College of Agriculture and Natural Resources

Teaching Material for the Course

Fruit Crops Production and Management (PlSc3094)

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CHAPTER ONE
INTRODUCTION

Definition

1.1 Status and Scope of The Production of Tropical and Sub Tropical Fruits

Horticulture is a fascinating subject. Since it deals with beautiful flowers and foliage and delicious and nutritious fruits and vegetables. It can be both a profitable business and a rewarding hobby. Bailey (1939) observed that horticulture is concerned with production within an **enclosure.** Janick (1986:1) defines horticulture as that branch of agriculture concerned with **intensively cultured plants** used for food, for medicinal purposes, or for aesthetic gratification.

Horticultural crops often have high cash value and are intensively cultivated on relatively small areas. The high cash value of horticultural crops justifies a large input of capital, labor, and technology per unit area of land. Horticulture deals with a large number of plant species. Traditionally, it includes fruits, vegetables, and ornamental plants. Even medicinal plants, beverage plants (tea, coffee), and spices are considered horticultural crops. Horticulture is an art as well as a science. It deals with a combination of the botanical and agricultural aspects of plants. Basic principles of physics, chemistry and biology are used by horticulturists to understand and manipulate plant life. Biotechnology is now finding direct applications in horticulture.

The definition of 'fruit' presents certain difficulties. In simple botanical terms it is customary to say that a fruit is the product of the matured or ripened ovary (gynoecium). However, both the stigma and style may also play a part in fruit formation. There are also many instances where other floral parts –the floral receptacle, calyx, even the axis of inflorescence – may also contribute towards fruit formation. These organs may develop simultaneously with the development of the gynoecium and become an integral part of the ripened fruit. When distinguished botanically, such structures are known as false or spurious fruits. The function of the fruit is to develop, protect, nourish, and ultimately disperse the seeds contained in it. The horticultural consumer's definition of fruit is a plant product with aromatic flavour which is either naturally sweet or normally sweetened before eating.

The commercial production of fruits is known as orcharding. It is typically based on long-lived perennials, many of which do not bear fruit until several years after they are planted. Grape plantations are called vineyards, and the cultivation of grapes is called is called viticulture. Similarly, citrus orchards are typically called citrus groves and the cultivation of citrus is known as citriculture.

All major fruits are clonally propagated. In most cases, the commercial varieties are used as scion, and the rootstock is of a different species or variety. Farm operations like pruning and training of trees and thinning of fruits are unique to pomolgy. With the exception of a few nuts, fruits are highly perishable. Post-harvesting handling of fruits is itself a specialized discipline, dealing with grading, packing, storing, processing, and shipping operations. Similarly, marketing of fruits requires special attention to take advantage of seasonal markets and to avoid losses due to perishability.

Ethiopia has a wide range of edaphic and climatic conditions that permit production of tropical and sub-tropical horticultural crops. Temperate crops can also be grown in the highlands. Irrigation can be provided from rivers and fresh lake water throughout the year. In addition to the growing demand in the local market, the neighboring Arab countries and winter export to Europe are potential markets for the expansion of fruit industry. Current time the largest share of fruit cultivation is under the peasant sector and large scale farms are concentrated in the HDC, and other state farms
Exports of fresh produces are currently negligible due to several reasons:

- Quality problem
- Management problem of cultivated land (salinity etc.; nematode, etc.)
- Transport and marketing problems
- Increasing demand for local processing
- Sustainable production

1.2 Economic Importance and Nutritional Use of Fruit Crops

Food and nutrition security is realized when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life.

Globalization, industrial development, population increase & urbanization have changed patterns of food production & consumption in ways that profoundly affect ecosystems and human diets; Diets low in variety but high in energy contribute to the escalating problems of obesity and chronic disease which are increasingly found alongside micronutrient deficiencies and undernourishment; The causes and consequences of the dramatic reduction of food diversity and the simplification of diets are complex and are not limited to specific cultures.

In general fruit have uncountable benefits which play a great role in human life directly or indirectly. Moreover those macro as well as micro elements will be used to minimize thye incidence of disease and many related problem which caused by shortage of fruits and vegetables: we can get the following by consuming those horticultural crops comparing with animal used

Technical terminologies

Food : any product obtained from plants or animals that can be taken into the body to yield energy and nutrients for the maintenance of life and the growth and repair of tissues. Includes all foods and drinks acceptable to be ingested by a certain society.

***Diet*:-** is defined as the **sequence of meals** in a day. It is concerned with the eating patterns of individuals or a group. e.g. breakfast, lunch and dinner; and other may add snack

Balanced diet:- is a diet that **contains all the nutrients** in the proportion that is optimal for long-term health and survival.

***Nutrition*: -** the scientific study of food and its nutrients; its functions, actions, interactions and balance in relation to health and disease.

***Nutrients*:- Chemical substances** that are **essential to life** which must be supplied by food to yield energy and nutrients for the maintenance of life and the growth and repair of tissues.

Macronutrients are nutrients needed by the body in relatively **large quantities** (many grams per day) and include carbohydrates, fats, and proteins.

Micronutrients are nutrients needed by the body in very **small quantities** (usually less than 1 gram per day) and include vitamins and minerals.

Malnutrition

- ***Under nutrition***: results from **inadequate** intake of macronutrients and micronutrients or inability to fully utilize the food they eat due to illness.
- ***Over nutrition***: results from **excessive intake** & deposit of nutrients (carbohydrate & fats)
- ***Micronutrient deficiency:*** deficiency in one or more minerals or vitamins

Food security: a situation that exists when **all people, at all times**, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life.

Pillars of food security

1. **Accessibility**
2. **Availability**
3. **Utilization**
4. **Sustainability**

Nutritional value of food crops

Major nutrient groups

- Proteins
- Carbohydrates
- Fats and oil
- Vitamins
- Minerals

Macro-nutrients

Micro- nutrients

- *Together with **water**, these nutrients are essential for life*

Activity 1.1

- As an agrarian plant science graduate should be equipped with nutrition related knowledge. In line with this concept every one of you need to familiarize those macro and micro nutrients: its source, definition, amount required by human being

Energy

In one banana and a few strawberries give you as much as energy as an entrecote! You will not feel as fulfilled, but your body really can extract as much of energy out of fruit.

Proteins - Fat - Sugar

As the energy fruit contains consists of sugars the fruit is digested in 30 minutes. This chemical process has no toxic waste products that are difficult to remove from the body and it even stimulates the removing of toxic elements.

The energy animal products contain consists of fat and proteins. Because of the high amount of proteins it is digested in 6-8 hours. This chemical process does produce toxic waste-products that have to be removed from your body.

Fibers

Another remarkable difference is that fruit contains a substantial amount of fibers while animal based products don't contain any. Fibers are very important.

Water

The water percentage of fruit (80%) is higher than that of meat (15%) and comes more near the water percentage of the human body (80%).

Importance of fruit crops

Fruits are important because of their various advantages.

1.Providing nutrition: the fruits supply vitamins required for maintenance of health and for resistance to diseases. Some fruits are excellent source of vitamins, e.g Mango (vitamin A 4800 IU), papaya (vitamine A 2020 IU), the amounts mentioned above are present in 100 gm of edible parts.

2.Fruits provide minerals like calcium, iron, phosphorous, etc., whose deficiency may lead to disturbances in metabolism. Certain fruits are especially rich in minerals. Besides, fruits supply carbohydrates, fats and proteins, (e.g., carbohydrates –banana; fat-avocado; protein-water melon).

3.Fruits also supply dietary fiber (cellulose, hemicelluloses, legnins) which is essential for normal peristaltic action of the intestine. Organic acids which stimulate appetite and digestion also come from fruits. Many fruits have medicinal values. Nutrition fruit garden concept in the backyard of each house therefore, has to be popularized to supply fruits for balanced diet.

Vitamins Page - Minerals Page

Food	**Energy**	**water**	**fiber**	**fat**	**protein**	**sugar**	**vit.A**	**vit.C**	**vit.B1**	**vit.B2**	**vit.B6**	**vit.E**
substance = 100 g.	**kJ/Kcal**	**%**	**g**	**g**	**g**	**g**	**ug**	**mg**	**mg**	**mg**	**mg**	**mg**
Apple	207/49	84	2.3	0	0.4	11.8	2	15	0.02	0.01	0.05	0.5
Avocado	523/126	81	0.2	10	2.0	7.0	20	17	0.06	0.12	0.36	3.2
Banana	375/88	76	2.7	0	1.2	20.4	3	10	0.04	0.03	0.36	0.3
Date	1275/300	20	7.5	0	2.0	73.0	0	0	0.05	0.10	0.10	0.7
Grapefruit, Red	128/30	90	1.4	0	0.9	6.6	0	40	0.07	0.02	0.03	0.5
Grapes	274/64	83	2.2	0	0.6	15.5	0	3	0.03	0.01	0.08	0.6
Guava	306/72	81	5.3	0	1.0	17.0	30	218	0.04	0.04	0.14	-
Lemon	51/12	96	1.8	0	0.0	3.0	0	40	0.06	0.02	0.04	0.8
Lime	156/37	91	0.3	0	0.0	7.0	0	40	0.03	0.02	0.08	-
Mandarin / Tangerine	177/42	88	1.9	0	0.9	9.5	12	30	0.08	0.03	0.084	0.4
Mango	255/60	84	1.0	0	0.0	15.0	210	53	0.05	0.06	0.13	1.0
Orange	198/47	87	1.8	0	1.0	10.6	2	49	0.07	0.03	0.06	0.1
Papaya	136/32	91	0.6	0	0.0	8.0	40	46	0.03	0.04	0.04	-
Passion Fruit	158/37	88	3.3	0.4	2.6	5.8	125	23	0.03	0.12	-	0.5
Peach	151/36	89	1.4	0	1.0	7.9	15	7	0.01	0.02	0.02	0.0
Pineapple	211/50	84	1.2	0	0.4	12.0	20	25	0.07	0.02	0.09	0.1
Strawberry	99/23	91	2.2	0	0.7	5.1	10	60	0.02	0.03	0.06	0.4
Tomato	48/11	97	1.4	0	0.9	1.9	140	15	0.05	0.02	0.08	0.7

Source: Nevo table 2008, Nevo Foundation, Netherlands Nutrition Center

Activity 1.2 discuses the 6 key food groups which is involved in human nutrition?

1.3 Classification of fruit crops

1. **Botanical Classification of Fruit Crops**

Fruits can be botanically classified into three main groups, namely, simple, aggregate and multiple. Simple fruits are obtained from a single ripened ovary and may be fleshy or dry. The berry, pepo, hesperidium, drupe and pome have a pericarp which is soft and fleshy, while in dry fruits the pericarpis often hard and brittle at maturity.

The entire pericarp of the berry is fleshy and usually edible. Pepos are berries that have a hard rind around the fruit. Hesperidiums have a leathery rind. The drupe has a thin exocarp, a mesocarp that is thick and fleshy and an endocarp that is hard and stony. In the pome, the portions produced by the pericarp are enclosed within fleshy parts that are derived from parts of the flower other than the ovary.

Dry fruits may be either dehiscent where the carple splits at maturity along definite seams. In indehiscent fruit, the fruit wall does not split at any certain point or seam at maturity. A dehiscent fruit may contain many seeds whereas an indehiscent fruit usually contain one or two seeds. The legume follicle, capsule and silique are dehiscent fruits. The achene, caryopsis, samara and nut are the examples of indehiscent fruits.

The ovary changes to fruit after fertilization. When the fruit is formed from ovary only, it is known as true fruit, e.g., mango and when the fruit is formed with flower parts, inflorescence, etc., along with the ovary, it is known as false fruit or spurious fruit or pseudocarp, e.g., apple, chalta, jackfruit, pineapple.

This method of classification is very useful for botanists and breeders who are interested to study their botanical relationships in respect of morphology, cytological similarities and dissimilarities, their phylogeny, palynology, crossability and other taxonomic characters.

The fruit crops are broadly classified into two groups-monocotyledoneae and dicotyledoneae.

Monocotyledoneae

Family

Bromeliaceae-*Ananas comosus*-Pineapple

Musaceae-Musa pradisiaca-Banana

Dicotyledoneae

Anacardiaceae-*Mangifera indica*-Mango.

Caricaceae-*Carica papaya*-papaya

Lauraceae-*Persea Americana*-avocado

Myrtaceae- *Psidium guajava*-Guava

Rosaceae-*Malus pumila (Pyrus malus*)-Apple

Rutaceae-*Citrus* sp.-Citrus

Vitaceae-*Vitis vinifera*-grape

2. Classification Based On Temperature Requirement

This classification is primarily based on temperature during the growing season on the basis of the minimal temperature which the plant can tolerate they are grouped as hardy, semi-hardy and tender.

Hardy plants can withstand minimum temperatures of -4 to -2 0C while semi-hardy plants can survive -1 to 0 0C and tender crops are those which can not withstand 0 0C. On the basis of temperature requirement the fruit plants are classified in to three categories: temperate, tropical and subtropical.

3. Classification Based On Structural Similarity

The stature of the plant is the primary consideration in this classification.

a. Strong trunk – trees having very strong trunk with huge canopy, e.g., mango, walnut.
b. Moderately strong trunk-comparatively less as compared to former group, e.g., apple, guava.
c. Shrub-like tree – the plants are bigger than usual shrubs. The branches are weaker, e.g., pomegranate, pear.
d. Shrubs – plants are low in stature with branching habit from the base, and have weak stem, e.g., lime, lemon.
e. Vine – plants have creeping habit with hardy and heavy stems and need support for climbing, e.g., passion fruit, grapes.

f. Herbaceous – virtually no woody stem. They may be perennial in nature, e.g., banana, papaya, strawberry or annual in nature, e.g., cape gooseberry.

4. Classification Based On Flowering Habit

a. Seasonal – plants flower in a specific season. Sometimes variation in the climatic condition, particularly during the flowering season, may favor continuance of vegetative phase. E.g. litchi.
b. Non-seasonal – variation in flowering within a plant is particularly prominent when grown around equator. However, the same plant exhibit seasonal behavior when grown away from equator. E.g., mango.
c. Ever flowering - plants flower throughout the year, e.g., papaya.
d. Gregarious flowering – flowering at indefinite time may be produced due to climatic variation. Rainfall in drier period or chilling may induce indefinite flowering. Precocity at long interval may also be attributed as gregarious flowering, e.g., quince.

5. Classification Based On Respiration Rate During Ripening

Ripening in fruits is associated with typical changes in respiratory rate, lowering in the mature fruit followed by a significant rise during the time of ripening. This phenomenon is known as respiratory climacteric. Thus the fruits are grouped as climacteric and non-climacteric. The climacteric may occur rapidly (avocado, banana), at intermediate rates (pear, mango, apple) and not at all (orange, lemons).

The non-climacteric fruits maintain a steady rate of respiration during ripening. Some fruits show only a decline in respiration during the ripening period. However, this classification is related to fruits and not to fruit plants.

6. Classification Based On Photoperiods Responses

a. Long-day plants – longer day length is obligatory for induction of reproductive phase, passion fruit.
b. Short-day plants-shorter day length and longer dark period helps in the induction of reproductive phase, e.g., strawberry.
c. Day-neutral plants – the plants flower irrespective of day length, e.g., papaya, banana.

7. Classification Based On Nutrient Content Of Fruits

This may be termed as consumer's classification of fruits. This classification may be utilized for growing fruit trees, particularly in homestead land.

1. Carbohydrate rich (per cent): banana (36.4), apricot (72.8).
2. protein rich (per cent); cashewnut (21.2), almond (20.3).
3. fat rich (percent): walnut (46.9), avocado (22.8).
4. vitamin A rich (IU per 100 gm edible part): mango (4800), papaya (2020)
5. vitamin B rich 9mg per 100 gm edible part): Thiamine (B1-almond 240), riboflavin (B_3-bael-1191), etc.
6. vitamin C rich (mg per 100 gm edible part)
7. calcium-rich (per cent): Litchi (0.21)
8. iron rich (per cent): date (10.6).
9. energy rich (calorific value 100 gm): walnut (687), cashew (596)

CHAPTER 2
PRINCIPLES AND TECHNIQUES OF FRUIT PROPAGATION

Section learning objectives

After completing this section students should be able to:

- Define what is a seed?
- Recognize the general parts of a seed
- Describe the process of germination
- Compare methods for measuring germination
- Define the environmental and disease factors influencing germination
- Describe the types of seed dormancy and how dormancy controls germination
- Recognize the general aspects and importance of asexual propagation
- Explain how hormonal control affects root and bud formation
- Identify the different types of cuttings
- Discuss the types and uses of layering
- Define grafting, scion, rootstock and cambial layer
- Discuss techniques of grafting and budding

Content

2.1 Sexual

2.2 Asexual

2.3 Micro-propagation

Activity 2.1 Define plant propagation and state the purpose of propagation.

Plant propagation is the art and science of increasing numbers of plants. Successful plant propagation depends on a series of factors, all of which need to take place before a plant is reproduced. These factors change from plant to plant. From seed germination to the successful rooting of cuttings, certain principles must first be understood before a plant propagator can perfect methods for growing plants. The various propagation methods can be separated into sexual methods as seeds and spores and asexual methods like cuttings, layers, divisions, natural reproductive structures such as bulbs, grafting, and *in vitro* micro-propagation.

In Ethiopia since the beginning of flower production the most commonly used methods of propagating ornamentals is through the use of seeds and cuttings (asexual means). Propagation using seeds is the most commonly and widely used practices in Ethiopian ornamental production.

Seeds can be purchases from abroad or agricultural shops and these seeds are sown/planted either in controlled or outfield environment for transplanting further.

2.1. Sexual plant propagation

Activity 2.2. Differentiate between sexual and asexual plant propagation.

Most bedding plants and a significant number of cut flower, potted flowering plant, and foliage plant species are propagated from seeds. In a number of species, sexual reproduction produces plans that are too variable for commercial production and asexual methods are therefore required. Asexual reproduction produces a clone consisting of all individual plants propagated from one original plant. Asexual propagation is also used in situations when seed propagation is either too lengthy or too expensive. Although seeds can be sown by hand into open flats or trough flats, the majorities are mechanically sown into individual cells or plug flats with automatic seeders.

Activity 2.3. What is seed and what are the main parts of a given seed?

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Seed is the end result of the sexual fertilization and has three parts: a protective outer covering, storage tissue, and an embryo. A seed is, "botanically a matured ovule containing an embryo that is usually the result of fertilization". It can also be thought of as a young plant with minimal life activity going on. A seed forms as a result of the combination of the mature male and female gametes, which come from the stamen and pistil of the flower, respectively. This process is called fertilization and is the result of the development of a plant and ultimately the development of the flower.

Activity 2.4. Define germination and explain the environmental conditions required for a given seed to germinate.

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Conditions for seed propagation

Media: should be well drained, have a low soluble salt level (EC) of less than 1.0 dS/m and fine texture, and contain no pathogens.

Temperature: Low temperature is often the primary reason for poor seed germination.

For most species, optimum media temperature is 21 to 24^0C, but varies among species. The temperature should rarely go below 21^0C or slow, erratic germination will occur. Conversely, the temperature should remain below 27^0C. Medium temperature should be monitored, as it is often 3 to 6^0C cooler than the air temperature, due to water evaporation.

Light: Seeds of may species germinate faster when exposed to light; others will not germinate unless exposed to light. In particular, small seeds often germinated better with light and should be sown on the top of the medium and not covered. Generally, relatively low light levels are needed, as little as 0.2 fc in some cases. The seeds of a few species such as Dahlia and marigold (Tagetes) require darkness and should be covered or germinated in a dark germination chamber.

Water: High quality, low EC water and uniform application are also critical for proper seed germination. High water EC may prevent seedlings from germinating, cause erratic germination, and increase susceptibility to disease. The medium has also be maintained with uniform moisture. If seeds begin the germination process but the medium subsequently dries out, the seedlings will be injured or die.

Nutrition and **disease protection** is also an important activity in seed propagation processes. Plant species perpetuate in two ways, sexually or asexually. Reproduction through seed is sexual, except in some apomictic species. Seeds of some species, including mango, give rise to more than one seedling per seed. In such cases, however, only one seedling is zygotic; the rest are produced from nucellus cells and are called nucellar seedlings. This phenomenon is called poly-embryony. Nucellar seedlings can be utilized to raise uniform plants.

Seed dormancy

Activity 2.5. Define seed dormancy and explain the methods of overcoming seed dormancy?

Seed dormancy has been defined as the failure of an intact, viable seed to complete germination under favorable conditions (Bewley, 1997).

If in case there are extra seeds after using, optimum seed storage conditions should be maintained for the seeds. Optimum seed storage conditions occur when both the humidity and temperature are as low as possible but the temperature is above 2^0C.

2.2. Asexual plant propagation

Activity 2.6. Define meristematic cells?

The concept of vegetative propagation is that an exact copy of the genome of a mother plant is made & continued in new individuals. This is possible because plants have **meristematic**, undifferentiated cells that can differentiate to the various organs necessary to form a whole new plant. A piece of plant shoot, root, or leaf, can therefore, grow to form a new plant that contains the exact genetic information of its source plant. Whereas sexual reproduction by seeds provides opportunity for variation and evolutionary advancement, vegetative propagation aims at the identical reproduction of plants with desirable features such as high productivity, superior quality, or high tolerance to biotic and/or abiotic stresses, and as such, plays a very important role in continuing a preferred trait from one generation to the next.

Activity27. Why vegetative propagation?

Reasons for vegetative propagation

The most important reasons for vegetative propagation are:

- maintaining superior genotypes
- problematic seed germination and storage
- shortening time to flower and fruit
- combining desirable characteristics of more than one genotype into a single plant
- controlling phases of development
- uniformity of plantations

2.3.1 Principles and techniques of propagation cutting

The most common method to propagate plants asexually is from cuttings. Cuttings can be made from stems, roots, leaves, or combinations of plant parts such as stems with leaves. Cuttings should be taken from healthy plants with desirable characteristics, and placed in a warm, humid environment to hasten root development and prevent them from drying.

Activity2.8. Differentiate between cutting types (stem, leaf and root cuttings)

a. Stem cutting

i. Hard-wood cutting

Cutting material is typically taken closer to the base of the stem. Tip cuttings, unlike in softwood cuttings, are usually discarded. The cutting must be of moderate size, approximately the width of a pencil, and must contain enough food reserves (carbohydrates) to support the cutting during rooting. If large amounts of hardwood cuttings are needed, they can be cut to size using handsaw or band saw, making preparation easier for the propagator

ii. Semi-hardwood cutting

Intermediate between hard and soft wood cutting.

iii. Soft wood cutting

Softwood cuttings consist of a flush of new green growth. To prepare a softwood cutting many steps are taken and several treatments can be used. Soft wood cutting has high meristematic cells and low level of stored carbohydrate.

b. Leaf cutting

Leaf cuttings may be comprised of only the leaf blade or the leaf blade and petiole (leaf stem). Begonias and sansevierias are commonly propagated by leaf cuttings. Leaf cuttings of some plants, such as the Rex begonia, are wounded by cutting the underside of the main veins before placing the leaf surface flat and in firm contact with the propagation medium. Sometimes it is helpful to pin these leaves to the moist medium with small stakes or toothpicks. Leaf cuttings of many plants can be stuck upright in the propagation medium. When sub-terminal sections of leaves are used, make sure the basal end of the cutting is inserted into the propagation medium. Roots and new shoots will start at the base of the leaf or at points where the veins were cut.

Leaf-bud Cuttings

Leaf-bud cuttings include the leaf blade, the petiole, and a 1/2- to 1-inch (1.2 to 2 5 cm) segment of the stem. Axillary buds located at the union of the petiole and stem produce new shoots under warm, humid conditions. This method is often used for plants in short supply that have long internodes. Every node (joint) on the stem can be a cutting.

c. Root cutting

Root cuttings are usually taken from young plants in early spring or late winter, before they start growing. Healthy roots have ample food (carbohydrates) stored to support shoot development at this time. Root cuttings are typically 2 to 7 inches (5 to 18 cm) in length depending upon root diameter. Large roots can be cut shorter than small roots and still have an adequate food supply for root and shoot initiation and growth. Small, delicate root cuttings (1/8 to 1/4 inch or 3.2 to 6.4 mm in diameter) should be positioned horizontally in the propagation medium and covered with 1/2 inch (12 mm) of medium. Larger root cuttings (1/4 to 1/2 inches or 6.4 to 12.8 mm in diameter) can be planted vertically with the end of the cutting originally nearest the plant crown positioned upward. Optimum temperatures for most root cuttings range from 55°F to 65°F (13°C to 18°C). Root cuttings may be transplanted after shoots have emerged and sufficient new secondary roots have developed. The principal disadvantage of this method is the amount of work involved in obtaining the root cuttings.

Activity2.9. Recognize about polarity of cutting.

2.2.2. Principles and techniques of propagation layering

Activity 2.10. What is the basic difference between cutting and layering?

The term layering is used for all types of propagation in which roots are formed while the stem is still attached to the mother plant. Only after the root formation, the layer is detached and planted as a new plant. Layering is often used in species that are particularly difficult to root from cuttings, as the layered branches allow a continuous supply of water, nutrients and plant hormones to the place of root development. Dehydration, a common problem in cuttings, is prevented, as well as nutrient leaching, which often occurs under mist propagation. As layering beds are often used for many years, utmost hygiene has to be practiced to prevent the spreading of pests and diseases, especially nematodes and viruses.

As layering methods are often used with species that are otherwise difficult to root, it can take several months until roots have formed on the layered branch.

a. Simple layering

Simple layering is usually done with many-stemmed shrubs that produce long & soft shoots after coppicing. Plants are coppiced at the end of the dormant season & the developing young shoots are bent down & pegged into the ground about 15-20 cm below the tip, thus forming a 'U'. During the season, the shoots grow and will produce roots where they are pegged down. To improve on the rooting success, the shoots can be wounded, or auxins applied. The stems are usually allowed to grow for one to two seasons before cutting the rooted stem off and planting it under shade. For this method to be successful it is important that the substrate used for layering is kept moist, but not waterlogged at all times and that soil-borne diseases are avoided.

b. Compound layering

c. Air layering

Air layering can be done with almost any woody plant and is an excellent method to propagate small numbers of individual trees. It involves the girdling of a relatively young shoot, thus leading to an accumulation of rooting promoting plant hormones at the cut, without hindering water and nutrient supply to the tip. The shoots should be young and vigorous yet woody enough to withstand the treatment; best is the previous season's growth. It seems that the individual development of the shoot is more important than the season in which the marcot is set.

d. Mound layering

Stooling or mound layering is done with plants that have been severely cut back (to between 2.5-5 cm above soil level) and that have the natural vigour to produce many strong coppice shoots. New shoots developing are continuously covered with moist soil, sawdust or other light substrate to about half their height. If they are covered too high, leaves may be covered leading to weakening of the shoot. At the end of the season, roots will have formed at the base of the shoots, which can then be cut off and planted as separate plants. Also with this method, the substrate has to be kept moist and free of pathogens.

2.2.3. Principles and techniques of propagation by Grafting and budding

Grafting, the technique of combining two or more different plants, has been practiced for many centuries. Initially, grafting was practiced on trees that were culturally and economically important, such as olives and citrus in the Mediterranean by the Greeks and Romans. In later centuries, the grafting of ornamentals, such as roses, and of the many other plants imported from foreign countries into European gardens, became important. Grafting is a technique of vegetative propagation that is relatively labour intensive and requires skilled and experienced people for successful and satisfying results.

The following definitions are needed to understand grafting and budding techniques and their underlying principles:

- **Grafting:** the technique of connecting two pieces of living plant tissue together so that they will unite and form a functional plant.
- **Scion:** the aerial part of a tree that will form the crown of the new plant. This part contains the dormant buds of the tree whose desired characteristics need to be multiplied.
- **Budding:** a special form of grafting in which the scion consists of either a single or several buds. It is a more economical form of grafting, as more scions can be produced from a single mother tree.
- **Rootstock:** the below-ground or lower part of a tree, sometimes including part of the stem and some branches, that will form the root system of the new plant. This part may also contain dormant buds, which should not be allowed to develop in the new plant since they (suckers) do not have the desired characteristics that need to be multiplied.
- **Vascular cambium:** a thin layer of meristematic cells between a trees' bark (phloem) and wood (xylem). Meristematic cells are capable of dividing into new cells that may differentiate into new tissues and organs.
- **Callus (tissue):** a mass of undifferentiated cells formed around a plant wound. In grafting or budding, this callus will form around the wounds at the union of the scion and the rootstock. From the callus cells, new vascular tissue develops that will allow scion and rootstock to function as one plant.

Physiology

Grafting can be seen as the healing of a wound into which a piece of another plant has been inserted. Physiologically, the same mechanisms as in wound healing, the rapid division of meristematic cells and their following differentiation into the damaged organs, takes place. A successful graft not only has the physical stability of an undamaged plant, but it also functions as one unit after phloem and xylem cells unite.

Healing process

The usual sequence in the healing of a graft union is as follows:

- ✓ **Lining up of vascular cambiums**. The person carrying out the grafting places the freshly cut scion into direct contact with the freshly cut rootstock. It is of utmost importance that the cambial layers of both plants are in direct contact.
- ✓ **Wound healing response**. Necrotic (black) material is formed from the cells damaged by making the cuts.
- ✓ **Callus bridge formation**. The next, undamaged layer of cambium cells, produces a large number of parenchyma (tissue) cells that form a callus, and provide a mechanical link between the scion and the rootstock.
- ✓ **Cambium formation**. Certain callus cells line up with the cambial layers of both scion and rootstock, and differentiate into new cambium cells.
- ✓ **Vascular tissue formation**. Secondary phloem and xylem cells are formed from these new cambium cells, finally establishing a firm vascular connection between the two plants.

Techniques of grafting

a. whip and tongue graft

This method is more common in practice, especially in the case of pear and apple trees. It is used to graft thin stems. It may be used on roots, stems or tops. The scion should have two or three buds with the graft made below the bottom bud. The first cut is a 2-5cm sloping cut at the bottom of the scion. The second cut is made with a distance 1/3cm from the tip of the first cut.

The same process is repeated on the rootstock. In apple propagation, the tongue grafting is mainly used to graft on M4 (semi-dwarfing – 5m height) and M9 (very dwarfing – 3m height) rootstock.

b. splice grafting

The graft is useful for plants that unite easily. It can be used to graft root, stem or top graft. The diameter of the scion and rootstock should be the same, from the size of a pencil to 10-15 mm. This type of grafting practice includes the process of a simple sloping cut on both the scion and the rootstock. The two parts should over lap each other perfectly. In any case, one rule must be followed: The wider the scion and root stock, the longer the cut surface.

c. Cleft or split graft

This method has been practiced throughout the history of horticulture and is one of the oldest fruit propagation techniques. It is suited for apple and pears, but, in tropical areas, in can also be used for propagation of mango and avocado trees. Citrus and guava trees also use this method. In the case of top and side work, the scaffold limb is usually wider than the scion. In the case of tree propagation, both parts, the rootstock and scion, should be the same size.

d. Bark or rind graft

Bark grafting is used when the stock is too large for whip grafting. It is one of the most difficult grafting techniques. Perfect application of this method requires much practice and experience. The use of this technique is common for pear, apple and different nuts grafting.

e. Wedge grafting

This method is one of the most difficult propagation techniques. To perform a good quality wedge grafting requires a high level of skill and a great degree of experience. This method is to be used for working on the tops of trees. For small trees, graft into the trunk; while for large trees, graft into the main branches. The stock may be much wider than the scion.

The method may be used during dormant stage. The scion, like in other cases, should contain a minimum of 3 buds and its length should be approximately 20-25 cm. Now, cut the base of the scion to a long wedge that is sloping both downward and inward. Use a thin-bladed saw to make a cut (or various cuts according to the size of the stock) to approximately the center of the stub. Wide the cuts with a round-bladed grafting knife to fit the cuts on the scion. Place the scion into the cut. If the scion matches the cut in the stub, they are held by being tapped in place. Be sure, that the cambium of both, the scion and stock, is in contact to each other. Finally, cover the graft union and the end of the scion with grafting wax.

f. Approach graft

This is a form of grafting particularly suitable for difficult combinations. Both scion and rootstock remain intact plants until a secure graft union has been formed, thus allowing both to use their own vascular system for assimilation and water uptake.

g. Bridge grafting

This technique is mainly used to repair damaged trees or branches and not for propagation. Like in the case of the slipping grafting, bridge grafting requires grafting under the bark. Where bark of the branch or trunk is damaged, first clean up the surface and cut a wedge in the bark horizontally. Next, prepare 3-6 scions according the size of the damaged area and graft both ends of each of the scions under the bark.

Budding techniques

a. T-budding (shield budding) and inverted T-budding

Most forms of budding should be done when the bark slips off easily from both scion and rootstock, which is at a time of high metabolic activity. T-budding is most commonly used in the propagation of citrus. It is generally limited to small nursery stock of between 6-25 mm diameter, which are actively growing, so that the bark slips easily from the wood.

b. Patch budding

A rectangular piece of bark is cut out of the rootstock, usually with a special double-bladed knife. A matching piece of bark, including a bud, is cut from the bud-wood and matched into the prepared rootstock.

c. I-budding

d. Chip budding

Chip-budding does not use the protective bark flaps as T-budding does, but it also does not use slipping bark. The first step is to make a cut about 2-2.5 cm long with a depth of ¼ to 1/5 the diameter of the stock. With a horizontal cut made on the bottom, the cutting can be removed. The bud can also be cut off if necessary. The bud stick and stock must be the same diameter. The stock and scion must be placed together in such a way that allows the cambia of the bud and stock to match together as much as possible. Desiccation is a high risk when we use this method, therefore, the wound should be wrapped tightly with grafting tape.

3.2.4. Propagation by specialized organ

- Ψ **Propagation by bulb**
- Ψ **Propagation by corm**
- Ψ **Propagation by tuber**
- Ψ **Propagation by rhizomes**

2.3. Micro-propagation

Activity 2.11. What is micro-propagation?

Terminology

The following are the definitions of some of the terms used in the presentation needed to understand micro-propagation techniques and their underlying principles.

⇒ **Axillary buds**: dormant buds in the axils of leaves. These buds are stimulated to grow through hormonal changes, for example, when the main stem is coppiced.

⇒ **BA/IBA**: plant hormones (benzyl adenine, a cytokinin, and indole-3-butyric acid, an auxin).

⇒ **Callus**: undifferentiated cells growing after wounding. Under the influence of hormones and enzymes, callus can differentiate into various plant organs.

⇒ **Ex-plant**: any plant section/segment collected from existing plant for use in tissue culture work.

⇒ **Haploid**: having one of the usual two sets of chromosomes.

⇒ **Incubate**: to grow under special conditions, including temperature, light and nutrients.

⇒ **Micro-propagation**: propagation of plants under controlled, artificial conditions using plant growth media containing plant growth regulators and a balanced mixture of plant nutrients.

⇒ **Organogenesis**: the initiation of any organ from explants in vitro.

⇒ **Plantlets**: the very young plants developing from incubated cultures.

⇒ **Poly-embryony**: the development of more than one embryo after sexual reproduction.

⇒ **Primary culture**: the initial culture of an ex-plant from original parental plant material.

⇒ **Pro-embryo**: the product of the first (transverse) cell division after fertilization. The apical cell later develops into the embryo, the basal cell into the so-called suspensor which functions to absorb and transmit nutrients to the pro-embryo.

⇒ **Propagules**: the fully-grown plants arising from vegetative parts of plant segments that are ready for transplanting in the field.

⇒ **Regeneration**: the growing of shoots or roots from explants.

⇒ **Seedlings**: young plants grown from seed.

⇒ **Subculture**: the culturing of plant material originating from primary or subsequent cultures.

Reasons for micro-propagation

Activity 2.12. Why micro-propagation?

The main reasons why micro-propagation of ornamental plants can be considered are:

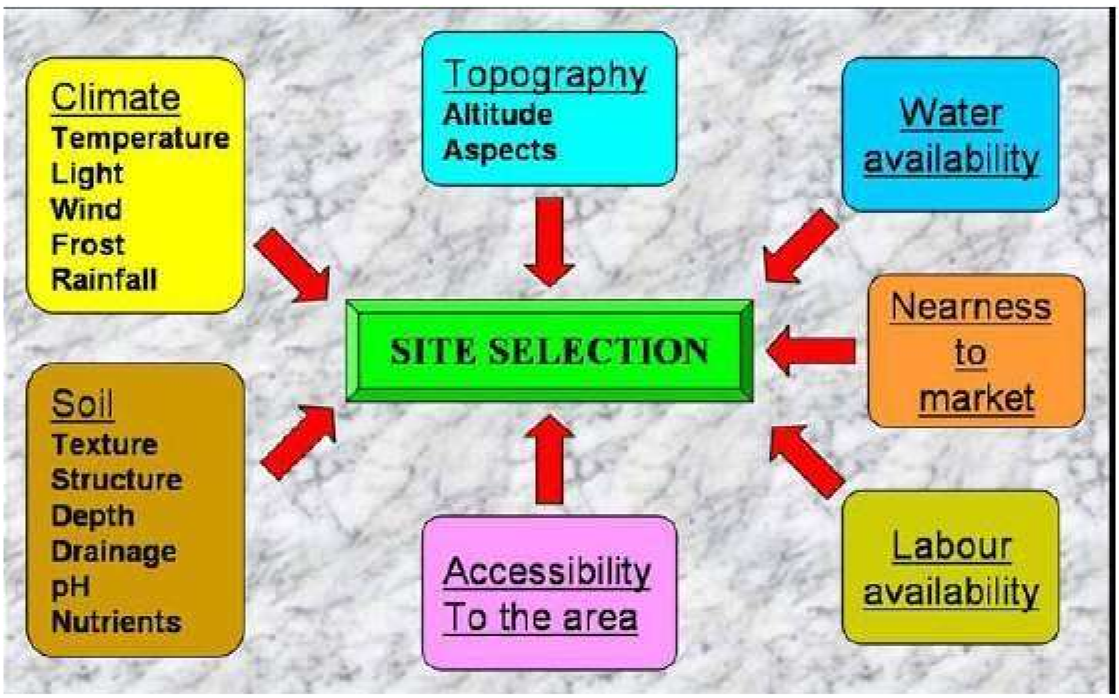
- ✓ To multiply a tree which cannot readily be multiplied by seed or conventional vegetative methods.
- ✓ To rapidly propagate large quantities of propagules of superior tree provenances.
- ✓ To clean pathogen infected clonal plant materia

CHAPTER 3

PLANNING AND ESTABLISHING ORCHARDS

Establishment of an orchard is a long term investment and deserves very careful planning. The selection of proper location and site, planting system and planting distance, choosing the varieties and the nursery plants have to be considered carefully to ensure maximum production.

Selection of site: The following factors are to be considered before selecting a site for an orchard.



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

1) Experience of the fruit growers and research stations in the locality regarding the acclimatization of the fruits under consideration.
2) The seasons of heavy rainfall, hail storms and hot winds.

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

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

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

5. **Transport facilities:** Fruits being perishable cannot be moved for long distances without quick and refrigerated transport. So; the orchards must be located where there is quick transport, preferably a refrigerated transport system.

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

7. **Proximity to established orchards:** It is an added advantage if the site is in proximity to the already established orchards because of compactness of areas of production facilitates provision of transport and storage facilities. It also enables formation of co-operative societies and other associations which can collectively own grading and spraying machinery and other costly equipment including storage facilities. If there are compact blocks of single crop say citrus, banana, mango etc. the spread of diseases and pests are more. In selecting a site close to other orchards, one must make sure that they are free from devastating pests and diseases like citrus scale, canker, panama disease of banana, the tristeza disease of citrus.

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

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

10. **Presence of nurseries close by:** It is an advantage if the nurseries are close by to the selected site for selecting the plants for the orchard after studying the scion parents

personally. It will also help to get cheap and quick transport of plants which will ensure better establishment.

11. Cost of the land: Cost of the land comes up for consideration when all the other requirements listed above have been satisfied. It should never be the prime consideration in the choice a little extra cost paid for the foregoing amenities is more than repaid in the long run.

Steps in Establishment of An Orchard

After the selection of the site and drafting the plan, next comes the establishment of an orchard with fruit plants. For this, the selected site should be thoroughly surveyed for studying its size, topography, flow of irrigation water, drainage and fertility gradients. The positioning of main and subsidiary roads, wells, wind breaks etc. should be planned clearly.

Steps:

1. Clearing of the land: Preparation of the soil depends largely on its condition, previous history and grower's plans. If the land has been under cultivation and has been well maintained, nothing further may be required. On the other hand if the site is a new one and was never under cultivation earlier, much has to be done well in advance for planting. If the land is a virgin land i.e. it is not under cultivation previously, the existing vegetation is to be cleared. Standing trees, shrubs, bushes etc. should be cut down and uprooted along with the stumps and removed. No vegetation should be left on the site. Otherwise, they may shade the young plants; compete for water, light and nutrients. Further, their removal at a later date is expensive and risky. All the stumps and roots may be removed. Otherwise they may harbour white ants, termite hills, diseases etc. and spread to the new plants. Along with vegetation, stones, rocks and ant hills, termite hills etc. should be removed.

2. **Leveling:** Leveling is important for efficient irrigation, drainage to check soil erosion and also for improving appearance. If the land is sloppy contouring (if the slope is 3 to 10%) or terracing (if the slope is >10%) is to be done. During leveling sub soil should not be exposed.

3. Fencing: Fencing is necessary to protect trees from stray cattle, human trespassing and also for attractiveness. The fence may be of stone, barbed wire or live fence. Growing of live fence is an expensive one. At the initial stage it may be cheap but afterwards the maintenance is costly. Live fence needs periodical punning or trimming to shape and also to control their growth and encouraging more branching. This is one of the costly items of the orchard cultivation.

4. Wind break plants: The wind breaks are provided to resist the velocity of wind which causes loss of bloom, wind erosion and evaporation of moisture and to keep the orchard warm by checking frost and cold waves. The beneficial effect of wind break is felt up to a distance equal to 3 times its height.

The characteristics of a tree suitable as wind break are:

- It should be fast growing
- It should be easily estabishable
- It should be able to acclimatize to the environment
- Should have dense canopy
- It should not harbour pests and diseases
- It should be frost resistant
- It should be drought resistant
- It can be propagated by various methods

Wind Breaks

Some plants usually employed for growing as wind break plants are: Casuarina (Most effective in open sandy soils), *Pterocarpus santalimus* (Redsanders), *Erythrina indica* (Requires pruning to make tree top bushy), Cassia‘s and *Polyalthia longifolia* (Slow growing) are some trees which can also be used. For mango orchards, seedling mangoes and polyembryonic mangoes may be planted as wind breaks to provide chance seedlings and root stocks.

There should a spacing of 12m between the row of wind break and the first orchard row. This space may be occupied by roads and drains. The wind break trees should be planted closer than their spread so as to form a thick screen. A spacing of 5m is maximum for most plants.

5. Roads and drains: These are laid out according to the plan prepared in advance taking the convenience and levels into consideration. Main irrigation channels also have to be plotted. Open drains should be straight, running parallel to the gradient. Silt catching devices should be employed in the drains. Covered drains should be filled with big stones at the base and smaller ones over them and the top 12 inches should be covered with the orchard soil so as not to impede ploughing and other operations.

6. Tillage: Tillage including sub soil should be done thoroughly at this stage, since it cannot be done after planting without disturbing the roots of the trees.

7. Sowing green manure crops: A green manure crop is sown thick and uniformly all over the area to be planted. Apart from the manurial value the crop reveals by its growth, infertile patches of the land, so that they can be examined and suitable steps are taken for amending them.

8. Marking plant positions: The system of layout should be decided first. Then one of the fence lines or a road should be chosen as the base line. In deciding the base line, due regard should be given to appearance of the rows from the road along which the visitor or the manager is expected to walk.

9. Digging and filling of pits: Generally the pits are dug 2 to 3 months in advance of planting Allow the pits to weather. A planting board (a plank about 1.5m long or longer with two end notches and a center notch) is applied to the marking peg by its central notch and two pegs are driven at the end notches. Then the board and the marking pegs are removed and a pit of 1-meter cube is dug. The two pegs driven at the end notches remain in position on either side of the pit. All pits are dug similarly so that plant position is not altered at planting time. While digging, the topsoil should be kept on one side and the bottom soil on another side separately as the topsoil is somewhat fertile than the bottom soil.

While filling the pits, the topsoil is mixed with farmyard manure or compost, leaf mould or green leaf and a kilogram of super phosphate. Then the pits are filled with the bottom layer of soil first and then with the topsoil mixed with the manures. The soil after filling should rise about a foot over the orchard level so as to allow for shrinkage on setting.

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

***11.* Selection of plants from the nursery:** The grower should visit the nursery and select the plants. Plants are selected on the basis of certain characters such as *branching, growth of the plant, age of the plants and pests and diseases.*

12. Lifting and packing: Before lifting of plants from the nursery the nursery is thoroughly irrigated one day in advance for easy lifting of the plants without damage to the root system. Then the plants are lifted carefully along with a ball of earth attached to the root system. The roots are wrapped in straw or grass or covered with a gunny cloth and placed in a basket or a wooden crate for packing.

Depending on the size of the basket or crate 6-7 plants are kept for each basket.4-5 long bamboo splinter or wooden pegs are forked into the sides of the basket and tied at the top. In between the plants and at the top of the basket after filling, the plants re covered with straw so as to avoid falling during transit.

13. **Season of planting:** The distribution of rainfall in the tropics and subtropics and the break of spring growth in temperate zone determine the season of planting. In tropical climate, most trees are planted between July and December and few in January also. In general planting is done during the monsoon in moderate rainfall areas and at the close of the monsoon in heavy rainfall areas.

Planting should be done on cloudy days and preferably in the afternoons rather than in the morning.

14. **Planting:** The planting board should be used at the time of setting the plants, so that they are in a perfect line. The plants should be set in the soil to the same level as it was in the nursery. The bud / graft joint should not be covered with soil. Plants should be irrigated once copiously to get the soil particles to closely adhere to the roots and also to drive away the air around the roots completely. The plants should be staked with a straight bamboo piece or other twig. Graft bandage should be removed if not already done. Any buds on the rootstocks should be rubbed off.

Systems of orchard plating

The arrangement of plants in the orchard is known as lay-out. The following points need to be considered before choosing a system of planting.

- It should accommodate maximum number of plants per unit area.
- It should allow sufficient space for the development of each tree.
- It enables equal distribution of area under each tree.
- The intercultural operations such as ploughing, spraying etc are easily carried out.
- It makes supervision more easy and effective.

Descriptions of the different systems

(1) Square system

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

Procedure for lay out:

Step no. –1: —ABCD‖ is the area where the trees are to be planted. The first step will be establishing a base line. Select the baseline parallel to the road or fence or the boundary of the orchard. This should be drawn at half a distance of the spacing that is to be followed. For example, if the spacing is 10m, the base line should be drawn at a distance of 5m from the periphery of the plot.

Step no.-2: Towards end of the base lines leave again a gap of half the spacing from the boundary or road or fence etc. and put the peg on one end of the base line. From this peg measure one planting distance and put the second peg on the base line. Thus, continue placing pegs at each of the planting distance till the total length of the base line is covered. The distance from the last peg to the boundary should also be at half the spacing.

Step no.-3: From the first peg and the last peg on the base line, draw perpendicular lines.

Merits and demerits:

1) Most commonly followed and simplest of all and easy to layout.
2) The possibility of cultural operations in two directions is the greatest advantage of this system.
3) The major disadvantage of this system is that a lot of space in the centre of each square is wasted.

(2) Rectangular system:

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

- Row to row distance is more than that from plant to plant in the row.

Procedure for lay out:

Step no's: 1, 2 and 3 are as same as in square system.

Step no.4: Mark the planting positions on both the perpendicular lines following the spacing to be adopted between the rows.

Step no.5: It is same as in square system, but following the spacing to be adjusted between the rows.

Step nos. 6, and 7 are as same as in square system.

Merits and demerits:

1. It has almost all the advantages of the square system but cultivation is some what difficult, especially when the trees have fully grown.

(3) Quincunx or filler system:

- This is also known as filler or diagonal system.
- This is the modification of a square system of layout distinguished to make use of the empty space in the center of each square by planting another plant is called filler tree. Generally the filler tree will be precocious and shorter duration and not be of same kind as those planted on the corner of the square. Guava, phalsa. plum, papaya, peaches, kinnow are important fillers. They yield some crop before the permanent trees come into bearing.
- The filler tree is removed when the main fruit trees grow to full stature and start bearing.

- This system is followed when the distance between permanent trees exceeds 8m or more or where permanent trees are very slow in their growth and also take longer time for coming to bearing. **Eg.** Sapota, Jackfruit**.**

Procedure for lay out:

Step no-1: Lay out the square system

Step no.-2: Draw diagonals of each square.

Step no.3: Mark the planting position of the filler tree by fixing a peg at the point of intersection of the two diagonals in each square.

Merits and demerits:

1. The main advantage of this system is that the plant population is about double than the square

system.

2. The greatest disadvantage of this system is that, it is difficult to carry out intercultural operations on account of the filler tree.

(4) **Hexagonal system:**

- This is also called as equilateral system. Some times a seventh tree is planted in the centre of the hexagon, and then it is called **septule** system.
- In this system the trees are planted in each corner of the equilateral triangle.
- This system differs from the square system in which the distance between the rows is less than the distance between the trees in a row, but the distance from tree to tree in six directions remains the same.
- This system is usually employed, where land is expensive and is very fertile with good availability of water.

Procedure for lay out: Steps-

- Mark the four sides as in the case of square system with the distances shown in the sketch. Locate the positions of the plants also on the first row.
- Take a rope slightly more in length than double the distance between the plants.
- Put a knot in the centre, so that the length of the rope on either side of the knot is as much as the tree to tree distance **or**
- Take an iron chain with a ring in the centre and either arm equal in length to the tree to tree distance.
- Hold the ends of the rope or chain, each at the positions of two consecutive plants on the first row, and stretch from the centre to give an equilateral triangle and there by the position of a plant on the second row is fixed.
- In this way the field can be laid out.

Merits and demerits:

1. This system permits cultivation in three directions.
2. The plants occupy the land fully without any waste as in square system
3. This system allows 15% more plants than the square system of planting.
4. This system is not generally followed because it is difficult to adopt in practice in the field and the inter-cultivation in such gardens is difficult to carry out.

(5) Triangular system:

- The trees are planted as in square system but the difference being that those in the even numbered rows are midway between those in the odd rows instead of opposite to them.
- Triangular system is based on the principle of isolateral triangle. The distance between any two adjacent trees in a row is equal to the perpendicular distance between any two adjacent rows.

Merits and demerits:

1. This system is not much of practical importance.
2. Plants are not placed at equal distance from all sides.
3. When compared to square system, each tree occupies more area and hence it accommodates few trees per hectare than the square system.

All the above systems are possible when the land is flat, plain or level, but not on uneven lands and sub-mountane areas (hilly areas).On undulating lands and hill slopes different types of planting systems are followed, Viz.,contour and terracing.

(6)Contour system:

It is generally followed on the hills where the plants are planted along the contour across the slope.

- It particularly suits to land with undulated topography, where there is greater danger of erosion and irrigation of the orchard is difficult.
- The main purpose of this system is to minimize land erosion and to conserve soil moisture so as to make the slope fit for growing fruits and plantation crops.
- The contour line is so designed and graded in such a way that the flow of water in the irrigation channel becomes slow and thus finds time to penetrate into the, soil without causing erosion.
- Terrace system on the other hand refers to planting in flat strip of land formed across a sloping side of a hill, lying level along the contours.

- Terraced fields rise in steps one above the other and help to bring more area into productive use and also to prevent soil erosion.
- The width of the contour terrace varies according to the nature of the slope. If the slope becomes stiff, the width of terrace is narrower and vice-versa.
- The planting distance under the contour system may not be uniform.
- When the slope is <10% contour bunding is practiced and if the slope is >10% contour terracing is practiced.
- In this system the trees are planted along the contour line at right angles.

Merits and demerits:

1) The trees may not be set at equidistance.
2) The no. of plants per unit area will generally be less than other system

Calculation of number of plants in different systems of planting

Square system of planting:==

$$\frac{\text{Area of the land}}{\text{Area occupied by a single tree}}$$

Area of the land = 1 ha. (10000 sq. m^2) Spacing between the plants and rows =10 m

Area occupied by a single tree =10 m X 10 m=100 m^2

-No. of plants required per hectare= $\frac{10,000\ m^2}{100\ m^2}$ = 100 plants.

Rectangular system:-==

$$\frac{\text{Area of the land}}{\text{Area occupied by a single tree}}$$

Area of the land = 1 ha. (10000 sq. m^2

Spacing between the plants =10 m Spacing between the rows =12 m

Area occupied by a single tree =10 m X 12 m=120 m^2

No. of plants required per hectare= $\frac{10,000\ m^2}{120\ m^2}$ = 88 plants.

Quincunx system:

$$\frac{\text{Area of the land}}{\text{Area occupied by a single tree}} \times 2$$

(Double the no. of plants of a square system)

Area of the land = 1 ha. (10000 sq. m^2)

Spacing between the plants and rows =10 m

Area occupied by a single tree =10 m X 10 m=100 m^2

No. of plants required per hectare= $\frac{10,000\ m^2}{100\ m^2}$ = 100 X2=200 plants.

As the plants are planted additionally in the centre of the square, hence first, the no. of plants are calculated for square system of planting which is: $\frac{\text{Area of the land}}{\text{Area occupied by a single tree}}$

$= \frac{10000\ m^2}{10 \times 10m} = 100.$

Additional plants = (No. of rows length wise –1) X (No. of rows width wise--1)

In 100x100 Sq metre field if planting distance 10x10 m then the number of rows length wise and width wise will be 10.

Hence, no of plants = (10-1) x (10-1) = 9x9=81.

So total no. of plants = plants planted in square system of planting + additionally planted plants in the center of the square =100+81=181.

Hexagonal system = $\frac{\text{Area of the land}}{\text{Area occupied by a single tree}}$

Method--1

In this system each tree occupies a parellogram area. Each parallelogram consists of 2 equilateral triangles.

Area of each parallelogram consists of 2 equilateral triangles. Area of each equilateral triangle is 3/4 X a^2

Where **a** is the length of a side of a triangle ie. Spacing between the trees in a row. So a tree occupies = **3/4** x $a^{2 \times}$ 2

Suppose if spacing is 10 m i.**e. a**

Area occupied by a single tree is **3/4** x $a^{2 \times}$ 2 =1.732 X10X10X2=86.60 m^2 Area of the land = 10000 m^2

No. of plants per hectare = 10000 m^2

---------   = 115/116.

86.60 m^2

Method-2

Suppose plant to plant distance is 10m, then row to row distance will be calculated as under:

ABC is equilateral triangle Hence

AB=AC=BC =10m

A perpendicular line AD is drawn on BC which divides it into two halves .It means BD=DC=5m

As per Pythagoras therom

$AC^2=AD^2+DC^2$ or $AD^2=AC^2-DC^2$

$AD^2= 10^2 - 5^2 =100-25=75.$

AD= 75 = 8.66m^2

Area occupied by a single tree is = Plant to plant distance x row to row distance

=10x8.66=86.66 m^2

No. of plants per hectare = 10000 m^2

------------ = 115/116.

86.60 m^2

Method-3

Each equilateral triangle area can be worked out by S(S-a) x(S-b) x (S-c)

Where S = half of the sum of three sides length of the triangle a,b,c – lengths of the three sides of a triangle.

Space occupied by each plant= S(S-a) x(S-b) X(S-c) x 2

Area of the land=10000 m^2

No. of plants required = 10000

S (S-a) x (S-b) x (S-c) x 2

High density planting / high density orcharding

Planting of fruit trees rather at a closer spacing than the recommended one using certain special techniques with the sole objective of obtaining maximum productivity per unit area without sacrificing quality is often referred as 'High density planting' or HDP. This technique was first established in apple in Europe during sixties and now majority of the apple orchards in Europe, America, Australia and New Zealand are grown under this system. In this system, four planting densities are recognized for apples viz., low HDP (< 250 trees/ha), moderate HDP (250-500 tree/ha), high HDP (500 to 1250 trees/ha) and ultra high HDP (>1250 trees/ha). Recently, super high density planting system has been also established in apple orchards with a plant population of 20,000 trees per ha. In some orchards, still closer, planting of apple trees is followed (say 70,000 trees/ha) which is often referred as 'meadow orchards'. The exact limits of plant density to be termed as is not yet well defined. It varies with the region, species, variety, rootstock, cost of planting material, labour and likely return from the orchard and agro-techniques adopted for a particular crop.

The underlying principle of high density planting is to make best use of vertical and horizontal space per unit time and to harness maximum possible return per unit of inputs and national resources.

Advantages

1) It induces precocity/precocious bearing
2) Higher yields. The average yield in apple is about 5.0 t/ha under normal system of planting and it is about 140.0 t/ha under high density planting.
3) Higher returns per unit area
4) Early returns
5) Easy management of orchard tress
6) Reduces labour cost resulting in low cost of production
7) Enables the mechanization of fruit crop production and facilitates more efficient use of fertilizers, water, solar radiation, fungicides, herbicides and pesticides.

Disadvantages of high density planting:

1) HDP results in over crowding, over lapping not only in the tops, but also in the root system and heavy competition for space, nutrients and water.
2) More important is build up of high humidity, lack of cross ventilation in the orchard, which is more conducive for build up of pests and diseases.
3) Reduction in yield in the long run after 10-12 years of age.
4) Production of small sized fruits and poor quality fruit

CHAPTER FOUR
MANAGEMENT OF ORCHARDS

4.1 Irrigation and Fertilization

Irrigation is frequent, costly, repetitive, and time-consuming cultural practice in arid and semi-arid regions where the rainfall amount and distribution is insufficient.
Irrigation requirement depends on:

- **Type of the crop and**
- **The extent of the deficit**

e.g. two weeks of deficit seriously affects banana while citrus is not affected by 2 dry months if it is not at bearing stage. Good irrigation consists of: correct timing of application and supplying the proper amount of water and distributing it uniformly.

When to irrigate? Water balance in the soil - **based on climatic data rainfall, PWP, etc** using Tensio meters and Electrical Resistance Blocks - for measuring % moisture content. leaf symptoms - wilting, rolling etc may not be a good indicator for some fruit crops e.g. In citrus the leaves draw water from the fruits and may not show distinct symptoms on the leaves though there is deficit in the soil and plant soil feel and physical conditions (cracking, etc)

II. Methods of irrigation
surface irrigation, sprinkler, drip irrigation and sub surface irrigation are the general method the choice of each method is governed by:
a) method of delivery of the water (open ditch or underground pipe etc)
b) size of stream and duration of flow
c) topography and slope of the land
d) soil characteristics (infiltration rate and water holding capacity)
e) quality of irrigation water
f) cost of irrigation water

Surface irrigation

- Surface irrigation has evolved into an extensive array of classify which can be broadly classified as follow:
    - Flood irrigation
    - Furrow irrigation
    - Border irrigation
    - Basin irrigation

Flood irrigation

- Flooding is one of the oldest irrigation methods.
- Flood irrigation is the least expensive irrigation method where water is relatively cheap.
- It should only be used on very flat fields, where ponding is not a problem.
- Flooding is a good way to flush salts out of the soil.
- Highly inefficient

Furrow irrigation

- Furrows are small channels, which carry water down the land slope between the crop rows.
- Furrow irrigation is relatively inexpensive where water costs are low.
- This method is suitable for all row crops and for crops that cannot stand in water for long periods

Border irrigation

- Basins are flat areas of land, surrounded by low bunds. The bunds prevent the water from flowing to the adjacent fields.
- The border strip is an area of land flanked by two border ridges, dikes, or ditches. These ditches guide the irrigation stream from a point or points where the water is applied to the ends of the strip.
- Border irrigation is generally best suited to the larger mechanized farms as it is designed to produce long uninterrupted field lengths for ease of machine operations.

Basin irrigation

- The basin method is suitable for crops that are unaffected by standing in water for long periods.
- Basin irrigation is commonly used for rice grown on flat lands or in terraces on hillsides. Trees can also be grown in basins, where one tree is usually located in the middle of a small basin.
- It is less suited to small-scale farms involving hand labor or animal-powered cultivation methods.

Sprinkler irrigation

- Sprinkler irrigation is defined as the method of irrigation under pressure in which water is sprinkled in the form of artificial rain through lines

Sprinkler system capacity

- The sprinkler system capacity is the flow rate needed to adequately irrigate an area and is expressed in gallons per minute per acre. The system capacity is dependent on the:

- Peak crop water requirements during the growing season.
- Effective crop rooting depth.
- Texture and infiltration rate of the soil.
- The available water holding capacity of the soil.
- Pumping capacity of the well or wells.
- The State Water Commission permitted pumping rate.

Advantages of sprinkler irrigation

- Provides good control of water application, which can reduce vegetative growth and improve the product quality.
- Provides a high degree of flexibility in design and operation, and can be automated to save labour and energy expenditure.
- Nutrients can be applied through the irrigation system (fertigation).
- Can be used to cool the crop during heat waves, to protect against frost and to manage plant health.
- Has the ability to keep soil soft for emerging seedlings with frequent short irrigations.
- Promotes rapid germination and crop establishment.

Disadvantages of sprinkler irrigation

- High capital cost.
- Distribution uniformity can deteriorate over time.
- Prone to wind effects on uniformity of water distribution.
- May create a humid environment in the crop canopy which, can lead to disease.
- Can cause crop damage where saline irrigation water is applied.

Drip irrigation

- Drip irrigation is the process of distributing small amounts of water directly to the root zones of plants.
- This is the most expensive, but most water-efficient, method.
- Low-quality water (high in salts) should not be used, unless filtered, due to potentially devastating effects of clogged emitters.
- Also, the use of water high in soluble salts will result in localized soil salinity buildup around plants, since drip irrigation is an ineffective leaching method

II. Fertilization

The purpose is to supply essential elements in the soil to increase the return. The type of nutrients and the amount required are naturally a function of soil type, growing region and crop load on impoverished soil (low CEC) all major and micro nutrients may be required in good soils N and K (easily leachable) elements are supplementally needed. regions with high rainfall and temperature lose nutrients from the soil due to leaching or volatilization.

Generally the following approaches can be considered

a) Grower experience

b) Using programs of successful growers in the area as models

c) Replacing amounts of nutrients removed in the fruits

e.g. A citrus orchard producing 50 tones ha^{-1} would require 66, 9.5 an d 90 kg ha^{-1} N, P, K to replenish nutrients lost during harvest

* loss due to volatilization, leaching and vegetative growth is not considered

d) Symptomatology: -based on deficiency symptoms

- can overlap with disease symptoms

e) Survey and field experiments

f) Soil and leaf analysis: soil analysis is most useful in monitoring the level of immobile nutrients (Mg, Ca, Cu, and P).

- For most nutrients leaf analysis is preferred than soil analysis

Training and Pruning

Introduction

Training and pruning are important operations. Both the operations form an indispensable process having direct bearing on growth and vigour of plants and yield and quality of fruits. A properly trained and pruned plant sustain heavy crop load and produce bounteous harvest of quality**.**

Training refers to the judicious removal of plant part/s to develop proper shape of a plant capable of bearing a heavy crop load whereas **pruning** is defined as the judicious removal of plant parts like root, leaf, flower, fruit etc. to obtain a good and qualitative yield. Thus, it can be conceived that the **training** is related to shape and size of plants where as **pruning** is related with harvesting better yield and more so harvesting fruits of quality. Both the operations of training and pruning work together in maintaining shape and size of tree and harvesting desirable yield.

Training is a treatment given to the young plants to get a suitable or desirable shape with strong framework. It may or may not involve pruning.

Pruning is the removal of unwanted, surplus annual growth; dead, dried and diseased wood of the plants is called Pruning.

Training:

Before actually discussing the subject of training, it is necessary to understand the various terms used to make the subject more intelligible.

i. **Trunk:** The main stem of the plant.

ii. **Head:** The point on the trunk from which first branches arise.

iii. **Scaffold branches:** The main branches arising from the head are known as scaffold branches. Trees in which scaffold branches arise within 60-70cm height from the ground level are called **low head trees** and those in which they come out from the trunk above 120cm are called **high head trees**.

iv. **Crotch:** The angle made by the scaffold limb to the trunk or the secondary branch to the scaffold limb is called **crotch**.

v. **Leader:** The main stem growing from ground level up to the tip dominating all other branches is called **leader.**

vi. **Water shoot:** A vigorous growing unbranched shoot arising on any branch or leader is called **water shoot.**

vii. **Water sucker:** The growth appearing on rootstock portion is called **water sucker.**

The reasons for training fruit trees, ornamental trees, shrubs etc. are:

1) There are number of plants, which grow wild and don't bear if they are left to themselves and will not have any symmetry in their growth.
2) Most of the time, the unpruned trees put forth vegetative growth only. Hence, bearing will be delayed.
3) When plants are grown in rows at close spacing, they grow tall and occupy interspaces, making intercultural operations difficult to practice.
4) For want of sunlight, the lower branches wither and die. The shaded fruits (**apple, citrus** etc.) fail to develop colour.
5) Untrained trees will generally be less productive because of excessive vegetative growth for most of the time.
6) The framework being weak in untrained trees, it breaks easily due to strong winds as well as heavy loads of crop.

All the above problems can be overcome by training the trees. Man can train the plant to suit his desire. By training the plants, ideal conditions can be provided for better production.

The fruit trees are trained to a particular system depending upon their habit of growth and the flowering and ornamental shrubs etc. can be trained to a particular shape like animals, birds etc. It is necessary to pay attention to the training of a plant during the first few years when it is young. In this period, its permanent framework is built up as decided upon by the grower.

Most deciduous and evergreen woody trees are best trained to a single stem with a low head. In case of pomegranate, custard apple and fig it would be better to train two or three stem plant and remove the other stems that may grow later.

In the tropical climate, the high-headed trees are unsuitable as their exposed trunks are subject to sunscald in summer. Low headed trees are common all over the world. In such trees the heads or crown is kept so low on the trunk that there is only a distance of 60-90cm between the ground and the lowest branch. Such low headed trees come in to bearing comparatively much earlier, are able to resist stormy winds more effectively and their spraying and harvesting also become easy.

The formation of the main frame work of the tree is the most important part of the training.

1) Usually, two to four main branches are encouraged. These should be allowed to arise from different directions and also at some distance from one another, so as to form a well-balanced head.
2) The frame work is greatly strengthened, if the branches are spaced at about 15cm distance with medium crotches (40-50^0)
3) If two or more branches of equal size are allowed to arise from one place, they form a bad crotch and often split from their common joint.

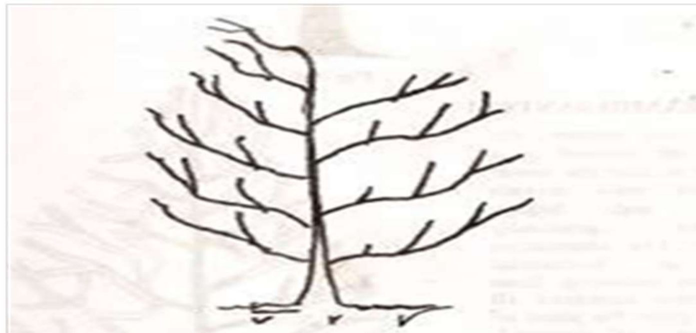
The most important systems of training followed in most of the fruit crops are:

a) **Central Leader system:**

- In this system, a tree is trained to form a trunk, which extends from the surface of the soil to the top of the tree.
- In many kinds of trees, the central axis or the main branch naturally grows vertically

upwards and smaller side branches grow from it in various directions.

- If the central leader is allowed to grow indefinitely, it will grow more rapidly and vigorously than side branches resulting in a robust close centre and tall tree. In such a tree the bearing is confined in top portion of the trees.



Central Leader system

Merits and demerits:

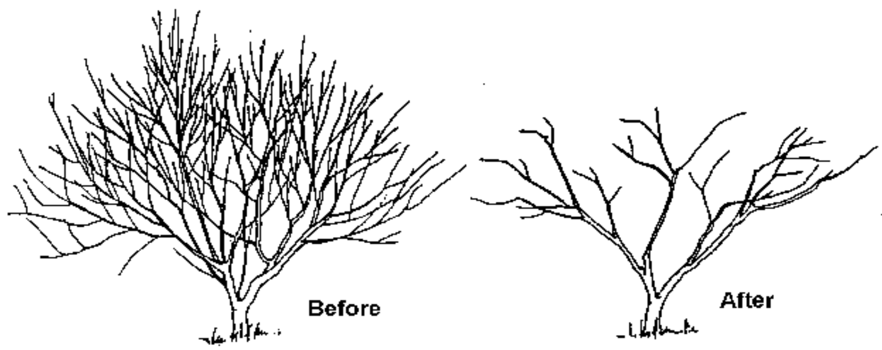
The main advantage of this system is the development of strong crotches.

Its main disadvantage:

1) Shading of the interior of the trees. This weakens the central leader and thus shortens the life of the tree
2) Since trees are very tall, harvesting and spraying become difficult and costly.
3) The lower branches, which remain more or less shaded, become ultimately less vigorous and less fruitful**.**
4) Owing to the shading of the inferior, the bearing surface moves to the periphery (outer shoots) of the tree. Thus fruiting surface is reduced and eventually yields are reduced.
5) The very high shape of the plants makes them prone to wind damage.
6) not suitable for high altitude and hot arid places where wind velocity is high.

This system is also called as **close centre**, since the centre of the plant is closed and also as **pyramida**l system, since the plant trained looks like a pyramid. This system of training is practiced in case of certain **apple** varieties and **pears**.

b) **Open Centre system**:



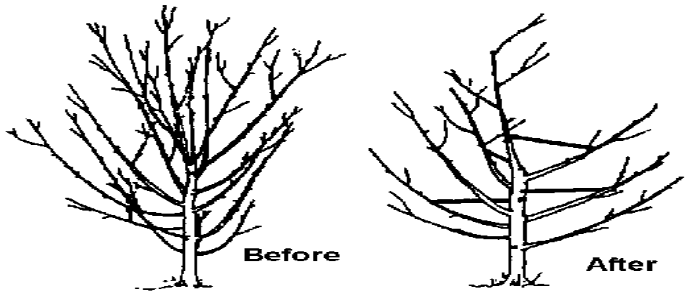
- In this system of training, the main stem of the plant is allowed to grow only up to a certain height by **beheading** it in the young stage i.e. within an year of planting and inducing all the subsequent vegetative growth by lateral branches
- This results in the **low head** in which the bulk of the crop is borne closer to the ground than in case of central leader tree.

Merits and demerits:

1) It allows more light to reach all parts of the tree which is helpful (a) for better colour development of the fruit (b) fruiting area is spread all over the area of the trees.
2) Trees become low headed. So, pruning, spraying, harvesting etc., are facilitated.
3) The branches form weak and narrow crotches, which may frequently break under severe stress and strain such as bearing of heavy crop and strong winds.
4) Sun scalding of central leader is also possible.
5) The branches form very close to each other all most from the same spot.
6) In this system the plants take a '**bowl or vase''**shape, which provides a good base for setting of frost. So this system is not suitable for high altitude areas where frost observance is common.

Since the main axis is removed, it leaves the centre open and hence **open centre** and the tree looks like a **vase (bowl),** hence it is otherwise called as **vase system**. This system of training is practiced in **plums** and **peaches**.

c) **Modified Leader system:**



- This is intermediate between the above two systems and has the advantages of the both.
- This system is developed by first training the tree to the leader type allowing the leader to grow unhampered for the first four or five years.
- The main branches are allowed to arise on the main stem at reasonable intervals.
- After the required number of branches has arisen, the main stem is headed back and lateral branches are allowed to grow as in the open centre system.

Merits and demerits:

1) This results in a low-headed tree with well-spaced limbs, well distributed fruiting wood and low height to carryout orchard operations conveniently. This system of training is practiced in fruit plants like citrus, pear, apple and walnut etc.

Which system of training is the best?

Among the above three a system of training, the modified leader system is the best and most desirable because:

- Narrow to medium crotches and there by breakages are eliminated
- The indeterminate growth of the central axis is also prevented keeping the tree height under control, so as to make orchard operations easy and cheap**.**
- No danger of sun scorching and fruit quality is good.

Principles of training:

Irrespective of the system of training practiced, the following general principles are observed:

1) The branches should arise on the main trunk alternatively at intervals of at least 15cm and not all at one place.
2) They should be equally distributed around the stem.
3) Up right branches should not be encouraged. Branches should have medium crotches.

Pruning

Pruning may be defined as the removal of any excess or undesirable branches, shoots, roots, or any other parts of a plant, so as to allow the remaining parts to grow normally or according to the desire of the pruner. Pruning is the removal of unwanted, surplus annual growth, dead, diseased, dried and broken branches of the plants. Pruning is an art of removing scientifically certain portions of a plant with a view to producing more and superior quality of fruit. Pruning of any kind according to its severity, changes the nutritive conditions within the tree and consequently, limits or encourages fruit bud formation.

Reasons for pruning

- There always seems to be surplus branches on a tree. But only those, which are useful to the plant in holding up the leaves to the sun to grow strong. Those which will have little chance of doing so, because of shade or other reasons become weak and eventually dry up. Evidently the plant is making a selection and eliminating the useless branches. But this process of selection and elimination is a slow one. Till they are eliminated the useless branches also draw some nutrients which is a waste for the tree ultimately. If such branches are recognized and eliminated earlier will help in conservation of food in the tree for better production.
- The second reason for pruning will be the removal of diseased twigs to check the spread of diseases
- In some fruit trees, fruits are borne on current flush (Ber, Grape etc.) which will be obtained in large number after pruning of certain no. of old branches.

Objectives of Pruning:

1) Remove surplus branches and direct the sap flow in to the remaining branches.
2) Develop a strong frame work which can carry the load of a good crop and can with stand strong winds.
3) Train the plants to a definite shape. Ex. Fence, Hedge, Topiary etc.
4) Thin out branches so as to admit more light into the interior of the tree top so that the inner wood also becomes fruitful.
5) Limit the size of the tree top to a convenient one so as to render spraying and picking more easily and economically.
6) Regulate the spacing and distribution / direction of branches.

7) Distribute the fruiting wood in all directions and to maintain a balance between vegetative and reproductive phases.
8) Improve the growth of the spur (A short lateral branch one inch or less in length with nodes close together, so that the leaves converge to form a rosette) shoots and production of more flower buds.
9) Check the further spread of the diseases.
10) Maintain vigour of the plant by removing the water shoots and other unwanted growth.

Responses of plants to pruning

The response of plants to pruning should be well understood for successfully achieving the object of pruning. The following are some of the important ways in which the plants show response to pruning.

1. Activation of buds: When a branch is cut or pruned, the buds on the branch below the cut are invigorated (activated). The bud close to the cut is most vigorous and this vigour decreases in the buds as the distance increases from the cut. This is due to the elimination of the apical dominance of the terminal bud from which the auxin flows down and inhibits the growth of the lateral buds. This response is made use of to determine the direction of the existing branches and correcting a crotch. If the crotch is a narrow (The angle between the branch and the stem on which it arises –Crotch), the branch is pruned to an outer bud, so that the bud will produce a branch towards the outer side usually at right angles to the branch or nearly so. As it grows larger, it pulls away from the stem and eventually widens the crotch. Similarly, a wide crotch can be narrowed down by pruning the branch to an inner bud.

2. Dwarfing response: The immediate effect of pruning is no doubt invigoration of new branches owing to the diversion of food, but due to removal of much foliage, there is an overall reduction in the manufacture of food result a shock on root growth. This in turn limits the further growth of the new shoots .When the growth of the new shoot is reduced, their length is also reduced. Therefore, the net effect of pruning a tree is dwarfing, which is in proportion to the severity of pruning. Both the spread of the top as well as the spread of the root system are reduced. This also results in dwarfing of the plant.

3. Production of water shoots: Severe pruning often activates resting or adventitious buds and buds on old wood may some time be stimulated to grow. They often produce branches, which grow vertically and very vigorously with **long internodes**; **angular stems large succulent leaves** and **thorns** (as in citrus). They are called **water shoots** or **water suckers** or **bull canes**. These highly vegetative water shoots are seldom fruitful till they are several seasons old. They are wasteful and unwanted because they draw much food and grow at the expense of the fruiting wood and are better removed as soon as they appear. However, they may be profitably used in some instances to fill in the gaps occurring in trees by lopsided development or loss of branches due to other causes. Eg.Citrus,Guava,Ber,Sapota,cashew etc.

4. Delay in bearing: When pruning is severe particularly in early years of the fruit plant, bearing is delayed. Sometimes severe pruning may also lead to poor yields, because a major portion of the foliage and fruiting wood are lost.

Methods of pruning

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

2. Trimming: Cutting the growth of the twigs to a pre-determined level as in the case of fence, hedge and edge.

3. Heading back: When the branches grow tall and vigorously without producing flowers, these shoots are headed back. When a branch is cut almost to the base, leaving a few inches of stump, carrying few buds, it is referred as **Heading Back**. These buds left on the stump will give rise to shoots which are important to the tree either being spur bearers or bearing flower buds or filling up of gaps in the tree or forming vegetative wood from which flowers may arise in the following year. The shoot from the bud nearest to the cut takes the place of the pruned shoot.

4. Pollarding: Mere cutting back of the shoots, indiscriminately to reduce the height of the tree is **Pollarding**.

5. Pinching (tipping): Removal of the tip of the shoot to stop its indeterminate growth or to encourage the growth of the lateral buds is **pinching or tipping**. This is practiced in marigold and chillies at the time of transplanting.

6. Disbudding (nipping or rubbing): Nipping or rubbing of young buds preventing a chance of their sprouting is **disbudding**. When the buds arise in wrong places they are rubbed off. Similarly sprouts (Buds) on root stocks are disbudded.

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

Seasons of pruning

1. It depends on the type of wood, type of plant species and time of flower bud formation.
2. Removal of diseased, dead, and dried wood as well as water shoots can be carried out at any time of the year.
3. Pruning of healthy branches should not be done when the trees are in flowering or fruiting, since the resulting disturbance leads to loss of blossoms or fruits.
4. In deciduous trees, pruning can be done before the termination of dormancy.
5. In ever greens, pruning should be carried out before the start of active growth or after the harvest of the crops.
6. Summer pruning of deciduous trees and also the pruning of evergreens in the active growing season delays the formation of flower buds by prolonging vegetative growth.

Pruning and Manuring

The sudden invigoration of a number of buds due to pruning makes a demand on the food resource of the tree, because the new shoots are not yet ready to manufacture their own food. The reserve food in the plant often may not be sufficient to meet this demand of new growth. Further, pruning means loss of much foliage and wood. So, to compensate the loss incurred due to pruning and to meet the demand of new shoots the pruned trees should be manured heavily, otherwise the new shoots ultimately wither and dry. This is particularly important when old (Senile) or neglected trees are pruned for rejuvenation.

Care of pruned wounds

Pruning leaves wounds and cut ends which should be protected to avoid the access of disease pathogens and insect pests through these wounds and cut ends. So, immediately after pruning, these cut ends and wounds should be protected by applying disinfectants like Bordeaux paste or blitox paste.

CHAPTER 5

HARVESTING, POST HARVEST HANDLING AND MARKETING OF FRUIT CROPS

The basic fact regarding the post harvest handling of horticultural produce is that they are 'living' structures. Most metabolic reactions and physiological activity continue after harvest. Fruits, vegetables and ornamentals respire oxygen and give off $C0_2$ and heat. Respiration and transpiration continue after harvest - since the produce is removed from its normal source of water, photosynthates and minerals, the produce is dependent entirely on its own food reserves and moisture content. Since losses of restorable substrates and moisture are not replenished deterioration commences.

Based on their respiratory behavior during ripening fruits are classified into

1. *Climacteric* - Apple, avocado, banana, cherimoya, papaya, peach etc.
2. *Non - climacteric* - Cherry, Cucumber, Grape, lemon, Pineapple etc.

Ripening - The completion of development of a fruit and the commencement of senescence. It is an irreversible event.

Climacteric - A marked and sudden rise in the respiration rate of a fruit prior to senescence.

Non-climacteric - There is no sharp rise in respiration. Fruits will not be edible ripe after harvest if they are picked immature. In avocado - climacteric sets only after harvest.

During ripening, fleshy fruits undergo major changes in their chemical and physical state. These changes can be grouped into three categories.

a) Textural changes
b) Changes in pigment and
c) Changes in flavour

5.1 Harvesting

5.1.1 Predicting Harvest Date

To most people mature and ripe mean one and the same. In postharvest physiology, are distance terms for different stages in fruit development.

Maturity- the stage at which a commodity has reached a sufficient stages of development that after harvesting and postharvest handling (including ripening where required), its quality will be at least the minimum acceptable to the ultimate consumer.

When considering perishable commodities, there are two types of maturity.

a) Physiological maturity - Maximum growth and maturation has occurred and the plant part will continue ontogeny even if detached from the mother plant.

b) Horticultural (commercial) maturity - The stage of development when a plant or plant part possesses the prerequisites for utilization by the consumer for a particular purpose. Horticultural maturity may occur at any stage during development or senescence e.g. Inflorescence - cauliflower partially developed fruits - cucumber Apple, Banana- are usually nearly fully developed. Therefore, harvestible maturity can occur throughout the developmental cycle, with the precise time varying with the product in question. Optimum harvest maturity is not a fixed point and varies depending on the criteria utilized to determine it.

How then do we determine when the harvestable maturity has been reached?

With most crops, optimum maturity is determined by specific physical and/or chemical characteristics of the plants or plant part to be harvested.

Requirements for Maturity Indices.

Maturity measures to be made by produces, handlers and quality control personnel must meet the following requirements.

A. Must be simple to perform and rapid

B. Must be readily performed in the field or orchard

C. Should requite relatively inexpensive equipment

D. The index should preferably be objective (a measurement) rather than subjective (an evaluation)

E. The index should consistently related to the quality and post harvest life of the commodity for all growers, districts and years. E.g. If firmness for mango with acceptable storage life and eating quality shows 10 pound force in one season and 20 pound force in another season, it is clear that firmness is not a satisfactory method for determining of this commodity.

Methods for measurement of maturity

Physical measurements:

- ***Physical*** attributes - such as size, color, or texture This can be made either subjectively (sensory evaluation) or objectively (numerical measurement of maturity)**.**
- ***Horticultural (commercial) maturity*** - requires measurement of some characteristics known, to change as the fruit or vegetable matures.
- ***Calendar date (based on flowering or planting*****)** - Experienced growers. Only reliable when the seasonal climates are more or less uniform from year to year.
- ***Commodity shape and size*** - ex. Banana (some cultivars become less angular in cross section

Objective or analytical measurements of maturity tend to be highly consistent.

- *Fresh firmness*-Dissolution of middle lamella of the cell wall resulting in softening.
  - Can be estimated by finger or thumb pressure.
  - By using pressure testes.
- *Optical measurements* - color changes
- *Respiratory behavior* - in climactic fruits.
- *Heat units* - is an objective measure of the time required for the development of the fruit to maturity after flowering in a particular env't.
- it also measure degree days - Thus, under unusually warm conditions, maturity will be advanced and under cooler conditions delayed.
- Ratio between sugars and acids (citrus, pine apple)
- Minimum juice volume (citrus).

Chemical measurements

Many plant products undergo distinct chemical alterations that are correlated with maturity. Either objective or subjective measure of these changes can be used.

- Tss - refractometer or hydrometer
- Acidity - titration

e.g. The ratio of TSS to titrable acidity more accurately reflects the proper maturity for harvest.

- Conversion of starch to sugar - intensity of iodine staining
- Taste and odour - as subjective measures

5.2 Harvesting

5.2.1 Harvesting date

Has a direct impact on the post harvest life of the produce. It can be determined by the maturity indices prepared to the produce to that particular area. For many crops harvesting must proceed within a certain narrow time interval. In some spps, however, fruit may be stored well on the tree for several day/weeks. There are also same conflicting factors - e.g. In apple, storage quality is adversely affected by daying maturity, yet on the other hand, red color tends to increase with time. There are external and internal signs of ripening that aid for harvesting the produce.

Generally the following changes occur during ripening of fruits

- The fruit becomes bigger until reaches full size
- Flesh gets softer
- Starch is converted to sugar
- Sucrose is converted into fructose and glucose
- the acid content goes down
- the green color disappears, other colors become visible
- the aroma and the taste develops.

Harvesting methods

1. Hand harvesting: - (picking, pulling) used for harvesting high-value crops that either sensitive to bruising or must electively picked e.g. straw berry

2. Semi-mechanized or completely mechanized harvesting (clipping, shaking). fruits dropped to the ground and collected by rakes pick up machines with revolving brush sweeps. fruit dropped (caught) on a padded catching frame (may be suitable for the fresh market) require machine-compatible plants-ripen at the same time and become uniform, resist excessive bruising. In many countries harvesting is the most expensive operation e.g. In Israel, packing represents - 40% of the no of working days.

5.3. Post Harvest Handling of Fruits

5.3.1. Post Harvest Physiology of Fruits Affecting Their Shelf- Life

Harvested fruits are still living organs. They continue to respire and lose water as if they well still attached to the parent plant. However, losses are not replaced in the postharvest environment. This metabolic process continues until a stage of over-ripeness is reached. A number of physiological and biochemical processes occur during the postharvest life of a produce. These processes may result in deterioration of the produce or improvement (in climacteric fruits). Hence, the major objective of postharvest physiology and technology is the development of the information (physiology) and methods (technology needed to maximize the duration of the period between ripening and deterioration. Moreover it helps to maintain the product as close to harvest condition as possible. Since death causes irreversible process the produce should be maintained in a living state. Otherwise, these changes may involve gross deterioration and drastic differences in flavour, texture and appearance.

Change that occur in harvested produce

Change	Process	Examples and significance
Water loss	Transpiration and evaporation	unattractive appearance, texture changes, loss, shriveling
CH_2O conversion	Enzymatic	starch to sugar (beneficial)
Change in flavors		usually detrimental, but beneficial in crops like pears and bananas.
Softening	Pectic enzymes	-usually detrimental
	water loss	-beneficial in bananas & pears
Change in color	pigment synthesis	- May be detrimental or beneficial
Change in vit	Enzymatic	May be gain (vit - A) or loss(vit-C) content
Decay and rot	Pathological; physiological	Detrimental

5.3.2. Environmental Factors Influencing Post-Harvest Life of Fruits

Among the environmental factors that influence the post-harvest life of fruits temperature, humidity, O_2 and CO_2 levels and ethylene concentration are the major ones. Life of fruits can be prolonged to some extent by:

- Slowing down respiration rate by control of temp, O_2 and CO_2

- Retarding microbial activity
- Preventing /reducing water loss- by controlling humidity.

➡ **Temperature:-** most important factor governing the postharvest life of fruits The optimum storage temperature varies from spps to spps. The optimum level has narrow ranges. For temperate and subtropical spps temp. Just above freezing point is optimum and for Most of tropical fruits store will at 10^0c ($\pm$). Low temperature causes chilling injury. Chilling injury affects the appearance of produce, and it may result in breakdown of tissue (due to inter and intra-cellular ice formation). A slight increase in temperature above the optimum hastens ripening. Temperature also increases ethylene production. The activity of enzymes in fruits declines at temperatures above 30^0C . Specific enzymes become in active (denature); many are still active at 35^0C but most are inactivated at 40^0c. When a produce is held above 35^0C, metabolism becomes abnormal and results in breakdown of membrane integrity and structure, with disruption of cellular Organization and rapid deterioration of produce. This causes - loss of pigment and atery or translucent appearance of the issue. This condition in banana and tomato is often referred as ***boiled***

➡ ***Humidity:*** Low humidity results in water loss that causes desiccation and wilting (detect). High humidity favors the development of decay, especially day temp is high Even in the absence of visible wilting, water loss can result in reduced crispness and/or early ripening of some fruits. Undesirable changes in colour, palatability and nutritional quality (in some in some vegetables). Hence, humidity control has become an important feature of modern storage facilities. For most fruits 85-90% R.H. is best.

➡ **CO_2 and O_2 levels:** The general equation for produce respiration is

glucose + oxygen $\rightarrow$ carbondioxide + water + energy

$C_6 H_{12} 0_6 + 60_2 \rightarrow 6C0_2 + 6H_2O$ + Energy (686 K cal)

This suggests that respiration could be slowed by limiting oxygen or by raising the CO_2 concentration in the storage atmosphere. In air tight containers, respiration of fruits consume the O_2 and at. The same time give up equal concentration of CO_2.

When O_2 is exhausted anaerobic respiration begins and alcohol is formed in the fruit. Before this Occurs, O_2 and CO_2 concentrations should be kept at a compensating levels. CO_2 level can be reduced by passing storage air through hydrated time. Moreover Wrapping individual or some fruits together allow differential permeability of CO_2 and O_2.

$\rightarrow$ Polyethene film is about 5 times more permeable to CO_2 than O_2.

$\rightarrow$ Increasing thickness and density of the film helps to regulate the concn of the two gases.

If respiration rate is reduced through the control of O_2 and CO_2 levels. Storage temperature can be kept higher than normally recommended.

- *Ethylene*

Regulates many aspects of plant growth, development and senescence. Depending on where and when it occurs, it may be beneficial or harmful to harvested crops.

Ethylene gas is commercially used:

→ in banana ripening rooms to produce uniform ripening or to accelerate ripening.

→For degreasing of citrus fruits which fail to produce natural orange colour. It destroys Chlorophyll in the peel.

* Increased ethylene production results from field infestation, bruising, raised storage temp ad R.H

5.4 Methods of Handling Fruits

Grading*;* grouping the produce on the basis of some standards. Used to eliminate unsatisfactory items. Hence, diseased injured, unripe, overripe, etc. fruits should be removed. It also This reduces variability, which has an impact on aesthetic value.

Produces can be graded by, cultivar, size, appearance, and when possible by quality. Grading is the basis of long-distance trade. Both seller and consumer can understand each other. Without grading produces should be inspected individually.

Packaging: - has significant effect in reducing wastage. educes mechanical damage, undesirable physiological changes and pathological deterioration during storage, transportation and marketing. Packaging can provides protection, convenience, economy and appeal.

The two main functions of packaging are;

1. To assemble the produce into convenient units for handling (utilization)
2. To protect the produce during distribution, storage and marketing (protection)

Modern packages must:

- Have sufficient mechanical strength to protect the contents during handling and transport, and while stalked.
- Be largely unaffected, interms of mechanical strength, by moisture content when wet or at high R.H.
- Stabilize and secure the product against movement
- Not contain toxic chemicals
- Meet handling and marketing requirements interms of weight, size and shape.
- Allow rapid cooling and insulation from external heat
- Have sufficient permeability to respiratory cases.
- Offer security for the contents.
- Accurately labeled
- Facilitate easy disposal, reuse or recycling

- Be cost - effective.

Pre - cooling: refers to rapid removal of heat from freshly harvested products inorder to show ripening and reduce deterioration prior to storage or shipment. Internal temperature of fruits harvested on a hot day may so about 100c higher than the air temperature. The removal of field heat, to reduce the temp of the harvested produce to ≈ 0-40c, must be as rapid as possible. Consequently, a great deal of energy is required.

Hence, harvesting is done at night or early in the morning to avoid excessive field heat and related expenses in removing it.

Methods of pre - cooling

I. Contact icing - crushed ice is placed in or on the package. Ice source

ii. Hydrocooling - Water flows through the containers and absorbs heat.

iii. Vacuum cooling - utilizes rapid evaporation of water at reduced pressure.

iv. Air cooling - circulation of cold air.

Transportation

Marketing depends on short-haul movement and handling by growers and upon large-scale, long haul transportation facilities.

The products is effected by -

- Road, truck (refrigerated containers fit), air freight
- Boat uncooled but well ventilated - short distance
- Sophisticated ships.

In general, fruit crops are exported as rapidly as possible after harvest since he majority have short postharvest lives.

Storage and Preservation

- Fruits have continuous demand. Inorder to insure extended supply storage is essential. Extending supply of fruits require retarding the natural physiological deterioration as well as preventing decay by micro-organisms. The method of choosing different storage's depends on the product, its use and the required storage time.

Types of storages

a. *Common storage:* Caves, mounds, trenches etc.

- In places where temp is low
- Temp is regulated by natural circulation & insulation.

b. Cold storage:

- Temperature and RH are regulated by refrigeration
- Large structures with better insulation can be built e.g. Nura era and Etfruit A.A. store

C. Controlled and modified atmosphere storage (MA and CA)

- The level of 02, CO2, Temp and RH are controlled
- Provide overall reduction in qualitative and quantitative losses.

Processing

Long- term preservation achieved by physical and chemical process.

- Sterilizing the food or
- avoids the growth of microorganisms.

This includes –

- Drying
- Fermenting
- canning
- pickling
- freezing

Canning: (thermal preservation): Sterilizing food by heating on air-tight container. The heat destroys human pathogenic and food spoiling microorganisms. it also inactivate enzymes that may decompose the product during storage. Heat may affect color, texture and nutritive values. The Cost of glass or metal containers sometimes exceed the cost of food they contain & are sometime uneconomical. And its use is limited to few products.

Freezing- (doesn't remove moisture): Inhibition of microbial activity by reducing temperature It also ceases enzymatic activity.