac{10000 \times 9.4}{11700}$ = 8.03 ha.

F.A.Q.:

1. Name three aspects of irrigation.
2. Name different systems of irrigation.
3. Name the most efficient irrigation system.
4. Which traditional irrigation system is better for young orchard?
5. Name newly developed irrigation for fruit plantations in the arid zone.
6. Give four basic components of drip-irrigation system.
7. Which system is suitable for eliminating soil erosion?
8. What is fertigation?
9. Give three basic criteria for scheduling irrigation.
10. Give the full form of FC and PWP.
11. What is available water?
12. What is consumptive use of water?
13. Name important climatic parameters that govern irrigation requirements.
14. Define optimum water requirement.
15. Name most important plant parameter that suggests water status of the plant.
16. What are the advantages of drip-irrigation?

LECTURE – 9

SOIL MANAGEMENT IN RELATION TO NUTRIENT AND WATER UPTAKE

Objective: To know the effect of different soil management practices on nutrient and water uptake by fruit plants in the orchard.

Introduction:

- Soil is one of the most important factors associated with the success or failure of fruit production.
- Most of the soil management practices in the orchard enhance nutrient and water supply needed for growth and production of fruit trees.
- This they do so by improving soil nutrient status, conserving soil moisture, altering of soil properties like soil pH and soil structure, maintaining soil organic matter contents and useful soil organism.

Nutrient uptake:

Sod culture and cover crops:

- Practice of establishing a complete sod cover on the orchard floor often cause a reduction in vigour and growth of the fruit plantations, which is commonly associated with reduced nutrient uptake, particularly the nitrogen.
- Fruit trees under permanent sod usually have lesser leaf nitrogen contents, particularly during mid to late growing season.
- In order to maintain soil fertility status, mowing down of sod should be done regularly, in addition to adequate nitrogen fertilization.
- Interestingly, nitrogen return to the orchard floor via sod clipping is estimated to be higher at 400-600 kg ha^{-1}, and overall total soil nitrogen under sod is higher than over herbicides and clean cultivation.
- Sod cover also supplies high amounts of available nitrogen, however, it also uses large amount of the available nitrogen as it is mineralized and thus decreases its availability to the tree roots.

➢ On the contrary, sod culture usually increase leaf phosphorous concentration in apples.
➢ Elevated leaf phosphorus concentration may be due to an inverse relationship between phosphorus and nitrogen uptake or more mobility of phosphorus induced by mycorrhizal infection transferable from cover crops to the tree roots.

- Sod can also increase leaf potassium concentration and reduce leaf scorch symptoms typical of potassium deficiency.
- Potassium returns are high from sod clippings with annual estimates of 600 kg ha^{-1}, for orchards under long term sod culture.

- Sod cover may increase soil and leaf calcium and magnesium contents and decrease leaching losses from the soil. However, if magnesium supply is inadequate, it may be associated with a sod-induced increase in leaf potassium.
- Sod may also decrease iron deficiency symptoms as observed elsewhere in apple.

Mulching:

Nitrogen:

- Organic mulches add significant amount of nitrogen to the soil and consequently improve soil fertility, which may cause long term beneficial effect to orchard nutrition.
- Decomposable mulches increase soil organic carbon contents and soil with a favourable C: N ratio expected to increase leaf nitrogen concentration as a result of increase in available soil nitrogen.
- In addition, mulches whether organic or inorganic, suppress the competition for nitrogen by under tree vegetation.

Phosphorus:

- Available phosphorus generally increases in orchard soil under decomposable mulches, especially seaweeds.
- Average water-extractable phosphorus has been estimated to be around 20 mg l^{-1} beneath the mowed grass mulching on the top of herbicide strip in comparison to 3 mg l^{-1} beneath sod between the rows.
- In spite of this, leaf phosphorus concentration is often reduced due to reduced under tree vegetation in mulched trees, apparently as a consequence of increased nitrogen uptake.

Potassium:

- Increased soil potassium availability as a consequence of mulching with hay and straw is generally noticed.
- This reflects large amount of potassium is added to the soil by many mulching materials; alternatively, improved potassium availability may also be due to reduced potassium fixation. Whatever the reason may be, more leaf potassium concentration as a consequence of organic mulching is most frequently observed.
- However, increased leaf potassium under mulching adversely affects leaf calcium and magnesium concentration, despite of increase in soil calcium and magnesium concentration.

Magnesium

- Magnesium deficiency in apple is more pronounced under mulch than sod.
- Organic nutrient content of soil and the kind of mulching material are also important consideration in interpreting such contradictory results.

- Conversely, mulching increases leaf boron concentration and thus may help to combat its deficiency (Plate 9.1).
- This may be related to the increase in warm water soluble boron under mulches.

(Source: ohioline.ag.ohio-stste.edu)

Plate 9.1: Symptoms of corky spots on Melrose apple

Cultivation:

- Cultivation often increases the availability of soil NO_3-N, especially relative to full ground cover.
- However, there is always seasonal variation in NO_3-N, which is associated with the extent and timing of weed and cover re-growth.
- Cultivation accelerate the mineralization of organic matter and increase NO_3-N availability, however total nitrogen tends to decline under cultivation.
- Cultivation improve leaf size and colour, leaf nitrogen concentration and availability of soil nitrogen.
- This may be due to mineralizing of nitrogen from the soil. However, cultivation may increase leaf nitrogen in the short term, but in the long term, it may not consistently increase leaf nitrogen.
- Cultivation may not have a major role in affecting the soil contents of other nutrients, however it affect leaf concentration of some of these.
- Different experimental reports suggest that leaf phosphorus and potassium increase and leaf calcium concentration decreases under cultivation.

Herbicides.

Nitrogen:

- Soils in orchard under herbicide weed control are richer in NO_3-N in comparison to grasses orchards, and its value in the former may be as high as 21 mg cm^3 in the former compared to 10 mg cm^3 of soil in the later during the mid summer.
- Effect of herbicides on leaf nitrogen content is variable. It may increase leaf nitrogen temporarily, due to removal of competition or may not affect leaf nitrogen concentration consistently.
- Variation of this effect in comparison to other practices such as cultivation and mulching may relate to variation in soil nitrogen mineralization potential and initial nitrogen status of the trees.
- Among different herbicides, simazine might affect nitrogen nutrition directly as it may increase leaf nitrogen concentration, but only in certain growing condition.
- Amitrole plus simazine herbicides can partially substitute nitrogen.

Phosphorus:

- Soils of untilled herbicidal strip accumulate greater quantities of phosphorus than under grassed alley, probably from the applied phosphorus.
- However, leaf phosphorous concentration is usually lower in trees under herbicidal strips than under grass.

Potassium:

- Potassium concentration normally does not vary considerably in the soils under herbicidal plots in comparison to phosphorus.
- However, vegetation control with herbicides generally causes a reduction of fruit trees leaf potassium concentration, which is occasionally accompanied by an increase in leaf magnesium.

Calcium and magnesium:

- Surface soils under herbicidal plot usually are much lower in exchangeable calcium and magnesium.
- This is related to the cycling of these cations by orchard floor vegetation since it is known that vegetation reduces leaching of these cations from the surface soil.
- Leaf calcium concentration however, varies with the type of herbicide.
- Higher leaf calcium concentration can be observed with Paraquat treatment, whereas a combination of Paraquat plus simazine has little effect.

Soil moisture and water uptake:

- The efficiency of orchard soil management method is generally judged by its ability to conserve soil moisture and make it available for use by the trees for growth and development.
- However, in certain circumstances, some soil treatments are given with the purpose of reducing, at least temporarily, water content of the soil.
- In water logged areas, sometimes soil is dried out in the fall for the purpose of hastening maturity, and in heavy compact soil tiling simply to provide better aeration may sometimes be profitable.
- In general, soil management aims at conserving soil moisture rather than dissipating it.

Sod culture and cover crops:

- Soil under permanent grass may begin to lose water 15-30 days earlier in the spring as comparison to the cultivated soil.
- Grasses in orchard require a large proportion of water for maintaining growth, and therefore in non-irrigated orchards this competition of water with fruit trees can become critical.
- The extent of soil moisture depletion varies with the vigour, rooting depth, and frequency of mowing of the orchard sod.
- Shallow rooted grasses such as Kentucky bluegrass (*Poa pratenses* L.) or annual blue grass (*Poa annua* L.) deplete less moisture from the orchard soil profile than deep rooted sods such as Landino clover (*Trifolium repens* L.) or S.23 perennial ryegrass (*Lolium perenne* L.).
- Competition of sod with fruit trees also modify the pattern of water depletion with more water being used from deeper in the profile.
- In summer, regular mowing of grasses is suggested to conserve moisture in soil by reducing water use by grasses.

➢ On the other hand, sod improves other physical properties as reflected by decrease in bulk density and increase in soil porosity.

➢ Decrease bulk density means an increase in total pore space available for root growth and increase in water holding capacity.

➢ Such changes are likely to increase earthworm populations.

➢ Such changes are expected to reduce surface moisture runoff and erosion and moisture conservation.

Mulching

- It is well recognized that conservation of soil moisture is the most significant advantage of mulching.
- This useful effect is more pronounced during the drying periods of May-June.

- The general improvement in soil moisture is likely a consequence of both improved infiltration capacity, particularly under hay, straw or pine needle mulch and reduced evaporation.
- However, the moisture conservation properties of organic mulches on a silt-clay soil may sometimes be undesirable; as such soils are likely to become susceptible to water logging in winter.

Cultivation

- Removal of weed and cover crop competition by cultivation increases soil moisture content relative to permanent orchard vegetation.
- However, moisture content of cultivated soil may not differ significantly from mulched soil, and may be less than herbicide-treated soil.
- Also, the moisture content of cultivated soils may show considerable seasonal variation depending upon the time of cultivation and cover crop or weed re-growth.

Herbicides

- In general, herbicide-treated orchard soils have a lower soil moisture deficit in comparison to grassed or cover cropped soil.

F.A.Q.:

1. How sod/cover crops reduce leaf scorch symptoms?

2. Why fruit orchards under permanent sod require additional nitrogenous fertilization?

3. How mulching increase available nitrogen?

4. Availability of which nutrients are increased under mulch.

5. How clean cultivation increased NO_3-N availability?

6. Why exchangeable Ca is higher under herbicidal strip?

7. Name most efficient system(s) for conserving soil moisture.

LECTURE 10

SOIL MANAGEMENT: EFFECT ON SOIL PROPERTIES AND SOIL ENVIRONMENT

Objectives: To know the effect of different soil management practices on soil structure, soil organic matter content, soil pH and soil environment.

Introduction:

- Soil may be fertile or infertile. Even a fertile soil may not be necessarily productive. Therefore, the aim of a soil management practice is to keep soil in good physical condition, improve its fertility and make it productive.
- Soil management practices greatly influence the soil environment.
- All the soils are not suitable for successful fruit growing.

Effects of different management practices on soil properties and soil environment have been discussed below.

Soil properties:

Organic matter

Sod culture and cover crops:

- Increased soil organic matter content in orchards appears to be a natural consequence of sod culture (Plate 10.1).
- In the top 5 cm soil, about 2% increase in organic carbon in comparison to cultivation has been noticed.
- Decaying of cover crop roots can increase organic matter, but only to their rooting depth.

(Source:*www.dpi.nsw.gov.au*)

Plate 10.1: Sod culture in citrus orchard

- The benefits of increased soil organic matter content can be seen in improved physical and chemical properties, including in nutrient exchange capacity, water absorption, soil structure, and maintenance of a healthy soil flora and fauna.

Mulching

- Addition of organic mulching materials to orchard soil surfaces also conserves and can even increase the organic matter content of the orchard soils.
- The nature of organic mulch can also influence the potential increase in organic matter.
- For example, organic matter content of soil is higher under hay mulch than under seaweed or sawdust, since the later decomposes very slowly.

Cultivation

- It is well known that there is a rapid decline in soil organic matter content under clean cultivation.
- It has been seen that the decline in organic matter content is particularly pronounced for surface layer of the soil.

Herbicides

- In general, the tree rows of orchards, in which herbicides have lower soil organic matter content than grassed alley.
- In some experimental studies, organic matter remained constant for the initial few years after killing of grass with herbicides, but later it tended to decline. It may be because of the fact that the use of herbicides in no-till management may preserve temporarily the original distribution of organic matter in the soil profile, as compared to tillage, but in the later years the organic matter content was found usually lower than that under the sod.
- Soil organic matter is generally higher in soil under continuous tillage, probably because the natural compaction the soil surface provides conditions less favourable for mineralization.
- However, soil organic matter can be expected to decrease with continuous herbicides use due to less plant material being returned to the soil.

Soil pH:

Sod culture and cover crops

- Soil pH is generally higher in orchards under grass than when orchard vegetations are removed.
- However, it is unlikely that the existence of sod can prevent the inevitable pH decline associated with continuous use of acidifying nitrogenous fertilizers.
- A pH decline from slightly acidic to 4.1-4.4 is common in fertilized [$(NH_4)_2SO_4$] and herbicide-treated plots, in the long term.

Mulching

- Long term use of mulching may result in higher pH due to transfer of calcium and magnesium into mulched area of the orchard.
- However, there is little consistent research data to support this, and more frequently mulches do not affect soil pH.

Cultivation

- Soil pH can decline in cultivated soil in comparison to orchards with permanent sod or cover crops. This has been attributed to increase in leaching of calcium and magnesium from the soil surface of cultivated plots.
- Other ground vegetation treatments may also have the similar effect on pH decline. Incorporation of lime before planting can help to maintain soil pH and prevent the problem of acidity in the orchard.

Herbicides

- Long term use of herbicides in an orchard usually causes decline in soil pH.
- Although, there is a considerable variation in the rate of soil pH change in different locations, which is due to the variable soil properties, fertilizer application, and moisture regimes at different locations, however there is consistent reduction of soil pH with the use of herbicides in all the orchards.
- Moreover, soil in orchards under herbicide treatments has lower pH at all the different tree rooting depths.

Soil temperature:

Sod culture and cover crops

- Soil temperature affects fruit tree performance.
- Year round temperature fluctuation of top soils (10- 25 cm) under sod is intermediate. It is several degrees Celsius cooler in the summer and warmer in the winter relative to year round cultivation on straw mulch.
- However, day night temperature fluctuation in orchards under sod may be greater in spring, owing to heat losses to radiation.
  - Soil temperature may influence fruit tree indirectly by its relationship with air temperature.
  - Although summer air temperature in orchards with sod have been observed to be cooler than in orchards with tilled bare soil, differences have been observed mainly in spring during radiation frosts.
  - Such frosts occur on clear nights when unchecked soil radiation cools the air nearest the soil below freezing.
  - Since, orchards with permanent vegetation have cooler spring soil temperatures than tilled, herbicide used, or plastic-mulched soil, the amount of heat to be radiated is less.

- In addition, grass or other vegetation has a larger surface area for radiation to the air above and looses heat rapidly.
- In the temperate regions, orchards under sod are about 2-3 ^{0}C cooler than the bare soil. Therefore, grasses under trees should be cut during blossoming time to reduce spring frost injuries to floral parts.

Mulching

- Organic mulches generally insulate the orchard soil and consequently decrease the fluctuation in daily and annual soil temperature extremes.
- Soil temperatures beneath mulch in summer are frequently lower, especially on day with high incident solar radiation.
- Mean monthly temperatures at 10 cm depth below a 10-20 cm thick straw cover have frequently been 1^0- 2^{0}C less than those beneath bare soil in the summer months while during the winter similarly measured temperatures could be 1^{0}C higher under mulch relative to bare soil.
- Mean daily summer season soil temperatures are about 2- 3^{0}C higher under black plastic mulches than organic mulches.

- Mulch-induced soil temperature changes can be important if they are near critical thresholds. For example, in countries in the Northern hemisphere, where summer temperatures are lower than warmer countries, organic mulching reduces the summer temperature to the level at which it has negative effect on apple fruit quality.
- The reduction in heat transfer from soil under straw mulch to atmosphere during cool spring periods could increase the risk of frost damage at the time of flowering of certain temperate fruits e.g. almond, apricots, apple etc.
- In areas where winter damage to fruit trees can be of concern, extreme soil and air temperature fluctuation under mulching with black plastic also has a risk of accelerating the effect of frost damage to fruit trees.

Cultivation

- Daily summer temperature of soil under cultivation tends to exceed by 1-3 ^{0}C than those under mulch or sod.
- In contrast, during winter daily soil temperatures are normally 1^{0}C cooler.

Herbicides

- Summer soil temperature under herbicide is usually higher than the soil under sod.
- However, it can be lower by 2- 4^{0}C when compared with soil temperature under black plastic.

Other soil properties/environment:

Sod culture and cover crops:

- Sod and cover crops usually improve other physical properties as reflected by decrease in bulk density and increase in soil porosity.

Mulching:

- Use of organic mulches in orchards is also beneficial in improving soil properties such as increase in porosity and development and stability of a desirable soil structure.
- This useful effect of mulching can be attributed to a regular supply of organic matter, especially in fine textured soils, to the protection of soil surface from raindrop impact and to retardation of soil surface slaking and sealing.

Cultivation

- Compared to other soil management systems, cultivation frequently results in a deterioration of other soil physical properties.
- Increase in bulk density, decrease in stability of soil aggregates, macro-porosity and oxygen diffusion in fine-textured silt soils can occur under clean cultivated plots.
- Other disadvantages of clean cultivation are rapid deterioration of soil structure and possible development of hardpan layer restricting root growth immediately below the zone tillage.
- Over long term cultivation practice in an orchard, soil aggregation deteriorates resulting in increased susceptibility of soil to crusting and impeded drainage.
- However, regular cultivation in orchards with gravely soils is unlikely to cause any serious impact on the soil.

➢ Decreases in soil infiltration capacity and saturated hydraulic conductivity of cultivated orchard soils can deteriorate physical properties of soil and cause water runoff.
➢ Thus, this can adversely affect growth of fruit trees, particularly peaches which require well aerated soils.
➢ For this reason, several alternate soil and water conserving systems of cultivation such as contour or strip cultivation, trashy cultivation and annual cover crops in combination with minimum early spring cultivation can be suggested.

Herbicides

- Bulk density of herbicide-treated soil can be about 10% higher than grassed or cultivated soil.
- Long time herbicide use also affects pore size distribution but the proportion of large pores (> 15 m) may not necessarily reduce.
- A reduction in total pore volume can occur by reducing pores within a limited range of pore sizes or across the entire range, depending on the soil.

F.A.Q.:

1. Why day night temperature fluctuation is greater under sod?
2. Which systems of management keep soil cooler in summer and warmer in winter?
3. Why grasses under mulch should be cut during spring?
4 Suggest practices for improving organic matter content of soil in orchards.
5. What are the effects of different soil management systems on soil pH?
6. How sod culture, mulching and clean cultivation affect soil physical properties?

LECTURE – 11

INTEGRATED NUTRIENT MANAGEMENT IN FRUIT CROPS

Objective: Maintenance and improvement of soil fertility and plant nutrient supply at an optimum level for desired crop productivity.

Introduction:

- In case of integrated nutrient management, all types of nutrients are supplied in the form of organic or inorganic manures and fertilizers to maintain uniform soil fertility.
- Continuous use of fertilizers spoils the soil structure and soil becomes unproductive in due course.
- Fertilizers applied along with sufficient quantities of organic manures will improve the efficiency of the fertilizers. Green manuring (Plate 11.1) should be done every year or once in two year during the rainy season.
- Suitable bio-fertilizers should also be applied from time to time.

Plate 11.1: Fully grown green manure crop in the inter tree space

- Plants need adequate supply of sixteen *essential* nutrients for their normal growth and production, out of which carbon (C), hydrogen (H), oxygen (O), nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg) are needed in larger quantities and are referred as *macro-nutrients*, whereas, zinc (Zn), copper (Cu), iron (Fe), manganese (Mn), boron (B), molybdenum (Mo) and chlorine (Cl) are required in smaller quantities and thus called as *micro-nutrients*.
- An essential element is distinguished from a non essential one on the basis of following criteria laid down by Arnon and Stout (1954):

i. The plant is unable to grow normally and complete its life cycle in the absence of the element.
ii. The function of the element is specific and cannot be replaced by any other element.
iii. The element plays a direct role in the metabolism of the plant.

- Carbon, hydrogen and oxygen are taken up by the plants from water and air; all other nutrients are drawn by plants from the soil.
- These elements are found in the soil in varying quantities depending upon the fertility of the soil. Fruit trees remove a large quantity of nutrient elements from the soil.
- Optimum doses of nutrients vary from crop to crop. For example, nitrogen requirement per hectare basis varies from 50 kg for mango to 650 kg for grapes, whereas P_2O_5 requirement varies from 30 kg for mango to 434 kg for papaya.
- Potassium requirements of fruit crops are much higher than that of nitrogen or phosphorus. Potassium is very important for fruit quality.
- Even fertile soils have a limited ability to cope with the nutritional requirement of plants.
- For healthy growth and optimal yield, nutrients must be available to plants in correct quantity, proportion and in a usable form at right time. To fulfil these requirements chemical fertilizers or natural manures are needed.
- Fruit crops are mostly perennial and therefore, require long term nutrient management strategies.
- No single source of plant nutrients viz., fertilizers, organic manures, FYM, bio-fertilizers, green manure is capable to satisfy the crop requirements.
- Application of chemical fertilizers though, makes the soil fertile and increases productivity of plants, but also has an adverse effect on soil and environment.
- Organic sources have enormous abilities to improve physical properties of soil, but have meagre nutrient contents to meet nutrient needs of fruit trees, when used alone.
- It is important that fertility and productivity of the soil be restored/ maintained on sustainable basis by combining organic and inorganic fertilizers.
- Use of organic manures, apart from improving physical and biological properties of soil, helps in improving the use of efficiency of chemical fertilizers.

Therefore, there is a need to organize the supply of nutrients to crop through organic and renewable sources and strengthen the idea of 'Integrated Nutrient Management' (INM).

- **Integrated Nutrient Management** (*definition*): The combined use of different sources of plant nutrients i.e. organic, biological and inorganic amendments for the maintenance and improvement of soil fertility and plant nutrient supply at an optimum level for desired crop productivity may be termed as integrated nutrient management.

Needs for INM:

- Unbalanced use of N:P:K have caused detrimental long term effects on soil fertility.

- In areas subjected to intensive cultivation, application of mere chemicals is not sufficient for sustaining the yields, and it also leads to deficiency in the soil of secondary nutrients and micronutrients which limit crop productivity.

- Use of organic manure, crop residue and biodegradable rural and urban waste not only supplement the chemical fertilizers but also increase the efficiency in nutrient supply, leading to improvement of physical and biological properties of the soil.

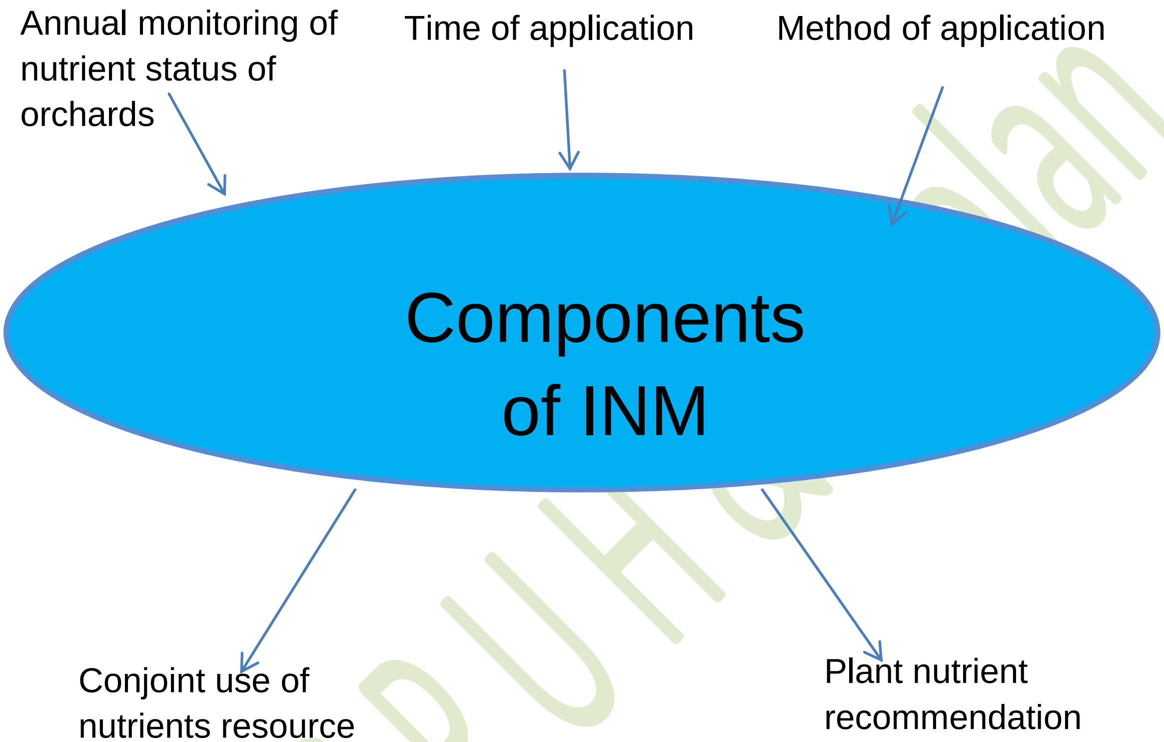


Figure 11.1. Different components of INM

Importance of INM systems:

- The INMS helps to restore and sustain soil fertility and crop productivity.
- It may also help to check the emerging deficiency of nutrients other than NPK.
- It brings economy and efficiency in fertilizer use and favourably affects the physical, chemical and biological environment of soil.
- It helps to produce fruits of high nutritional quality in sufficient quantity.
- Currently, decreasing soil fertility has also raised concerns about the sustainability of agricultural production.
- Future strategies for increasing agricultural productivity will have to focus on using available nutrient resources more efficiently, effectively than in the past.

- Integrated management of the nutrients is needed for proper plant growth, together with effective crop, water, soil, and land management.

- The categories considered in the INM are compost, farm yard manure, green manure, manure of gobar gas plant, oil cake, bone meal, steamed bone meal, fish manure, wood ash, sewage and sludge, *biological sources, sugar cane press mud, coir pith, bio-fertilizers.*

Biological sources:

- Bio-sources are the specific micro-organisms derived either from the nodules of plant roots or from the soil of root zone (rhizosphere).
- These micro-organisms have the ability to fix atmospheric nitrogen either by living symbiotically with the roots of leguminous plants or non-symbiotically (free living).
- They transform atmospheric nutrients from non usable to usable form through biological processes.
- There is a lot of potential of this source to supplement inorganic fertilizers for productive agriculture.

Sugarcane press mud:

- Sugarcane is used in the preparation of jiggery.
- The spent material after processing is known as press mud.
- It contains high amounts of cellulose and hemicelluloses which needs to be broken down into simpler constituents.
- Hence, the raw material needs to be properly digested and composted before it is applied to the soil.

Coir pith:

- This is the raw material obtained from coconut.
- It is available in plenty and also the cost is reasonable.
- Acts as excellent mulch in young plantations and conserves moisture during the drought months.
- It has the capacity to absorb moisture many times over its weight and is used in composting and nursery preparation.
- It has high amounts of silica and hence should be sparingly applied.

Bio-fertilizers:

- These are biologically active inputs and contain one or more types of beneficial micro-organisms such as bacteria, algae or fungi.

- Every micro-organism has a specific capability and function. There are broadly seven types of bio-fertilizers.

1) *Blue-green algae*:

- Blue-green algae or cyanobacteria are free-living nitrogen-fixing photosynthetic algae that are found in wet and marshy conditions.
- Blue-green algae are so named for their colour but they may also be purple, brown or red.
- They are easily prepared on the farm but can be used only for rice cultivation when the field is flooded and do not survive in acidic soils.

2) *Azolla*:

- Azolla is a free-floating water fern that fixes nitrogen in association with a specific species of cyanobacteria.
- Azolla is a renewable bio-fertilizer and can be mass-produced on the farm like blue-green algae. It is a good source of nitrogen and on decomposition, a source of various micronutrients as well.
- Its ability to multiply fast means it can stifle and control weeds in (flooded) rice fields.
- Azolla is also used as a green manure and a high-quality feed for cattle and poultry.

3) *Phosphate-breaking micro-organisms*:

- These are a group of bacteria and fungi e.g. VAM capable of breaking down insoluble phosphates to make them available to crops.
- Their importance lies in the fact that barely one third of phosphorous in the soil is actually available to the crop as the rest is insoluble.
- They require sufficient organic matter in the soil to be of any great benefit.

➢ A point to consider before using bio-fertilizers produced by commercial units is the issue of using micro-organisms native to another area or region.
➢ It is possible to isolate the required species of micro-organisms from a farm's soil and mass produce them.
➢ Besides allowing a better chance of survival of the organism used, this ensures that local species of micro-organisms alone are used.
➢ There are a few crude as well as standard laboratory procedures for isolation and mass production of bio-fertilizers.

Integrated Plant Nutrient Supply (IPNS)

IPNS

Components

Residues...

1. Crop and animal residues FYM, compost.
2. Green manuring with legumes

Biofertilizers:

Micro organisms – BGA, Azolla,
Azatobacter, Azospirillum
P. solubilizer, Michorrhiza

Agronomic manipulation

1. Time & method of fertilizer application
2. Source of plant nutrients
3. Crop and its variety
4. Time of seedling/planting
5. Water management and weed control

Gains

Natural resources

1. Reduced use of chemical fertilizers
2. Saving of non-renewable natural sources, Natural gas, rock PO_4 elemental S deposits and thermal and electrical energy

Economics

1. Reduced instrument on chemical test.
2. Money saved can be used for purchase of other inputs/equipment

Other advantages

1. More jobs for production of bio-fertilizers
2. More rural labour employment

F.A.Q.:

1. Differentiate between macro and micro nutrients, citing suitable examples.
2. What are the criteria of nutrients essentiality as given by Arnon (1954)?
3. What do you means by Integrated Nutrient Management?
4. Why INP is needed in the present fruit production scenario?
5. What are the importances of INM?
6. Name important categories that should be a part of INM.
7. Name different components of INM.
8. Define bio-fertilizer.

9. Name important bio-fertilizers.

10. Name phosphate solubilising fungal bio-fertilizers.

11. Name phosphate solubilising bacterial bio-fertilizers.

LECTURE 12

INTEGRATED PEST MANAGEMENT IN FRUIT ORCHARDS

Objective: Protection of crops involving economically justified and sustainable system that leads to maximum fruit productivity without having any adverse effect on environment.

Introduction:

- Pest problems in fruit production has increased the cost of tree/plant protection and squeezed the profit of the fruit growers.
- In India, **there are several existing or potential key pests for each fruit trees whose population densities must be kept at sub-economic levels to sustain higher per unit production at the farmers fields.**
- During the second part of 20th century, the major emphasis was on pest control, which involved a set of actions to avoid, alternate or delay impact of pests on crops, which mainly involved pesticide application with the sole aim of eradication.
- Because horticultural crops like fruits are intensively cultivated that allow more inputs cost, thus the use of insecticides for the control of specific pests of a particular fruit crop has increased manifold during the last few decades.
- However, the toxic materials generated from chemical use in crop production has polluted the environment, because majority of these are not biologically degradable and harmed consumers' and farmers' health. Uses of broad-spectrum chemicals for pest control have a very negative impact on our efforts to conserve biodiversity.
- Because of their broad spectrum nature of effect, it not only kills enemy insects but also useful insects like honey bees.
- The pest control option based on pesticide applications virtually eliminates the bee keeping activity.
- Now, a more environment friendly and economical alternative for fruit cultivation has been adopted, namely 'Integrated Pest Management (IPM)'.
- Due to considerable awareness about the harmful effects of pesticides on human health and the environment, recently there has been a renewed interest in IPM in almost all countries.

Definitions:

- **Pest** is any living organism, which competes with human beings for resources of its interest. A phytophagous insect assumes pest status when its population is alarming to inflict significant damage in yield or quality of any economic crop such as fruits.

- **Integrated pest management** can be defined as "a sustainable approach of management of pests by the combination of biological, cultural, mechanical and chemical tools in a way that minimize economic, health and environmental risks".
- In other words, IPM is economically justified and sustainable system for the protection of crops that leads to maximum fruit productivity without having any adverse effect on environment. IPM is now used all over the world, which lay emphasis on the use of bio-pesticides and bio-agents with rarest and smallest use of safe chemical pesticides.

Aims of IPM:

- Reduce the use of synthetic organic pesticides
- Adopt environmentally sound tactics for pest control
- Pest minimal risk of human health
- Re-usable return on investment
- Provide consumable safe food

Principles of IPM:

- Identification of key pests and beneficial organisms
- Defining management unit, the Agro-ecosystem
- Establishment of Economic thresholds (loss & risks)
- Development of assessment techniques
- Evolving description of predictive pest models

Tools of IPM:

1. **Monitoring insect pest and natural enemies:**
    - Keeping a track of phytophagous insects and their natural enemies is basic requirement of IPM for taking management decisions.
    - This provides knowledge about the current pests and crop situation and is helpful in selecting the best possible combinations of pest management methods.
2. **Pest resistant varieties/rootstocks:**
    - It involves the breeding of pest resistance varieties, followed by selection of variety for resistance against a particular pest prevalent in a region/ area.
    - For example, use of Malling Merton series rootstocks in apple can prevent/or reduce the attack of woolly apple aphid (*Eriosoma lanigerum*).
3. **Cultural pest control:**
    - It includes all crop production and management techniques which are utilized by the fruit growers to maximize their crop productivity and farm income.

- It includes decisions on varieties to be grown, crop production practices that make crop environment less susceptible to pests.
- Crop rotation as practiced in vegetable and field crops, cover crops, row and plant spacing, application of fertilizers, planting and harvesting dates, destruction of old crop debris/residues are a few examples.
- Cultural control is based on pest biology and development, a few examples of cultural pest control are:
  - Spacing may influence the population and damage many insect pests by modifying the micro-environment of the fruit crop or affecting health, vigour and strength of the crop plants.
  - The type and time of tillage can markedly influence the soil environment and affect the survival of insect pests or their natural enemies.
  - Intercropping with suitable crop can either divert the population of insects from the main fruit crop or inhibit the incidence of insect attack.
  - Use of organic manure release nitrogen in small quantities over a longer period and hence their application does not generally leads to pest outbreak in comparison to the use of inorganic fertilizers. Integrated nutrient management (INM) must, therefore, form an integral part of IPM programme.

4. **Mechanical control:**
   - These are based on knowledge of pest behaviour.
   - Hand picking, installation of bird perches, mulching, and installation of traps (Plate 12.1) are a few examples.

Plate 12.1: Insect trap *Courtsey: Dr Mohinder Singh, Dept. EAP, UHF,* Solan

5. **Biological control:**

   - Pest control with pesticides is not only harmful for environment but also a capital intensive technology as financial resources are required to buy the spray machines, pesticide, labour and technical guidance.
   - However when other means of pest control fails, pesticides are used to keep the pest population below economically damaged levels.
   - It is applied only when pest's damage capacity is nearing to the threshold. Furthermore, time of application of pesticide is very important.
   - Pesticides should be applied at most susceptible stage of a particular insect.
   - For example, it is important to apply insecticides for the control of *anar butterfly* at the early stage of insect development (initial instars) otherwise they bore into the fruit where they are difficult to control.

IPM Packages:

- IPM packages of some fruit crops are available.
- It is not possible to cover these here.
- These should be taught to the students as per recommendations for important fruit crops of the adjoining areas of Universities/Colleges.

Economics of IPM:

- To date, successful IPM programs have produced many benefits. These include
  i) lower production costs (at farm level),
  ii) enormous savings for governments from reduced pesticide imports and subsidies for pesticide use,
  iii) reduced environmental pollution, particularly improved soil and water quality,
  iv) reduced farmer and consumer risks from pesticide poisoning and related hazards, and
  v) ecological sustainability by conserving natural enemy species, biodiversity, and genetic diversity.

F.A.Q.:

1. What do you understand by IPM?
2. Why IPM is required in the present fruit production scenario?
3. What are the aims of Integrated Pest Management?
4. What are the aims of IPM?
5. Why intercropping can be an important tool of IPM?
6. Name important categories that should be a part of INM.
7. Name different tools of IPM.
8. Name two important bio pesticides.

LECTURE – 13

UTILIZATION OF RESOURCE CONSTRAINS IN THE EXISTING SYSTEMS-LAND/SOIL RESOURCES

Objectives: To utilize available land and soil rationally for sustainable fruit production.

Introduction:

- Production systems for fruit crops underwent a large scale proliferation all over the world during the last half century. However, all of the production systems have to work within clear physical, biological, climatic and economic constraints coupled with a set of horticultural tools and skill.
- Before taking a decision on all the other possible alternatives under consideration, it is important to undertake feasibility study of the available resources to the orchard management.
- Performance of the orchard largely depends on the availability and quality of land and water resources and their management in fruit production.
- Other conditions in the growing environment, such as climate and weather conditions, disease and pest management and other factors affecting crop growth also affect production.
- With ever increasing population in India, today the major problem confronted in fruit cultivation is to improve or at least sustain the production to meet ever increasing demand for fresh or processed fruits.
- Fruit production can vary widely in response to management of available resources.
- India cannot afford to mismanage its natural resources. Therefore, there is urgent need to utilize available resources rationally. The following resource constrains are required to be judiciously handled in the management of fruit orchards.

  - Land/Soil type and soil fertility
  - Control of land degradation
  - Irrigation water
  - Climate
  - Trained farm labour
  - Geography of growing area

Land

- Land is a vital component of sustainability of any orchard system.
- Fruit crop must be suited to a particular land and climate in order to achieve a desired success.
- Land use pattern for a particular system depend upon its geographical location such as tropical, sub-tropical, temperate, arid zone, topography, slope etc.

Soil*:*

- Soil and water are the most important factors for successive plant growth.
- A basic understanding of the soil and water is most important to the horticulturist.

Soil:

- Soil may be defined as superficial earth crust "Which function as store house or reservoir of water and nutrients for plant growth.
- Soil is a natural laboratory carrying out several biochemical processes to support plant life, soil micro organism, soil temperature, soil moisture, soil aeration and nutrient levels in the soil are the most important factors in making any soil fertile.
- Fruit trees will do well only if the soils are deep, well drained and without hard pan underneath.

Soil fertility is lost by:

a) crop removal,

b) Leaching,

c) Erosion,

d) Volatilization etc.

- The loss of nutrients should be replaced by suitable measures like addition of manures, fertilizers, green manuring, green leaf manure, incorporating plant residues in the soil etc.
- Organic matter in the soil plays very important role in maintaining good physical condition and thereby helps in maintaining soil fertility.
- Soil reaction or pH is another important factor. Most of the plants prefer nearly neutral pH only. In some special cases the pH of the soil can be altered slightly towards more acid by applying acid producing chemicals like aluminium sulphate, sulphur, Gypsum (Calcium sulphate) etc. soils can be made more alkaline by adding lime.
- In heavy rainfall areas, soils tend to become more acid so suitable amendments should be added to the soil from time to time.
- Soil air is the most important for the healthy growth of the root system. Soil air and soil moisture are interdependent on each other. More air means less moisture and more moisture means less air. So, proper care should be taken during irrigations so as to maintain proper balance between soil air and soil moisture.
- Repeated irrigation will result in blocking the pore spaces and reduces soil aeration. So soil should be stirred after every 2-3 irrigations depending upon the nature of the soil.
- Soil culture or cultivating the soil is another important factor; all practical horticulturists should have a thorough knowledge of soil culture. Soil culture should mainly depend upon the rainfall of the area. In heavy rainfall areas it is better not to cultivate soil before rains. Soils may be cultivated after the rains which help in conserving the soil moisture.
- In low rainfall areas the soil surface should be stirred lightly so as to prevent the runoff and make the water enter into the soil.

Popular cultural methods followed in orchards are.

1. **Clean cultivation:**
    - This is keeping the soil clean without any other vegetation, by repeated ploughings.
    - If it is not done properly, it will harm the soil.
    - The main aim of this is to control weeds; it could be done with weedicides for better advantage.

2. **Sod culture**:
   - This is keeping the orchard soil covered by grass growing *in situ* which will be cut down from time to time and left on the soil itself to add organic matter to the soil.
   - This is best suited for heavy rainfall areas only.

Advantages of Sod culture:

- ➢ During heavy rains, it uses the excessive water and keeps the soil water in control.
- ➢ During dry periods, it acts as natural mulch and conserves soil moisture.
- ➢ It helps in reducing the damage to the fallen fruits.

Sod should not be maintained in young orchards as there will be competition for nutrients with the young.

Plate 13.1: Sod culture with clean strip

Plate 13.2: Dry grass mulching in pomegranate

3. **Mulching:**
   - It is keeping the surface of the soil covered by a layer of any organic material (Plate 13.2) like leaves, straw, ground nut hulls, cottonseeds hulls, corn waste, saw dust, paper pieces, paddy husk, sugarcane task or any plant residue etc.

Advantages of Mulching:

- ➢ Conserves soil moisture
- ➢ Regulates soil temperature
- ➢ Improves quality of produce
- ➢ Avoids weeds
- ➢ Adds organic matter to the soil on decomposition.
- ➢ Reduces soil erosion
- ➢ Improves activity of soil micro organisms.

- Improves availability of soil nutrients.

Disadvantages:

- Sometimes problems of rat menace and fire hazards may occur.

As discussed in lecture 4, mulching can be done with polythene sheets also but they will not be adding any organic matter to the soil, but gives all other advantages.

4. **Intercropping:**
   - It is the practice of growing some suitable short duration crops in between plant rows in the orchard.
   - Intercrops if taken should be supplied with all their requirements separately to reduce competition with orchard plants.
   - Intercrops should occupy a secondary place in the orchard, primary consideration being given to the perennial fruit trees.
   - Leguminous intercrops help in improving soil fertility also.
   - Intercropping can be followed to the maximum advantage in the preparing stage of the orchard plants.

Advantages of intercropping:

- Inter cropping helps on getting some additional returns from the same land putting land to maximum utilization.
- This system is advantageous to the main plants from the culture operation carried out for the intercrops.

5. **Cover cropping**:
   - It is the practice of keeping the soil covered by growing creeping types of plants.
   - These also act as mulches but will be drawing some nutrients from the soil.
   - Leguminous cover crops add nitrogen to the soil.
   - Cover crops when ploughed in to the soil improve its organic matter content.

Soil degradation:

- Soil erosion is one of the major problems in orchards, especially where growers use sprinkler and flood irrigation systems and in hilly areas.
- Water-induced erosion results in the transport of soil particles into downstream waterways.
- These sediments may carry unwanted pesticides and nutrients that adhere to them.

- There are several management practices that can be employed to control erosion.

- Improvement of the soil's physical qualities through orchard floor management is an attractive option because it often results in improved yields, better water use efficiency, and reduced runoff as discussed earlier.
- In addition, contour cultivation and terracing in hills, conservation bench terraces (CBT) can be followed.

Contour planting:

- It is followed in apples, apricots, almonds, cherry, pears, plums etc. in hills with high slopes.
- In this, trees are planted along a uniform slope without disturbing the topography, with the objective of reducing the loss of top soil due to erosion (Fig 13.1).

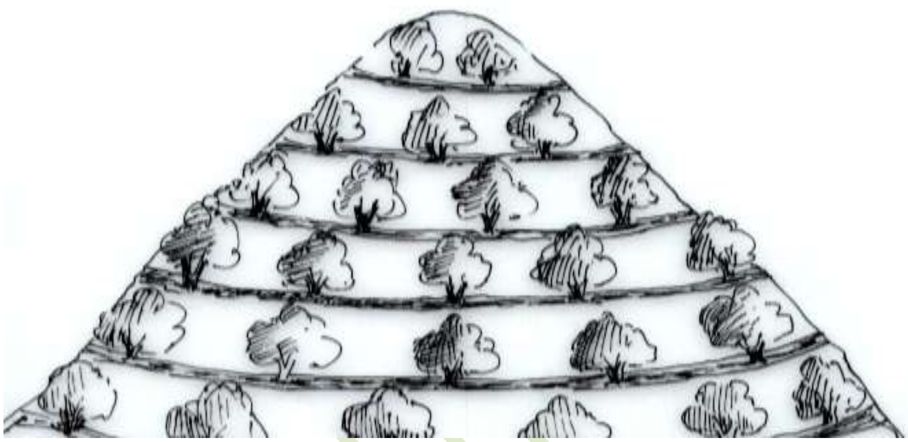


Figure 13.1: Plan for contour planting and terrace planting on sloppy lands.

Terrace planting:

- In this method, small terraces are made, and trees are planted in the middle of these and thus this will provide sufficient space for inter cropping for additional income.
- This method is even more effective in preventing runoff and soil loss than contour planting (Figure 13.2).

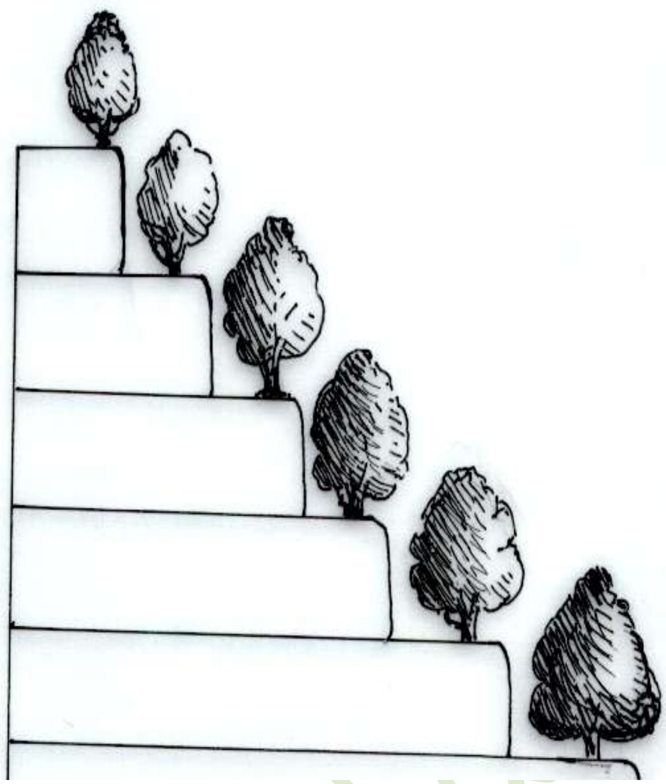


Figure 13.2: Plan for terrace planting on sloppy lands.

Impact of climate change on fruit crops:

A. Influence of elevated CO_2

- Increase in atmospheric CO_2 is reported not only to improve the yield but also to alter the quality of the produce.
- The quality (carotene, starch and glucose content) starchy fruits increased in elevated CO_2 conditions. Under high CO_2 level, the water use efficiency of crops is reported to increase.
- In coconut, areacanut and cocoa are reported to benefit due to CO_2 concentrations. Studies indicated that the elevated CO_2 (550 and 700 ppm) increased growth of coconut seedling by 20 to 30 %.

B. Influence of Temperature

- Each fruit crop requires a specific temperature range from minimum to maximum `within which a crop will survive. What kind of impacts might occur when a crop is planted outside this range?
- Cold waves during December 2002 – January 2003, caused considerable damage to fruit crops like mango, guava and papaya in India.

- Even though elevated CO_2 is expected to cause positive impacts, however, this may be nullified by increased temperature and less water availability and thereby can decrease production under the current level of management.

    i. **Growth and development**: Experimental findings indicate increased leaf production in banana with increase of 1 – 2 ^{O}C temperature beyond 25-30 ^{O}C thereby, reducing crop duration and increasing production. Occurrence of frost during January has affected mango flowering resulting in crop yield.

    ii. **Flowering and pollination**:

    - Weather conditions during flowering, pollination and subsequent fruit growth determine the production quantity and quality.
    - It has been reported that mild winter temperatures followed by warmer springs advanced bud burst exposing buds to frost damage in almond and apricot.
    - A cool and dry period, generally in winter, that slows or stops vegetative growth is essential in inducing flowering. On the other hand, low temperature (4 to 11 ^{O}C), high humidity (> 80 %) and cloudy weather in January delayed panicle emergence, low temperatures during inflorescence development reduce number of perfect flowers.
    - The perfect flowers in mango were significantly higher in the temperature regime of around 27 / 13 ^{0}C than in a temperature regime of around 21/4 ^{0}C.
    - In citrus, ultimately winter rains promoted vegetative flushes instead of flowering flushes while, dry spell during flower emergence and fruit set affected flower initiation and aggravated pest (*Psylla*) incidence.
    - Washout pollen grain during flowering has been reported by various workers from different parts of the world.
    - During rainy days pollinating insects remain dull and effective pollination cannot occur and affects fruit setting. After continuous moist weather severe attack of mango hopper certain fungi cause heavy shedding of flowers and fruits and often results in crop failure.
    - Pre harvest low light intensity due to cloudy weather reduced content of ascorbic acid and sugar in fruits.
    - Heavy rains during harvest period adversely affected production and quality of cashew nuts due to nut germination.
    - Extension of monsoon rains beyond October in west coast delays bud break and flowering.
    - Entrapment of back radiated heat from the soil by the clouds is attributed for fruit let and flower dropping in mango.
    - During prolonged rainless periods, supplemented irrigation should be provided.

iii. **Yield**:

- Apple productivity declined up to elevation of 1500m msl to tune of 40 – 50 % due to warmer climate resulting in lack of chilling requirement during winter and warmer summers in lower elevations resulting into shifting of apple production to higher elevation (2700m msl).
- High temperature and moisture stress resulted in sun burn and cracking in apples, apricot, cherries and litchi, dehydration injury to panicles and low fruit set in mango.

iv. **Quality**:

- Climate change may alter quality of fruits.
- It may impair quality in terms of colour and different quality parameters which may need appropriate investment for targeted quality of produce.
- In vine grapes anthocyanin development is influenced by difference between day and night temperatures, with high variation (15 – 20 ^{0}C) promoting colour development.

v. **Pests and diseases**:

- Under the changing climatic situations, existing fungal pathogen, bacteria, viruses may cause more damage.
- Some of the minor pests may become major pests in future. Added to these, vector population may increase and new pathogens may emerge.
- Increase in temperature with low RH (< 60 %) reduced leaf spot diseases in banana in the sub humid region.
- Tea mosquito bug populations and damage score in cashew were negatively correlated with minimum temperature (15 – 20 ^{0}C), RH (85 – 90 %) and positively with bright sunshine hours (9 -10 hours).
- Bright sunshine hours less than two hours per day triggered incidence of inflorescence blight in cashew.

What are the damages caused by high temperature?

- In summer the leaves, new shoots, branches, flowers and fruits are exposed to sun and high temperature. High temperature is generally more harmful when accompanied by low humidity. This causes excessive transpiration and wilting of leaves and twigs.
- The ability of plants to withstand such condition varies greatly with species; e.g. banana is more sensitive than guava plants.
- Young trees are affected more than old plants.
- High temperature and low humidity is a limiting factor in case of certain fruits like banana.

- Sun burn of leaves, fruits (pineapple) and bark is sometimes a serious factor. Plants planted in a east and south aspect are more affected than in other directions as they are exposed to sunlight for longer time.
- Flowering and fruit set are adversely affected by high temperature as in mango and mandarin. **Citrus fruits** suffer a production loss when temperatures over 37^{o}C are experienced.

Preventive measures:

- Planting of thick and tall growing wind breaks are required to be planted at the time of orchard establishment.
- Severe pruning of trees be avoided during summer season.
- Adopt protection measure before the commencement of high temperature. White washes the main stem and also small branches and young plant shoots at the beginning of summer season.
- Irrigate properly to have more humidity in the orchard.
- Spread the mulch in the basins of young and old trees. Provide grass cover to fruits as in pineapple.

What are effects of low temperature on plants?

- In the hills and plains of north India frost occurs either during winter or in early spring. Low temperature effects due to freeze and frost occurrence in these area.
- Low temperatures (Freezing) occurring either during the rest period of fruit plants or afterwards, cause damage to roots, stems and buds. At lower temperatures, water is withdrawn from protoplasm and ice is formed in the intercellular spaces. If this process proceeds beyond critical limits the protoplasm of the cells disintegrates and dies from loss of water.
- Frost causes damage to the newly opened blossoms of fruit trees, to young growth and newly set plants. Frost occurs when there is sufficient moisture in the air and the temperature of the exposed surfaces fall below 32 ^{o}F.
- Important types of injuries due to occurrence of frost observed in fruit plants are (1) Black heart—Inner wood of nursery fruit plants becomes dark; (2) Splitting of bark—this may be extended to trunk and branches; (3) Killing of shoots and young branches— if there is early growth in spring and flowering in fruits like mango, flowers may be killed while in others like citrus and papaya even fruits anre injured; (4) Frost damage—evergreen tree are damaged heavily but deciduous fruit trees shed their leaves and not normally damaged. In young fruit plants, the damage is very severe.

Preventive measures:

- Delicate young fruit plants be planted in the inner side of the orchard.
- Wind-breaks should be planted in time on west and north side of the orchard.
- Apply adequate manures and fertilizers to make the plants stronger and more tolerant.
- Plants of frost tolerant varieties be given preference for planting in the new orchard.
- Irrigate orchards regularly during the frost periods.
- Burn dry leaves and twigs in orchards (10 – 12 places in one hectare).
- Cover the trunk with grass. The young plant may be covered on three sides leaving south east side exposed for light and sun.
- Plants quick growing green manuring crop around young plant to provide protection.

➢ Climate change has been a cause of serious concern if the fruit industry has to grow in the context of country's overall economic growth, to respond to rural households' livelihood, country's nutritional security and poverty alleviation.

➢ It may take some years to fully experience the devastating effects of climate change on quality fruit production but the time is ripe for the Government, private sector and public to have adequate concern, commitment and accountability to mitigate the effects of climate change.

LECTURE 14

SOIL RESOURCE CONSTRAINTS AND MAINTENANCE FOR IMPORTANT FRUIT CROPS

Objectives: Management of orchard soil for maintaining its physical conditions and fertility status and avoid its degradation so as to provide proper physical and sanitary environment for the growth and production of fruit crop.

Introduction:

- The Soil includes such factors as soil moisture, texture, chemical composition and temperatures during the lifetime of the orchard affects fruit quality and productivity.
- A suitable soil is a basic requirement for a particular crop. Before deciding a particular production system, one should thoroughly check soil conditions of the available land.
- Therefore, an analysis of soil type, its fertility and land degradation etc. is needed for each alternative under consideration. Knowledge of the effects of various soil and climatic conditions on fruit growing is essential for every successful fruit grower, as different fruits differ widely in their soil and climatic requirements.

➢ A fruit crop has particular soil requirement to grow well. Among the main criteria, the 'physical environment' and 'sanitary environment' aspects of the site are essential.

➢ Fruit trees will do well only if the soils are deep, well drained and without hard pan underneath. Soil requirements and management of soil constraints for different fruit crops based systems are as hereunder.

Citrus:

- Citrus is endangered more by the consequences of too much water than by temporary rationing.
- Poorly drained low-lying zones and very heavy soils with a hydromorphic tendency should be ruled out.
- Ideal sites for laying out orchards have light and above all well filtering soil, a neutral to slightly acid pH (6 to 7.5), no excess limestone and sufficient organic matter.
- The management of minor defects such as alkalinity, slight salinity, etc., can be handled partly by the choice of suitable stock and possibly appropriate orchard management techniques such as the application of organic-mineral amendments before planting.
- As grapefruit varieties are extremely susceptible to *Phytophthora* and other diseases affecting the trees, high quality planting material must be used and planted with the graft 30 cm above the soil.
- Planting distances vary according to the climatic zone and rootstock vigour. Density is about 6 x 4 m or 6x 6 m in Mediterranean countries and the trees are spaced more

widely in the humid tropics (8 x 8 m or more) where growth is continuous and the trees developed more rapidly. Wind-breaks must be planted around the orchards in exposed locations.

Orchard soil maintenance:

- Trees do not cover the entire space available in an orchard. With a few rare exceptions, the land must be protected during the rainy season.
- Permanent or temporary grassing depending on the availability of water is the most common management technique.
- The grass strip is generally limited to the central part of the inter-row.
- Weed growth below the tree foliage is controlled by one or two applications of weedicides each year. In zones with a long dry season, it is preferable to choose a cover crop that withers and does not compete with the trees for water.

Apple:

- Although apple trees will grow well in a wide range of soil types, a deep soil ranging in texture from a sandy loam to a sandy clay loam is preferred. A minimum soil depth of 4 feet is desirable.
- Very heavy soils are not desirable for apple growing. Apple trees will not thrive in a soil that is poorly drained or subject to water seepage.
- If free water is allowed to persist in the soil, the trees will suffer. Roots of affected trees will die and this will eventually result in die back of the aerial parts.
- Installation of drains in areas subjected to seepage water or where water table comes within 4 feet of soil surface at any time of the year are advisable.
- Since availability of nutrients is adversely affected by an excessively high or excessively low pH, a pH of 6.5-7.0 is most suitable for apple trees.
- For soils with low pH and in orchards where through years of irrigation and fertilizer use, soil pH has dropped to an extremely acidic state, use lime to correct the pH.
- On the other hand high pH tends to cause most trace elements and some major elements to be less available to the trees.
- Application of calcium sulphate or use of ammonium sulphate may improve availability of a nutrient such as iron.

Grapes:

- Soil structure is more important for grapes than fertility status. Grapes require a well drained soil, especially in tropical south India, where the development of roots coincides with stagnation of water continuously for several days during rainy season, damaging the roots. Also desiccation of soils reduces root growth, resulting in cessation of new growth in *V. vinifera* in the tropical areas.
- The brown and gray soil series and the heavy black soils of Maharashtra are not suitable.
- The later soil has 1% or more salt concentration but the chloride injury should be avoided. However, damage to grape vine by salt stress may be minimized by

exogenous application of proline or cytokinins in the initial stages, and gibberellins at the later stages of the planting.

- Though, the cultivars differ markedly in tolerance to salt, grapes can be grown on soil with higher salt concentration by using resistant rootstocks like ‘Salt Creek’, *V. riparia*, *V. rupestris* 3309, ‘ARG No. 1’, and ‘ARG No. 9’.
- Most of the micro-nutrients become unavailable under high soil pH conditions, which can be supplied through foliar sprays.
- Important micro-nutrients generally applied through spray include zinc, iron, boron and manganese. Foliar application of 0.2% boric acid applied at pre-bloom and bloom stages for the improvement of fruit quality and yield in Thompson Seedless grapes.
- Micro-nutrient sprays apart from improving fruit quality and growth of vines also improve berry set, berry retention and yield. For concentration and timing of application, it is advisable to adhere to location specific recommendations.

Mango: Depending on the conditions under which the mango is grown, i.e. dry land or under irrigation, the response to the soil type will vary.

Soil requirements for cultivation under irrigation:

Drainage

- Mango trees grow best on a slight slope which enables runoff of excess water and prevents water logging. Avoid plantings on depressions or where, basins are poorly drained. The roots will turn black and become desiccated in oversaturated soils as a result of a lack of aeration. Under such conditions the parts of the plant above the ground will wilt and show symptom of chlorosis.
- Mango trees do not grow and produce well in soils with impermeable layers.
- They also do not thrive on very steep slopes because excessive drainage in this case could lead to water shortages and soil erosion.

Soil depth:

- Under irrigation, mangoes grow well in soils with an unimpeded depth of more than 1 m. If irrigation scheduling is well planned, there should be no problem on soil with a depth of 750 mm, provided that any soil or rocky layers that restrict root growth to a depth of 750 mm allow excess water to drain easily.
- If not, a temporary shallow soil water-table could develop above this layer, with resulting damage to the trees.

Texture:

- The ideal soil texture for mango cultivation under irrigation is a sandy loam or loam (with a clay content of 15 to 25 %), but soils with a clay content of up to 50 % are also suitable.

Soil structure:

- The ideal soil has a fairly loose, brittle, crumbly structure.
- Compact or strongly-developed soil structures prevent effective water infiltration and root penetration. These soils are normally associated with high clay content in the subsoil.

Water:

- Allowing the soil to dry out for 2 or 3 months before the flowering stage will promote good flower formation. This phenomenon is attributed to a simultaneous stimulation of vegetative growth during the autumn months which, in turn, influences flower formation in spring.
- Fruit drop as well as the size and quality of mango fruit seems to be influenced by irrigation at certain times. Irrigation during the developmental stage of the fruit is essential to prevent fruit drop and to promote the development of young fruit. Additional irrigation from fruit set to ripening results in a considerable improvement in both fruit size and quality.

Soil requirements for cultivation under dry land conditions:

- Mangoes can be grown under dry land conditions, provided the soil has the ability to retain moisture that can be available to the plants in drier periods. These soils have a depth of at least 600 mm and a clay content of between 15 and 30 %.
- Soils with lower or higher clay content will not be able to supply sufficient moisture to the plants.

Soil pH:

- Mango trees grow best in soils with pH values of 6 to 7.2.
- If the soil-exchangeable aluminium (Al) is not more than 30 ppm, soils with a pH of 5.5 or higher may be used.
- At pH values lower or higher than 6 to 7.2 the trees may however, suffer trace-element deficiencies, especially phosphate and potassium.

Trace elements:

- A minimum calcium content of 200 ppm is desirable.
- The ideal potassium status is from 80 to 200 ppm.
- A phosphate content of at least 20 ppm is required

Soil preparation: Proper soil preparation is very important because it will last for the lifetime of the plantation.

The most important advantages are:

- Better root development
- Improved soil drainage and reduced runoff
- Improved water penetration (rain and irrigation)
- Better utilisation of nutrients
- Greater tolerance towards diseases
- Larger fruit size
- Increased yield
- Prolonged economic lifespan.

Components of soil preparation:

The most important components of soil preparation are:

- Proper examination of the soil (physical and chemical) which include soil type, soil strength (Compaction), soil texture, soil depth and drainage capacity of soil.
- Supplying lime and phosphate into the root zone: A chemical analysis is necessary to determine lime or phosphate requirements. Soils where mangoes are to be planted should be sampled at least 9 months prior to planting.
- Deep plough or rip cultivation
- Construction of ridges if necessary.

Supplying nutrients:

- Calcium and phosphate move very slowly downwards in soils. If there is a shortage of one of these elements, especially in the subsoil, it should be incorporated into the soil during soil preparation because there will not be a chance to plough it in afterwards.
- If it is necessary to rip the soil, lime should be ploughed in beforehand.

Banana:

- Banana is one of the few fruits which have a restricted root system; therefore depth and drainage are the two most important considerations for its cultivation.
- Deep rich loamy soil with pH 6-7.5 is the most preferred for banana cultivation.
- Poorly drained and nutritionally deficient soils are not suitable for banana.
- Saline soil and calcareous soils are also not suitable for banana cultivation, as wilt diseases in such soils are common.
- A soil that is not too acidic and not too alkaline, rich in organic material with nitrogen content, adequate phosphorus level and plenty of potash are good for banana.
- Banana production also suffers from inter-linked soil-borne pest and fertility constraints. Critical banana production problems include the banana weevil, banana nematodes, soil nutrient deficiencies, nutrient cycling and retention of adequate soil moisture. These problems cannot be managed independently. T
- he banana weevil and nematodes attack the root and vascular system, interfering with nutrient uptake and preventing the plant from utilizing soil amendments. Their combined attack result in smaller plants, lower yields and shortened plantation life.

- Nutrient deficiencies or imbalances may also leave the plant more vulnerable to pest attack. Thus strategies should be to integrate pest and soil fertility management.
- Soil fertility can be improved by the addition of organic and inorganic fertilizers, as per requirement ascertained by leaf analysis.
- Soil acidity can be overcome by lime application, as per recommended on soil pH status basis.
- In alkaline soils, prevalence of iron deficiency identified by in alkaline soils by interveinal chlorosis of young leaves and zinc deficiency by bunchy top can be corrected by foliar sprays of iron sulphate and zinc sulphate, respectively.

Guava:

- Guava trees can be grown in all type of soils provided if at least top soils are rich but cannot tolerate water logging. Soils that are either too acidic with pH < 4.5 or alkaline with pH > 8.2 are not suitable.
- Production and productivity of guava is significantly affected by nutrients and water. Because fruits are borne on the current season's growth, adequate manuring and fertilization should be practiced to encourage vegetative growth and fruiting. A sampling of two month old pair of leaves on fruiting terminal is appropriate for nutrient diagnosis.
- Guava wilt, a major fungal disease of guava is more severe in alkaline soil. Apart from the use of fungicides, amendment of soil pH with the incorporation of Gypsum (sodium sulphate) in the soil may be beneficial. This will also be helpful for combating soil salinity problem.

Plantation crops:

Tea (*Camellia sp*.):

- It is a calcifuge crop requiring comparatively low amount of calcium but high quantities of potassium and silicon. It can be grown in lateritic, alluvial and peaty soils. Optimum pH range in 4.5 to 5.0 and soil depth should be 1.0 to 1.5 m.
- In the hill soil due to the leaching of bases by rain and also the incessant application of acid forming fertilizers, the soil pH is often reduced which affects the physical and chemical properties of soil (Plate 14.1). Therefore, periodic application of lime is essential to amend the soil and maintain the optimum pH.
- Agriculture lime (calcium carbonate) and dolomite lime (calcium magnesium carbonate) are generally recommended for tea soils.
- The rate of application is based on soil pH, rainfall, fertilizer usage and length of the pruning cycle. Approximately, lime @ 1.5mt/ha for a pH range of 4.5 to 4.9, 3.0mt/ha for a pH between 4.0 to 4.4 and 4.0mt/ha for a pH less than 4.0 is suggested.

Plate 14.1. Tea cultivation on slopes

- Lime is applied by evenly broadcasting prior to pruning cycle.
- First manuring can be applied 6 weeks after liming and a minimum of 15 cm rainfall should have been received during this period.

- Zinc deficiency is often observed in young shoots characterized by reduced leaf size, resetting, and choruses. It can be corrected by soil application of zinc sulphate @ 6 to 8 kg/ha for high yielding gardens every year. The above quantity can be given in 4 to 5 split doses during the high cropping months i.e. during April/May and September/October.

Coffee (*Coffea Arabica* L. and *C. Canephora* Linden):

- The heavy rainfall in coffee growing region of south India bring about leaching losses of calcium and magnesium leading to soil acidity. Besides, continuous use of acid forming fertilizers like ammonium sulphate also makes the soil acidic.
- As the ill effect of soil acidity are more, periodic application of lime is essential to raise soil pH for higher productivity. The quantity of lime to be added to the soil depends upon soil pH. It is desirable to apply lime when there is sufficient moisture in the soil for quick response.
- Liming may be applied during May-June and November-February in the south-West monsoon area and January to March and June-July in North-East monsoon areas. It is applied between the coffee plants rows and then mixed into the soil with digging or forking.

LECTURE 15

UTILIZATION OF RESOURCE CONSTRAINS IN THE EXISTING SYSTEMS-WATER RESOURCE

Objective: Efficient management of water in order to ensure its supply in requisite quantity at critical stages of growth and development of fruit crops.

Water:

- Apart from soil, water is an important essential natural land resource affecting growth and production of fruit crops.
- Fruit trees require irrigation water for maintaining adequate growth, fruit quality and yield, particularly in dry months. However, availability of water is always a limiting factor in fruit cultivation, particularly in arid and semi arid conditions. Even in high rainfall (>1500 mm) areas, sufficient moisture may not be available in the root zone during the dry months and crops may suffer from drought at any stage due to erratic rainfall pattern and for the want of irrigation water.
- In order to ensure the supply of requisite quantity of water at critical stages of growth and development of fruit crops, efficient management of water is required. In rain fed areas, three essential components of water management are:
    - In situ moisture conservation
    - Water harvesting
    - Efficient utilization of conserved/harvested water through improved cultural practices

In situ soil moisture conservation:

- Mulching is known to conserve soil moisture, be it mulching with organic or inorganic material. This aspect of moisture conservation has been discussed in Chapter 4.

Water harvesting:

- Two natural water resources that can effectively be harvested are rainfall and low (as low as 1 to 30 l/min) water springs and rivulets.
- About 10 to 14 per cent of total rainfall, depending on soil and rainfall characteristics may be lost as surface runoff.
- Water harvesting can be done through *in situ* rainwater harvesting and water harvesting in farm ponds.

***In situ* rainwater harvesting:** In fruit plantations, rain water can be harvested in the tree basin areas by certain soil working techniques such as:

- Preparation of tree basins: Well prepared tree basins prior to rains aid in water infiltration, and subsequent frequent shallow hoeing not only remove the competitive weeds but also prevent evaporation losses of moisture from the soil by forming dry soil mulch over the sub soil.
- For arid and semi-arid regions, soil working techniques like ‘Crescent Bund with Open Catchments Pits’ (plate 15.1), ‘Trench Systems’, ‘V-ditch’ (plate 15.2) etc. provide satisfactory *in-situ* harvest of rain water. These techniques are found to be useful for conserving soil moisture in the root zone of trees for the dry months.

Plate 15.1

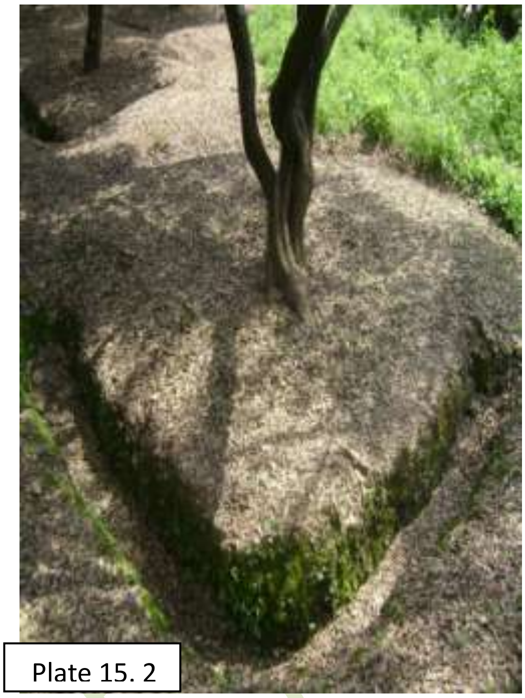


Plate 15. 2

Water harvesting through farm ponds:

- The run-off water from orchards and water flowing from other sources like spring and small streams that though cannot serve as water source for irrigating crops due to their meagre flow rates but, can be effectively stored in suitable small or big reservoirs.Small ponds may also be used as water reservoirs in which water is stored during lean period and used when required by crops. The provision of a small pond in one corner of the orchard to collect runoff water during high intensity rains and its utilization as life saving irrigation or during critical periods of the crop is an age old practice.
- Small ponds are ideal for growers who have scattered land holdings. In addition, they do not require elaborate management skills and resources.
- Ponds, however, vary in shape, size and mode of construction. Orchard ponds can be divided in to three categories:

➢ Dugout small ponds on flat lands (Plate 15.3)
➢ Ponds constructed by making barriers constructed in low lying areas or natural depressions or small streams (Plate 15.4)
➢ Dugout ponds constructed by making barriers constructed on lands with mixed topography

- Suitable sealants may be used to check/reduce seepage losses in ponds (see Plate 15.3). Ponds may be lined with polyethylene sheet (covered with soil or bricks or round boulders to protect it against UV sun light), silpauline sheet (UV resistant), bitumen, cement and concrete lining, RCC, etc. The cost and longevity of structure will depend upon the lining material used.
- Larger ponds can be made by damming the upper catchment area of a creek. Water harvesting in larger ponds is practiced on community basis (Plate 15.5). It involves proper planning and sincere participation of the inhabitants of the catchment and command areas. It may form a part of integrated watershed management involving participatory approach.

Plate 15.3 : Small dug out pond on flat land **Plate 15.4:** Pond made by constructing barrier

Plate 15.5: Large pond with black polythene sheet used as sealant

Efficient Utilization of Conserved/Harvested Water:

- The water conserved/harvested from natural resources must be used very efficiently for fruit crops.
- The water should be possibly be used through pressurized irrigation system e.g. drip irrigation.
- Drip irrigation system is ideal for fruit crops, because it enable to achieve higher water use efficiency and also help in maximizing crop production within limited water resource.

Climatic Constraints:

- Plant productivity depends upon the absorption of light energy by the green tissues and the conversion of that energy into biomass via photosynthesis. Fruit yield has been shown to be linearly related to light interception (Palmer, 1989; Lakso, 1994).

- Although high light interception is needed for high yields per unit land area, shade can have an adverse effect on fruit quality, fruit set and flower initiation.
- Shading can arise from within or between tree sources, including windbreaks. Fruit size, red skin colour, soluble solids concentration are all reduced by shading. This seems to be a general phenomenon among perennial tree fruits and has been reported for apples, citrus, red raspberry, kiwifruit, cherries, peaches and grapes (Palmer, 1989).
- Shading can also result in a reduction of flower initiation and fruit set. These effects of shade could be mediated via a direct effect of light on carbohydrate supply or through effects on the red/far red ratio.
- In some environments, excessive amounts of light falling on the fruit can result in downgrading of the fruit due to sunburn.
- For high yield and, in particular, high fruit quality, the orchard needs to combine both high light interception and good light distribution within the tree (Wünsche et al. 1996).

There are many possible ways of arranging fruit trees canopies in space.

Solutions

i. High density planting:

- Early cropping per hectare and the rapid establishment of the canopy has been achieved by high tree densities (1500-5000 trees/ha in different tree fruits, up to 100000/ha in pineapple), planting well feathered (branched) trees and an emphasis on tree training rather than pruning. In order to avoid later problems of excessive vegetative vigour resulting in poor fruit quality, size controlling rootstocks have been widely used, with more emphasis on rootstock inducing smaller tree size with higher tree densities.
- Smaller tree canopies are easier to spray, prune and fruits can be picked from the ground.
- As shade is known to be deleterious to fruit quality, smaller tree canopy permit penetration of light in the interior of canopy and thus ensure better fruit quality.

ii. Efficient training systems:

- Important aspects of any training systems include:
  1) a rapid achievement of high light interception and early cropping
  2) efficient harvesting and
  3) the maintenance of good light penetration into the canopy at all times.

- Conical tree shapes, Telephone system (plate 15.6), Tatura trellis (Plate 15.7), V system, Spindles, Kniffen system, etc. ensure better light penetration and interception and therefore production of higher quality fruits.

Plate 15.6: T-bar (Telephone system) training in kiwifruit **Plate 15.7:** Tatura trellis system in peach

Some other canopy forms:

Conical trees

- The Dutch have spearheaded the use of intensive systems for apples, with tree densities of 2,000 to 3,300 trees/ha, based on a small conical shaped tree, the slender spindle. Trees are frequently grafted on the dwarfing rootstock M.9, and tree height is restricted to 2-2.2 m.
- All tree management operations pruning, thinning and picking can be done from the ground or with short step ladders.
- The high tree densities ensure a high light interception and the combination of a size controlling rootstock with the conical shape ensures that light can penetrate into the lower parts of the canopy.
- Although use has been made of even higher tree densities and multi-row rather than single row systems, low fruit prices have made some of these very high density systems economically questionable.
- The French axe system has a similar conical tree shape, but is planted at lower tree densities than the Dutch spindle bush and is permitted to grow to 3-4 m tall.

Planar canopies

- To improve light penetration into the tree, the canopy can be trained into a thin layer which, with a suitable wire trellis, can be inclined at different angles to the vertical.
- The Australian Tatura Trellis, originally designed for the mechanical harvesting of peaches, has also been used for apples.
- There have, however, been numerous other forms of V as adopted in pears and Y canopies in peaches (Plate 15.7).
- In some cases individual trees are trained into two halves, in other cases alternate trees down the row are trained to the right and to the left. The horizontal 'Lincoln canopy' was also designed for mechanical picking but suffered from excessive annual, vertical shoot growth

from the horizontal canopy, with attendant shading of the fruit below. Although such growth could be mechanically pruned off in the summer time, fruit colour was often poor with red skinned cultivars.

- A narrow depth of canopy does not necessarily ensure good light penetration.

Other constraints:

- The soil can impose serious limitations to rootstock choice and similarly the climate can seriously limit the choice of rootstock and cultivar.
- The grower himself is not always seen as a constraint but it is important that the grower has the technical expertise and skill to manage the system; he may not, for example, be able to successfully change from a system he knows well to a new system.

LECTURE –16

CROP MODELS IN HORTICULTURE

Objective: To draw out a plan of work to grow crops to get maximum possible yields of high quality produce and a reduction of inputs.

Introduction:

- Farming is a complex agri-business where many activities are taken together like cultivation of cereals, fruits and vegetables, animal rearing and poultry. However, cultivation of various crops, including fruits and vegetables are generally the major components of a farming system.
- Agronomic practices adopted for a crop depends on many factors that include climatic factors, ecological environment, resource availability, and the level of knowledge about agro-techniques required for the crop.
- It is thus important to understand the impact of each factor on the growth and yield of the crop.
- This can be done independently or in association with other factors. Crop models allow us to do this so that we can changes required to improve our overall management of the farm.

Crop model – definition

- First let us understand what we mean by crop model. In very simple terms we can define a crop model as (i) *a well thought-out plan of activities to grow the desired crop to get maximum possible yields of high quality produce with the given resources*.
- It can be a mental or a written exercise (a "schematic representation of the system") that a farmer or a farm manager prepares for a crop or for an individual crop.
- In other words, we can also say that a model is (ii) "an attempt to describe a certain process or system through the use of a simplified representation, preferably a quantitative mathematical expression, that focuses on a relatively a few key variables that control the process or system".
- Successful farming depends on our knowledge of the impact of ecological, climatic and economic factors on crop yields.
- So, a model may be defined as (iii) "an attempt to describe a certain process or a system through the use of a simplified representation, preferably a quantitative mathematical expression that focuses on relatively few key variables that control the process or a system".

Utility of crop models

- Crop models help us to understand the crop production process or system in a more systematic way.
- The process of modeling is often equated to solving of a puzzle. A puzzle has to be considered as a whole even if we need to fit a one small block. Crop models provide us quantitative information about the amount of inputs like the doses of fertilizers, number of irrigations, amount of insecticides/pesticides, etc. required.

- These models also help us to consider various input requirements under different climatic conditions. This means models help us to get reasonably clearer picture of *otherwise hazy* scene.
- It is also said that models provide us reasonably acceptable answers to questions where we can only have vague answers.

- So we must be clear that models would not guarantee one hundred per cent accurate answers; even if we take a large number of variables into consideration. This is because crop cultivation is a biological activity and the final output depends on our knowledge of the state of climate that will prevail during the growing season, our knowledge about the appropriate technology required, availability of that technology, about input market conditions, about the biological risk factors associated with the crop, and such other factors.
- It is clear from this discussion that in finalizing a crop model we have to assume some mean or standard values (based on the past record, experience, expert judgment, etc.) of the variables which we may not be taking explicitly in our model.
- Since, there can be a large number of factors that may affect the crop, it becomes easier to understand their effect if these variables are grouped on some basis. Thus we may have a group of ecological variables, economic and social variables, technical and climatic factors that may need to be considered in our crop models.

Types of crop models

- Based on different groups of variables that affect crops production, we can categories crop model or models as;
  (i) *ecological models,*
  (ii) *climatic models, and*
  (iii) *socio-economic models*

  - The climate based models are formulated to predict the correlation of climatic variables (like temperature, rainfall or snowfall, humidity, day length, chilling hours, etc.) with a given biological phenomenon like survival rate of species, growth of vegetative parts, fruit-set, crop maturity or the crop yields, etc. These models are also used by the ecologists to identify the variables which affect the crop yields through their impact on modifying the local climate.
  - Understanding the interactions of farming systems with the surrounding environment is thus important for success in agribusiness and modelling helps us in doing the same.
  - The crop models with as many variables as possible are thus better in making predictions than the models with a few variables. However, modelling with a very large number of variables may not always be possible because of the problems of lack of relevant data, mathematical programming problems, etc. Most of the times, therefore, we have models with the variables in which we have the immediate interest.

Production Function – an algebraic representation of a model

- Most common crop models are the economic models analyzing the effect of some inputs on crop yields.
- In these models, influence of an independent variable is estimated on the crop yield or on the growth of the crop.
- We know that a production process is a set of sequence of rules for using different inputs that needs to be followed for using different inputs.
- The ultimate outcome of a production process is the final output of that process, i.e. the crop yield or the desired vegetative growth.
- In a simple modeling scenario, a production process can be considered as a *production function* (a mathematical or the symbolic expression of a production process). A production function is the most common crop model. In general, a production function can be algebraically represented as;

  $$Y = f(X),$$

  Where; Y is the *dependent variable (say output*) which depends on the amount of input (X) used. Since we can change the level of input being used, X, is also called an *independent variable*. We assume that the level of technology being used remains the same during the production process.

- For a multiple inputs case, a production function will take the following form; indicating that the final output depends on, or is a function of '*n*' inputs or '*n*' independent variables.

  $$Y = f(X_1, X_2, X_3, \ldots, X_{n-1}, X_n)$$

- However, it is common to analyze the effect of a single factor of production on an output; while the other variables are held constant at their mean use level or at predetermined levels. We can thus rewrite the above equation for a production function as follows;

  $$Y = f(X_1 / X_2, X_3, \ldots, X_{n-1}, X_n)$$

- The equation shows that although the output, Y, is a function of 'n' independent variables, currently, however, the effect of a single variable, X_1, is being analyzed and other variables have been kept constant (at their mean level of input use, or say at their current level of use). The functions can have linear, quadratic or other forms; and a suitable form is to be selected for detailed analysis.
- We can graphically represent the response of a dose of an independent variable, or a package of inputs, on the dependent variable (output) by plotting the output obtained by the use of each dose of the input in a production trial. Such a representation of the production data is termed as the *response curve* or the *total product curve* (Fig. 16.1). The shape of the response curve for a product depends upon the nature of the product and the production process being used. The response of different inputs, under given production conditions may be different over the range of a response curve. Response to application of input(s) may be increasing, decreasing, or even constant. Technically, we refer to these responses as the increasing, decreasing or constant *returns* to variable inputs, respectively. To analyze the behaviour of the response curve, it is always helpful to look at the average and marginal components of this curve.

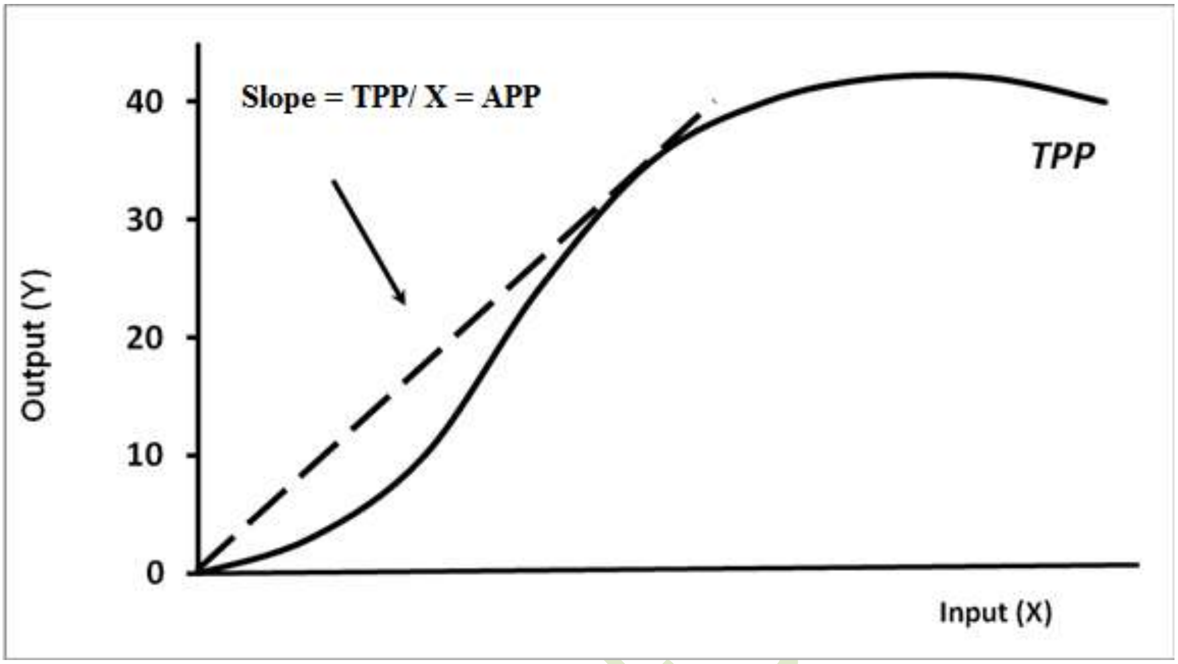


Figure 16. 1: Response curve or the total product curve

- Average response, or average product (AP) as it is commonly known, is defined as the output produced per unit of input used. Marginal product (MP) or marginal response, on the other hand, is defined as the change in total output resulting from a unit increase in input. Algebraically;
- AP = Y/X, and MP = ∆Y/∆X. Where, ∆ denotes the change; so when we estimate the change in Y, as a result of a unit change in X, we have estimated the marginal product.
- If we plot the average and marginal outputs, we can then add two more curves to the above figure showing the total response curve. It now becomes more intuitive to visualize as to what happens to the shape of the total product curve as the input use is increased. The two additional curves allow us the clearer picture of the average and marginal response to the input use.

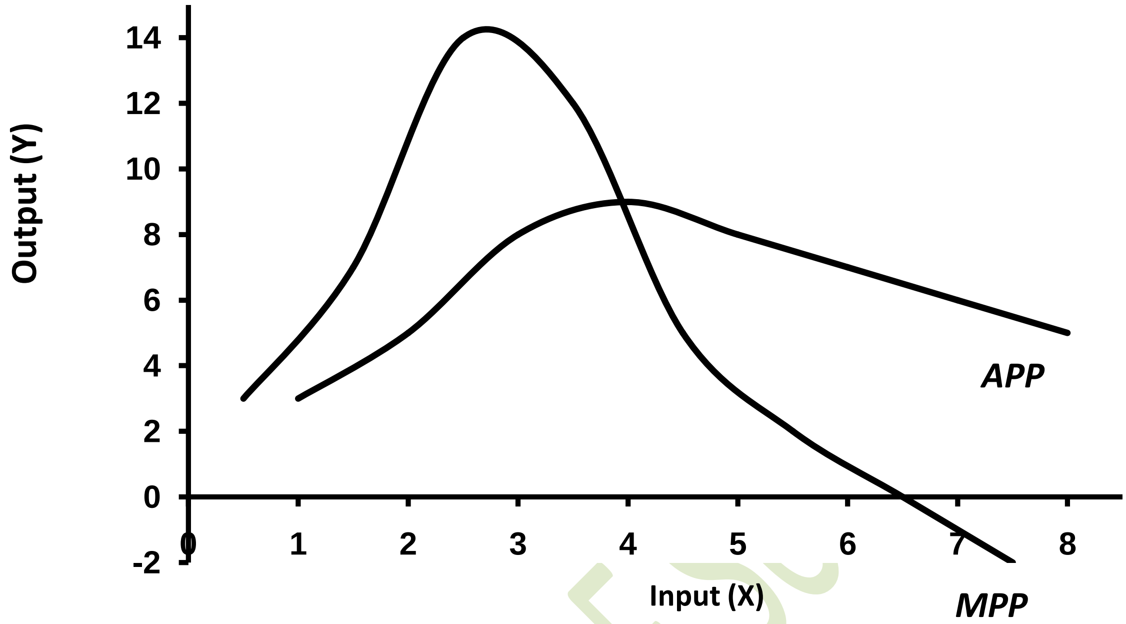


Figure 16.2: Average and marginal product curves

- We note that geometrically, MP is the slope of the total product curve. The behaviour of the marginal product curve reflects the output behaviour (i.e., the relationship between inputs and output) in response to the increase in a unit of input. When MP is increasing we say we have increasing marginal returns; that is when with the successive dose of input the addition to the total product is higher than the addition made by the previous dose of input. Similarly, when MP is decreasing, or constant, we have respectively the decreasing or constant marginal returns function. Summarizing, if;

$\Delta Y_1/\Delta X_1 < \Delta Y_2/\Delta X_2 < \text{- - -} < \Delta Y_n/\Delta X_n$ we have increasing marginal returns

$\Delta Y_1/\Delta X_1 > \Delta Y_2/\Delta X_2 > \text{- - -} > \Delta Y_n/\Delta X_n$ we have decreasing marginal returns

$\Delta Y_1/\Delta X_1 = \Delta Y_2/\Delta X_2 = \text{- - -} = \Delta Y_n/\Delta X_n$ we have constant marginal returns

- It is possible that for an activity we might notice increasing, constant and decreasing returns over the range of total product or response curve. This happens as a result of varying capacity utilization of the fixed resource due to increased use of variable inputs. As for example, in case crops the per unit response to input use is higher in the initial stages when the productive capacity of a fixed resource, say for example land, is not fully utilized. So when more input is used the output obtained per unit of additional input used is increasing. Later, the response may be constant over a restricted range and then it declines when the land resource gets over utilized. Most common examples of such responses are the fertilizer applications on a given piece of land or the number of irrigations in an irrigation trial. In both these cases, the yield response to initial input doses are higher and the response declines as we continue using additional doses of inputs. Finally, there may be losses due to toxicity or lodging etc., if the input use is continued beyond the absorptive capacity of land and the crop.

- Thus, it becomes important to decide as to what level of production (and thus the level of input use) is *desirable or profitable* and where one should stop using the input. It is important to consider economic aspects (profitability) because the inputs are scarce and have to be paid for. If the inputs are not scarce or are not paid for, then in general, one might target the biologically maximum yield. This mostly is the case in research trials where we need to find out the maximum yield or total production of the crop.

Applications in horticulture:

- Modeling has become relatively easy now with the use of computers. Computers help in reducing the complications of handling voluminous data. Therefore, apart from annual crops, modelling for perennial fruit trees is also commonly done. In the field of horticulture, the crop models are needed for modelling yield forecast, policy analysis and management options. It is very important to predict yields so as to prepare ourselves for marketing of the produce in a hassle-free manner. For example, it is important to know the timings of the arrivals of different produce in the market. If, through modelling, we can get an idea when the marketing season would be a lean season, and how we can change our harvesting to target this period, we can increase our profits. Similarly, we can target the production of flowers and pot-plants to suit the important fairs and festivals in a region. Well framed crop models can give us an idea of how we can improve some characteristics of the produce (e.g. in terms of length of stems, size of flowers etc.). The same is true for cultivation of vegetables.
- In perennial crops/fruit trees we need to model “the architecture of fruit trees and the relations between pruning and flower and fruit development” for maintaining the vigour of the trees. Such modelling is generally called biological modelling. When we combine the biological and economic considerations, we say we are doing a bio-economic modelling. The economic content of the model relate to the costs and returns from the production process while the biological content refers to the physiological production processes from planting to maturity of the crop. The annual fruit production is determined by the biophysical model which may use factors like tree density, pruning/training regimes.

Fruit tree models:

- The perennial nature of fruit tree implies that tree growth and the yields are also dependent on previous years’ growth and health of the tree. In deciduous fruit trees, for example, the number of flowers, and thus crop potential is determined by the condition of the plant in previous season. In fruit trees there is “a perennial woody skeleton which not only grows and develops during the annual cycle, but also accumulates and exports carbohydrates and other reserve materials. This complicates the estimation of the net increase in biomass of a fruit tree during the annual cycle". Nevertheless, we model the response by taking various assumptions or by keeping some of the factors at a known level in the model. Goldschmidt & Lakso have suggested an option for an overall, quantitative description of fruit tree's annual productivity through equations of carbon (C) supply and consumption. The equation is as under;

$$Pn + Sto = Sr + Rr + Dr + Fn.w.r + Pr + Sto$$

where;

Pn = photosynthetic production

Sto = non-structural carbon reserves

Sr = current year's shoot mass (including leaves and stem) multiplied by a respiratory quotient

Rr = current year's root mass, multiplied by a respiratory quotient

Dr = current year's drop of flowers and fruit-lets, multiplied by a respiratory quotient

Fn.w.r = fruit number, multiplied by fruit weight (w), multiplied by a respiratory quotient

Pr = perennial organ mass, multiplied by a respiratory quotient

- This expression indicates the major parameters that need to be determined experimentally or compiled from existing data in order to estimate annual productivity.

LECTURE – 17

CROP REGULATION IN FRUITS

Objectives: To ensure regular and quality crop annually and to take desirable crop in fruits like guava and pomegranate during a year for higher return.

Introduction:

- Crop regulation is the basis for the regular and quality crop. A range of methods are used to increase production with enhanced fruit quality by crop regulation. It can be achieved through manual thinning, chemical thinning, selective harvesting, training, summer and winter pruning, prevention of pre harvest fruit drop etc.
- It is well known that competition between fruits is one of the principal factors affecting fruit growth, ripening and fruit quality. Fruit competes with each others for assimilates according to their relative sink strength and the availability of assimilates.
- When crop density is higher as under high fruit set conditions, competition for assimilates is intense, which result not only in decreased fruit size and quality but also promotes alternate bearing. Crop density, a measure of fruit crop, influences fruit growth and ultimately fruit size at harvest. It is largely dependent upon flowering and fruit set.
- Under ideal conditions, most fruits often set heavier crop that cannot be adequately sized to meet market requirement for higher price. This necessitates retention of well spaced fruits (Plate 17.1a & 17.1b) after selective removal of some of the fruits on the trees. Leaf to fruit ratio fairly guide about the extent of thinning to be carried out in a particular orchard. Usually 30-40 leaves per fruit (Plate 17.2a) are sufficient to produce fruit of good quality (Plate 17.2b). Though, thinning may reduce the total yield, but net return increases as larger fruits fetch much higher price in the market (Plate 17.3a & b).
- The regulation of crop load begins at pruning.
- The management of irrigation is also vital, especially during the critical of fruit development, where the most rapid fruit growth occurs.
- Tree nutrition also affects the eventual fruit size.
- However, thinning has a much greater influence on fruit size by adjusting optimum crop load on the tree during the heavy cropping year. It can be done manually by selective removal of young fruit lets at pea size stage.
- In Redhaven peach cultivar, retention of 4-5 fruits per shoot at the time when fruits are of peas (14-15 mm in diameter) size assure optimum leaf to fruit ratio and higher production of large size fruits.
- However, manual thinning is labour intensive, expensive and only small number of trees in an orchard can be thinned at the optimum time.
- Use of chemicals including plant growth regulators (PGRs) as chemical thinning agents is gradually replacing hand and mechanical thinning in stone fruits.
- Various considerations like tree age and vigour, irrigation, pruning and fertilizer practices followed, chemical used, its concentration and time of application and local climatic conditions should be taken into account while adopting chemical thinning.

- Fruit setting in stone fruits is often limited by frost injury to flowers in spring frost affected areas.
- Evaporative cooling of flowering buds in spring has a delaying effect on bloom in stone fruits. In this, trees are sprayed with water during day time at frequent interval from bud swell stage until bloom. Frequency of tree misting depends upon the evaporation rate, which is done as and when water film on the aerial parts of the tree dries up. Evaporation of water from the shoots cools the buds and therefore delays their break.
- Fall (mid-October) application of growth regulators like GA_3 at 200 ppm and ethrel at 200 ppm delay flowering in spring by 3-7 days depending upon species and thus markedly increase fruit set.

Plate 17.1 - a) Heavy cropping; b) retention of 6 fruit-lets per fruiting shoot after manual after hand thinning in Kiwifruit.

Plate 17.2 a. Fruiting branch with lower leaf/fruit ratio

Plate 17.2b. Fruiting branch with higher leaf/fruit ratio

Uses of PGRs in crop regulation in temperate fruits

1. **Delay bloom:**
   - Autumn application of GA_3 and Ethrel cause delaying of bloom in spring in stone fruit, which can be a useful practice to increase fruit-set in frost affected areas.
   - Another advantage of PGRs treatment is that it facilitates better cross-pollination among varieties having different (non-synchronous) bloom period. For example, blooming of Red Beaut plum can be delayed by several days with fall application of GA_3 and Ethrel to help in better synchronization flowering period with cultivar Santa Rosa, inter-planted for cross pollination.
   - Concentration of PGRs and time of application depend upon fruit crop and environment.
2. **Thinning:**
   - Use of PGRs as crop thinning agents have been discussed above under crop thinning. In blossom thinning, chemicals are applied at bloom, whereas in fruit-lets thinning, chemicals are sprayed a few days after petal fall i.e. after fruit set.
   - Blossom thinning is adopted after assessing crop potential and is always risky, while fruit-let thinning is done after observing actual crop load.
   - In apple application of NAA at 10 ppm, 7-15 days after petal fall during the heavy cropping year (On-Year) causes satisfactory thinning and increases return bloom. However, thinning with chemicals is less satisfactory to achieve in stone in comparison to apples. Results are variable depending upon climatic conditions of the area and temperature at the time of application.

- Fruit crops grown in different climatic zones- tropical, subtropical and temperate are required to be trained and pruned accordingly, depending on the type of plant and specific objectives of fruit growers.
- Suitable chemical may be useful for this purpose in one condition but may fail to thin satisfactorily in another area.
- Follow local recommendations for the type of chemical to be used, dose and time of application for better results.

Plate 17.3 - a) Large fruits after thinning in kiwifruit
Plate 17.3b) NAA at 350 ppm 40 days after flowering in Kinnow

Mango:

Fruit drop:

- In mango, fruit drop is exceptionally high as only approximately 0.1% of the perfect flowers develop fruits to maturity. There are several causes such as lack of pollination, low stigmatic receptivity, defective perfect flowers, competition between fruit lets, and low soil moisture regimes.
- Extent of fruit drop in mango can be controlled by regular irrigation during fruit development period only after fruit set.
- Post setting drop of Alphonso mangoes can be controlled by foliar application of 25 ppm of NAA or 2,4-D (Gokhale and Kanitkar, 1953).
- In Neelum 2,4-D at 30 ppm proved effective control of fruit drop without having any adverse effect on fruit size (rao and Subba Rao, 1963).
- In other cultivars, use of lower (10-15 ppm) of 2,4-D about 6 weeks after fruit set i.e. end of April decreased drop (Gill, 1966). In Chausa mangoes, NAA at 50 ppm or 2,4-D at 10 ppm increased fruit retention (Prakash and Ram, 1985).
- Effective doses however, varies with cultivars and PGRs are effective only in ''off' years only (Chadha, 1963).

Biennial bearing:

- Problem of biennial is a major problem in mango associated with climatic factors, age and size of shoots, C: N ratio and hormonal imbalances in the trees. A number of remedial measures have been suggested from time to time, which include

1. Proper upkeep and maintenance of orchard
2. De-blossoming
3. Smudging and crop regulation through chemicals, pruning etc.

De-blossoming:

- In this, some flowers are removed during 'On Year' so that a good crop can be obtained even during 'Off Year'. When shoots are de-blossomed in 'On Year' during full development stage of panicle, it forces panicles to emerge during the 'Off Year'.

Smudging and chemical regulation: Smudging means building up slow fires, emitting smoke. It has been successful in Philippines but has not shown desirable response in India. Many chemical has been tested including, Ethrel (2-chloroethyl phosphonic acid), auxins, paclobutrazol and KNO_3 with inconsistent and often doubtful results.

Pruning:

- Opening up of the centre of the trees by topping off or thinning of branches have been reported to decrease biennial bearing in Mulgoa, Neelum and Bangalora cultivars.
- This improves light penetration into the interior of tree canopy. However, these practices have been unsuccessful in those cultivars which have inherent problem to bear irregularly.

Citrus

Fruit set:

- In citrus, fruit yield is often limited due to poor fruit set. Experiments with the use of PGRs have given some encouraging but, inconsistent results.
- Fruit set in Washington Navel Orange can be increased with the foliar application of 2, 4-D at 8 ppm.
- In India, a foliar application of 2, 4-D or 2, 4,5-T has been reported to be beneficial in improving fruit set and quality in mandarin.
- Sharma and Chopra (1978) observed increased fruit set in Pineapple and Valencia late orange following the application of 2,4,5-T at 10 to 15 ppm.
- In some studies in California, spray of GA_3 though has increased fruit set in sweet oranges and mandarin, but some undesirable effects like rough skin surface, thickening of skin, less juice contents in fruits often occurred.

Fruit drop:

- Excessive fruit dropping of citrus fruits is a major problem in India.
- If lack of soil moisture is the cause, use of organic mulching material like leaves or black polythene mulch can reduce the extent of fruit drop.
- Auxin, particularly 2, 4-D at varying concentrations is very effective in controlling pre-mature/pre-harvest fruit drop in citrus. Sprays of 2, 4-D at 8 ppm at 1.2cm diameter stage in Valencia orange, and at 15 ppm in Pineapple and 2, 4, 5-T at 30 ppm in Jaffa and Mosambi

are useful when applied in October. 2, 4- D have also been found to be useful in reducing fruit drop in sweet lime (Randhawa *et al.* 1959) and Darjeeling mandarin (Kar *et al.* 1985).

- In Himachal Pradesh, application of 2,4- D at 10 in May and September controlled fruit drop in Kinnow mandarin.

Fruit thinning:

- In Himachal Pradesh, application of NAA at 350 ppm (Plate 3 b) or Ethrel at 200 ppm in Kinnow mandarin during the 'On Year', 40 days after full bloom effectively control fruit drop and reduce the tendency of alternative bearing.

Guava:

Regulation of flowering and fruiting:

- In northern India, guava flower twice a year, once in February and subsequently in June. The February or spring flowering is called *Ambe-bahar*; its crop mature in June and the July to September or monsoon flowering is called *Mrig-bahar*; its crop mature from November to January. In western and southern India, a third flowering occurs in October.
- Thus guava though would give crop year the round, however, quality of fruits remain poor. The trees are therefore given some special resting and cultural treatments to skip a particular crop, so as to obtain high quality crop from the remaining cropping seasons.

Bahar treatments:

- In northern India, fruits produced in the rainy season are inferior in quality and this crop is escaped by removing all the flowers, while winter crop is desirable with respect to size and quality and is therefore taken.
- In Deccan region, where the climate is mild, only two desirable crops a year are taken and the third one is escaped.
- The practice, which is popularly called a *bahar* treatment, is achieved by root exposure and root pruning or exposure to hot sun before the onset of monsoon.
- Root pruning has however, adverse effect on tree longevity.

Withholding of irrigation:

- In Maharashtra, stopping of irrigation and removal of soil around the upper roots by June 10, and later again covering it with soil and manure mixture is a common practice for regulation of cropping in guava. In the pre-monsoon period, two light irrigations before a normally heavy one is recommended. This will allow escaping crop from rainy season.

Plant growth regulators:

- Auxin compounds have been very useful in thinning a crop in guava.
- Post bloom application of NAA at 80- 100 ppm has been useful in reducing fruit set. This treatment can reduce more than 80 % of rainy season crop and increase flowering of the following winter crop. NAD at 50 ppm and 2,4-D at 30 ppm are also effective for de-blossoming of summer flowers.

Pomegranate:

- Irrigation is withheld at least two months prior to the main flowering season. Manuring and fertilization followed by light irrigation is then followed two months later after flowering.

Then three to four days later, normal irrigations are given at recommended intervals. This will result in producing new growth and bloom and thus ensure good crop.

- In Deccan, there are three flowering seasons viz,, June-July (*mrig-bahar*), February-March (*ambe bahar*) and September- October (*hasta bahar*). It is however desirable to take just one crop a year depending upon market requirement for better price and availability of water. In the Deccan, *mrig bahar* is taken due to scarcity of water in hot summer months. For getting crop from *mrig bahar*, treatment with withholding of irrigation from December to March-May results suppression of growth during this period. Trees will shed their leaves in March and will remain dormant till May. Shallow ploughing of land up to 10 cm depth is practiced in April. In mid May, the manure and fertilizers are applied followed by one or two light irrigation prior to the onset of monsoon rains. Trees will put forth new growth followed by bloom in June and will bear a good crop.
- In irrigated areas, *Ambe bahar* is also taken in the Deccan. Crop from this will mature in June-July. Irrigation is stopped once rain commence during monsoons. Following monsoon period, when trees shed their leaves in October-November, shallow ploughing is done. Manures and fertilizers are applied in the months of December-January, subsequently in January, first light irrigation is given and flowers will appear a month after irrigation. Quality of fruits and yield are better in Maharashtra from *ambe bahar, whereas in Bangalore, fruit from mrig bahar* maturing in October-November are superior in quality than *ambe bahar*. Regulation of *hasta bahar* is practically not feasible due to rainy season.

Preparation of solution:

- Solutions of plant growth regulators are made by dissolving their measured quantity (Table 17.1) in small amount of solvent and then diluting in water, to make an appropriate strength/ concentration. The types of solvents for different PGRs are as follow:

PGR	Solvent
Auxin	95% alcohol
Gibberellin	90% acetone
Cytokinin	Diluted hydrochloric acid (0.1N HCl)

- Commercial formulations of PGRs are also available in liquid form and solutions of desired strength of these are prepared by diluting their required quantities in water.
- Before applying through spray, 0.1% of surfactant (e.g. Tween 20) is added to the solution, for quick absorption by the leaves. Spray operation should be carried out in the morning hours on a clear and calm day to run off.
- For making solutions of higher concentration of auxins as in quick dip method (rooting), the quantity of alcohol to be added to the water should be up to 50 % of the total quantity of solution.

Table 17. 1: Guide for preparing solutions of different strength

% solution	mg/liter	g/liter	ppm
100	1000000	1000	1000000
10	100000	100	100000
1	10000	10	10000
0.1	1000	1	1000
0.01	100	0.1	100
0.001	10	0.01	10
0.0001	1	0.001	1

Percentage (%) = ppm/ 10000

ppm = % x 10000


****Thanks ****


****all the best ****