नया आगाज़

आज समय की माँग पर
आगाज़ नया इक होगा
निरंतर योग्यता के निर्णय से
परिणाम आकलन होगा।

परिवर्तन नियम जीवन का
नियम अब नया बनेगा
अब परिणामों के भय से
नहीं बालक कोई डरेगा

निरंतर योग्यता के निर्णय से
परिणाम आकलन होगा।

बदले शिक्षा का स्वरूप
नई खिले आशा की धूप
अब किसी कोमल-से मन पर
कोई बोझ न होगा

निरंतर योग्यता के निर्णय से
परिणाम आकलन होगा।
नई राह पर चलकर मंज़िल को हमें पाना है
इस नए प्रयास को हमने सफल बनाना है
बेहतर शिक्षा से बदले देश, ऐसे इसे अपनाए
शिक्षक, शिक्षा और शिक्षित
बस आगे बढते जाएँ
बस आगे बढते जाएँ
बस आगे बढते जाएँ.....

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BASIC HORTICULTURE-I

Student Handbook

(Class XI)

Central Board of Secondary Education

2, Community Centre, Preet Vihar, Delhi-110092

Basic Horticulture - I for Class XI

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Preface

Indian topography and agro climates are well suited for horticultural crops, which are considered ideal for achieving sustainability of smallholdings, increasing employment, improving environment, providing an enormous export potential and above all achieving nutritional security. Furthermore, horticulture has the potential for improvement of wastelands as well as arid and semi-arid areas. The country has recorded significant growth rate in horticultural output among various agricultural products in the recent past. The horticulture sector contributes around 31 % of the GDP from about 14% of the area and 38% of the total exports of agricultural commodities. Moreover, globally India ranks second in the production of fruit and vegetables next to China.

Increasing horticultural production contributes to commercialization of the rural economy and creates many off-farm jobs. It also provides ample opportunities for sustaining large number of agro-industries, which generate substantial employment opportunities. Demand for horticultural produce is rising, both in domestic and international markets. Many consumers today purchase a broad range of relatively expensive commodities such as off-season produce, exotic fruits and vegetables, and organic produce. Demand for horticultural produce is expected to rise further, fueled both by affluent urban consumers in developing countries and consumers in developed countries. In addition, increasing urbanization and the needs of growing cities to feed their population will require more attention toward horticultural production. The foundation course on **"Basic Horticulture-I"** for class XI students has been introduced with the following objectives:

- This is a basic course to equip students with knowledge and skills in the field of Horticulture. Major topics covered in this book are introduction to horticulture, importance of horticulture in human diet and national economy, principles of horticulture crop production technology, principle and methods of plant propagation, essential plant nutrients, their deficiency symptoms and toxicities, organic and inorganic manures and fertilizers and their methods of application, water management, weed, major pest and diseases management, harvesting, handling, storage of horticultural crops and traits and quality standards of horticultural products etc.
- Students will get an exposure to vocational/professional course on the production of fruits, vegetables and flowers, which will motivate students to come up as entrepreneurs in the area of nursery raising or commercial horticulture.
- This course is an effort to sensitize student in the field of horticulture. The course will be useful and serve as guiding force for the students to choose career in the area of horticulture and they may further pursue diploma/ degree in this area.
- This course has been designed to provide entry level job skills to the students and will help to meet the human resource requirement for horticulture sector.

Vineet Joshi, IAS
Chairman, CBSE

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Basic Horticulture - I
Class XI

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भारत का संविधान

उद्देशिका

हम, भारत के लोग, भारत को एक [1]**[संपूर्ण प्रभुत्व-संपन्न, समाजवादी, पंथ-निरपेक्ष, लोकतंत्रात्मक गणराज्य]** बनाने के लिए तथा उसके समस्त नागरिकों को:

सामाजिक, आर्थिक और राजनैतिक **न्याय,**

विचार, अभिव्यक्ति, विश्वास, धर्म और उपासना की **स्वतंत्रता,**

प्रतिष्ठा और अवसर की **समता** प्राप्त कराने के लिए,

तथा उन **सबमें** व्यक्ति की गरिमा और [2]**[राष्ट्र की एकता और अखंडता सुनिश्चित]** करने वाली बंधुता बढ़ाने के लिए

दृढ़संकल्प होकर **अपनी इस संविधान सभा में** आज तारीख 26 नवंबर, 1949 ई. (मिति मार्गशीर्ष शुक्ला सप्तमी, संवत् दो हज़ार छह विक्रमी) को **एतद्द्वारा इस संविधान को अंगीकृत, अधिनियमित और आत्मार्पित करते हैं।**

भारत का संविधान

भाग 4क

नागरिकों के मूल कर्तव्य

अनुच्छेद 51क

मूल कर्तव्य- भारत के प्रत्येक नागरिक का यह कर्तव्य होगा कि वह -

(क) संविधान का पालन करे और उसके आदर्शों, संस्थाओं, राष्ट्रध्वजों और राष्ट्रगान का आदर करे;

(ख) स्वतंत्रता के लिए हमारे राष्ट्रीय आंदोलन को प्रेरित करने वाले उच्च आदर्शों को हृदय में संजोए रखे और उनका पालन करे;

(ग) भारत की संप्रभुता, एकता और अखंडता की रक्षा करे और उसे अक्षुण्ण बनाए रखे;

(घ) देश की रक्षा करे और आह्वान किए जाने पर राष्ट्र की सेवा करे;

(ङ) भारत के सभी लोगों में समरसता और समान भ्रातृत्व की भावना का निर्माण करे जो धर्म, भाषा और प्रदेश या वर्ग पर आधारित सभी भेदभाव से परे हो, ऐसी प्रथाओं का त्याग करे जो महिलाओं के सम्मान के विरुद्ध हों;

(च) हमारी सामासिक संस्कृति की गौरवशाली परंपरा का महत्व समझे और उसका परिरक्षण करे;

(छ) प्राकृतिक पर्यावरण की, जिसके अंतर्गत वन, झील, नदी और वन्य जीव हैं, रक्षा करे और उसका संवर्धन करे तथा प्राणिमात्र के प्रति दयाभाव रखे;

(ज) वैज्ञानिक दृष्टिकोण, मानववाद और ज्ञानार्जन तथा सुधार की भावना का विकास करे;

(झ) सार्वजनिक संपत्ति को सुरक्षित रखे और हिंसा से दूर रहे;

(ञ) व्यक्तिगत और सामूहिक गतिविधियों के सभी क्षेत्रों में उत्कर्ष की ओर बढ़ने का सतत प्रयास करे, जिससे राष्ट्र निरंतर बढ़ते हुए प्रयत्न और उपलब्धि की नई ऊँचाइयों को छू सके; और

(ट) यदि माता-पिता या संरक्षक है, छह वर्ष से चौदह वर्ष तक की आयु वाले अपने, यथास्थिति, बालक या प्रतिपाल्य को शिक्षा के अवसर प्रदान करे।

THE CONSTITUTION OF INDIA

PREAMBLE

WE, THE PEOPLE OF INDIA, having solemnly resolved to constitute India into a [1]**[SOVEREIGN SOCIALIST SECULAR DEMOCRATIC REPUBLIC]** and to secure to all its citizens:

JUSTICE, social, economic and political;

LIBERTY of thought, expression, belief, faith and worship;

EQUALITY of status and of opportunity; and to promote among them all

FRATERNITY assuring the dignity of the individual and the [2][unity and integrity of the Nation];

IN OUR CONSTITUENT ASSEMBLY this twenty-sixth day of November, 1949, do **HEREBY ADOPT, ENACT AND GIVE TO OURSELVES THIS CONSTITUTION.**

1. Subs. by the Constitution (Forty-Second Amendment) Act. 1976, sec.2, for "Sovereign Democratic Republic (w.e.f. 3.1.1977)
2. Subs. by the Constitution (Forty-Second Amendment) Act. 1976, sec.2, for 'unity of the Nation (w.e.f. 3.1.1977)

THE CONSTITUTION OF INDIA

Chapter IV

A Fundamental Duties

ARTICLE 51 A

Fundamental Duties. It SHALL be the duty of every citizen of India

(a) to abide by the Constitution and respect its ideals and institutions, the National Flag and the National Anthem;

(b) to cherish and follow the noble ideals which inspired our national struggle for freedom;

(c) to uphold and protect the sovereignty, unity and integrity of India;

(d) to defend the country and render national service when called upon to do so;

(e) To promote harmony and the spirit of common brotherhood amongst all the people of India transcending religious, linguistic and regional or sectional diversities; to renounce practices derogatory to the dignity of women;

(f) to value and preserve the rich heritage of our composite culture;

(g) to protect and improve the natural environment including forests, lakes, rivers, wild life and to have compassion for living creatures;

(h) to develop the scientific temper, humanism and the spirit of inquiry and reform;

(i) to safeguard public property and to abjure violence;

(j) to strive towards excellence in all spheres of individual and collective activity so that the nation constantly rises to higher levels of endeavour and achievement.

*(k) a parent or guardian to provide opportunities for education to his child or as the case may be ward between the age of six and fourteen years.

Contents

CHAPTER 1

Introduction to Horticulture

OBJECTIVES

After studying this chapter, students will be able to:

- Learn about the inception of horticulture and its distinguishing features
- Know about the various branches of Horticulture

INTRODUCTION

Horticultural Science is an exciting discipline with a variety of study areas and possible careers. Not sure what horticulture is? Did you eat any fruits or vegetables today? Enjoy beautiful landscaping in a park? Play golf at a well-managed course?

Horticulture affects everyone. It plays a very important role in society influencing our lifestyle and general health in many ways. This includes the production of fruit and vegetables which form a vital ingredient of our daily diet and the development of pleasant surroundings for living and working, which create positive effects for emotional health. In this chapter, we will discuss about horticulture, its distinguishing features and branches based on the crops dealt.

WHAT IS HORTICULTURE?

According to Liberty Hyde Bailey, one of the most famous American scholars of horticulture, "Horticulture is the growing of flowers, fruits and vegetables, and of plants for ornament and fancy."

Horticulture is defined by Webster's dictionary as "the science and art of growing fruits, vegetables, and flowers." It is the intensive commercial production of high-value and high-yielding plants. But it also includes the cultivation of garden crops and landscape ornamentals and the interaction of science and art. Horticulture contributes to the economy, provides good nutrition, and is a valuable spiritual and psychological therapy. Horticulture beautifies and enhances the environment.

The term Horticulture is derived from two Latin words i.e. *Hortus* meaning garden or enclosure and *Colere* meaning to grow or to cultivate. Garden in itself is a broad term. Garden is originated from the latin term *Gyrdan* meaning 'to enclose'.

The term Agriculture refers broadly to the technology of raising plants and animals .On the other hand, Horticulture which is a part of agriculture is concerned with the raising of garden crops.. Horticulture can also be defined as the branch of agriculture concerned with intensively cultivated plants directly used by man for food, medicinal or aesthetic purposes.

In olden days, food crops like Paddy, Maize, and Wheat etc. were grown in open fields on a large scale, while some crops of special interest like fruits, vegetables, flowers etc. were grown in the back yard of houses in an enclosure. In cases where fruits, vegetables and flowers were grown in areas other than backyards, they are protected by erecting walls, by raising live fences, non-live fences etc. i.e. they are enclosed. As such, the term Horticulture in the original sense referred to the cultivation of crops with in the protected enclosure, which is often called as a garden (Crops grown in a protected enclosure). So, the culture of crops in gardens is referred as Horticulture.

When fruits are grown in a definite area then that part is called as an Orchard

At present, fruits, vegetables, flowers etc. are grown not only with in the back yards, but also in large areas in open fields on a commercial scale. Traditionally garden crops include fruits, vegetables and flowers. But today's horticulture deals not only with the fruits, vegetables and flowers but also with other important crops like spices, condiments, plantation crops, medicinal and aromatic plants etc,. Besides cultivation of these crops, present day horticulture also deals with the utilization and improvement of these crops. Hence, modern horticulture may be defined as a part of agricultural science, which deals with the production, utilization, and improvement of fruits, vegetables, flowers, ornamentals, plantation crops, medicinal and aromatic plants etc.

MAIN DISTINGUISHING FEATURES OF HORTICULTURE

i. Horticulture crops are used in a living state while others like grains etc. are not used in a living state.

ii. Horticulture crops are comparatively more intensively cultivated than field crops.

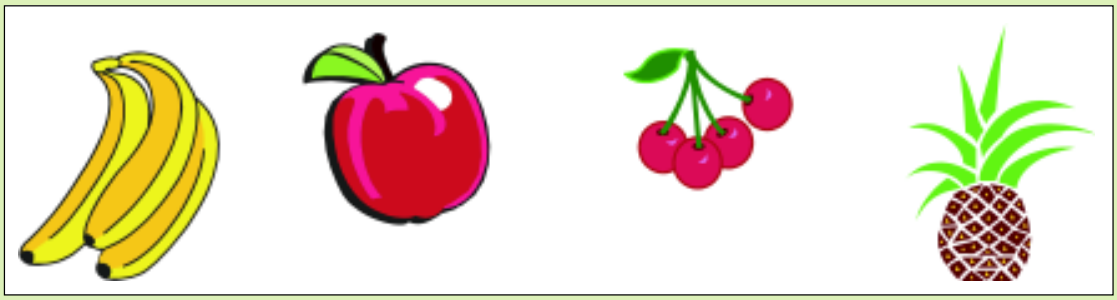
iii. Horticulture crops have high water content.

DIVISIONS OF HORTICULTURE

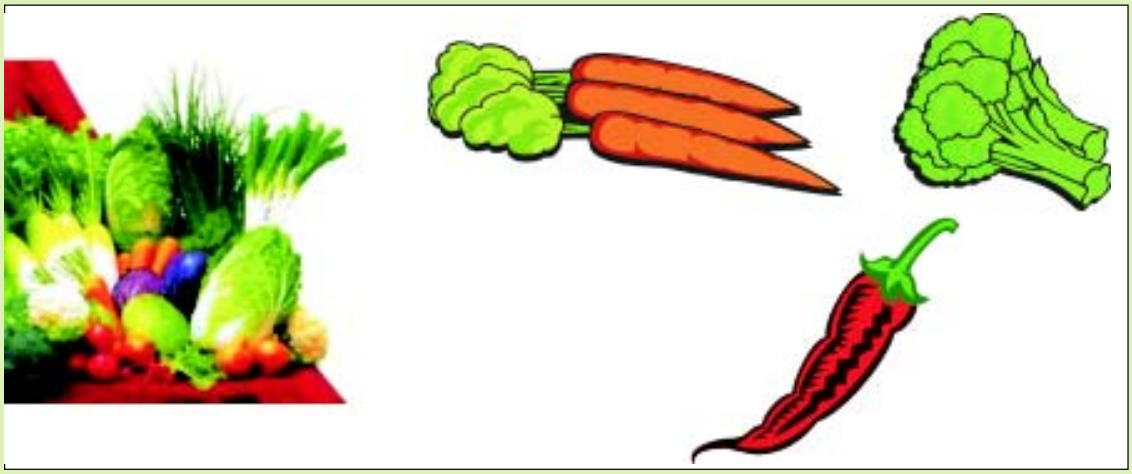
Horticulture is divided in to the following divisions for convenience based upon the crops dealt and also their purpose and utilization

1. **Pomology:** It is derived from two words i.e. *Pomum* meaning fruit and *Logos* meaning discourse or study. Therefore, pomology is study or cultivation of fruit crops such as Mango,

Litchi, Citrus, Sapota, Guava, Grape, Banana, Pineapple, Apple, Pear, Peach, Plum and Cherry etc.



2. **Olericulture:** It is derived from two words i.e. Oleris meaning Potherb and Cultra meaning cultivation. Therefore, olericulture literally means potherb cultivation of Brinjal, Okra, Tomato, Capsicum, Peas, Beans, Cucurbits etc.



3. **Floriculture:** It is derived from two words i.e. Florus meaning flower and Cultra meaning cultivation. Therefore, floriculture means study of flower crops such as Rose, Jasmine, Carnation, Aster, Marigold, Dahlia, Zinnia, Cosmos, Hibiscus, Balsam, Poinsettia, Hollyhock, Gerbera, and Gaillardia etc.

4. **Landscape gardening:** It deals with the planning and execution of ornamental gardens, parks, landscape gardens etc.

5. **Post harvest technology:** It deals with the processing and preservation of produce of horticulture crops.

6. **Plantation crops:** These crops are cultivated in an extensive scale in large contiguous areas, owned and managed by an individual or a company and whose produce is utilized only after processing. Coffee, Tea, Rubber, Coconut, Cocoa etc. are some of the important plantation crops.

7. **Spices and condiments:** This branch deals with the cultivation of crops whose produce is used mainly for seasoning and flavouring dishes.

Spices: These are those plants the products of which are made use of as food adjuncts to add aroma and flavour. For example, Pepper, Cardamom, Clove, Cinnamon, etc.

Condiments: These are those plants the products of which are made use of as food adjuncts to add taste only. For example,Turmeric, Ginger, Red chillies, Onion, Garlic etc.

8. **Medicinal and aromatic plants:** It deals with the cultivation of medicinal plants, which provide drugs and aromatic crops which yields aromatic (essential) oils.

Medicinal plants: These plants are rich in secondary metabolites and are potential sources of drugs. The secondary metabolites include alkaloids, glycosides, coumarins, flavonoides and steroids etc. Important medicinal plants are Periwinkle, Opium, Menthi, Cinchona, Dioscorea Yam, Belladona, Senna, Sarpagandha, Aswagandha, Tulasi etc.

Aromatic plants: These plants possess essential oils in them. The essential oils are the odoriferous steam volatile constituents of aromatic plants. Lemon grass, Citronella, Palmrosa, Vetiver, Geranium, Davanam, Lavendor etc. are some of the aromatic plants

ACTIVITY/EXERCISE

Visit an orchard, vegetable farm, landscape garden and a processing unit. Observe and write the differences in the respective specialized vocations being dealt. Further make your

observations on the use of spices and condiments in Indian foods._____

CHECK YOUR PROGRESS

1) Define horticulture? Write the distinguishing features of horticulture crops.

2) Enlist the various divisions of horticulture. Differentiate between pomology and olericulture.

3) How do fruit crops differ from plantation crops?

FILL IN THE BLANKS

1. The word 'Horticulture' consists of two parts namely ……and ……..
2. Garden is originated from the latin term *Gyrdan* meaning ……
3. A branch of horticulture which deals with the planning and execution of ornamental gardens, parks, landscape gardens etc. is referred to as …….
4. Medicinal plants are rich source of ……
5. Aromatic plants possess……..in them.

SUGGESTED FURTHER READINGS

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CHAPTER 2

Importance of Horticultural Crops

OBJECTIVES

After studying this chapter, students will be able to:

- Explain the importance of horticultural crops in day-to-day life of human beings and its impact on national economy
- Develop an appreciation of nature and the environment

INTRODUCTION

Do you know it is dangerous to your health if the right content of food is not consumed? Well, let's face it. Bad eating habit(s) contributes about 35 -40 per cent of death globally.

Several diseases are also associated with imbalanced diet. That is why it is important for one to know the right food to eat at the right time. It may sound needless to talk about this as some of us pretend we already know the health benefits of eating fruits and vegetables, yet, how well do we do as people to practice it? How often do we do this? That is why, as human as we are, it is important we keep reminding ourselves in order not to deviate. Fruits and vegetables are essential building blocks of any diet. Not only are they loaded with vitamins and minerals which are essential for healthy living, but also satisfy you as part of balanceddiet. By increasing an intake of fruits and vegetables, one is gradually reducing the risk of becoming ill, as this would boost the immune system as well as building resistance to common diseases and infections like: cardio-vascular diseases, kidney failure, stroke, hole-in-heart, and osteoporosis among others. Furthermore, it leaves you looking better and feeling great, as part of a healthy diet, which can be an all-round improvement for your well-being.

For the economy to flourish there must be an increase in productivity which highly depends on a healthy working force. The alternative is an increase in fruits and vegetable consumption.This is because of the natural goodness contained within these ultimate healthy foods that will provide the necessary energy to fuel you through the day and give you the drive and determination to progress through a course exercise to improve overall fitness.

Having said that, fruits can act as a substitute for sugary snacks, which otherwise deplete energy and lead to numerous other health problems.The natural sugar contained in fruits is

essential for the effective maintenance of the immune system and the body's natural defense mechanisms, as well as increasing fruits in the diet as a healthy snacking alternative.

Vegetables on the other hand, should account for a substantial proportion of each meal, to ultimately improve your diet and by ensuring a substantial role they play within your diet; you should end up seeing the benefits in your skin, hair and general health. On top of this, an increase in fruit and vegetable intake can leave you feeling physically better and more alert, increasing attention span and reducing fatigue. However, fruit consumption may have a side effect if not properly washed and rinsed and vegetables as well, if not well cooked. Therefore, maximum attention must be given to its preparation to avoid any damaging effect. Why not try introducing more vegetables and fruits into your diet today by doing a straight swap of fruits for sugary snacks and introducing vegetables to boost any meal as part of a nutritious and healthy balanced diet.

Fruit and vegetables have long been touted for their health benefits. In India, the virtues of horticulture now include the ability to lift rural communities out of poverty.

IMPORTANCE OF HORTICULTURAL CROPS IN HUMAN DIET

From human nutrition point of view, horticulture is most important to our daily living. Many of the horticulture crops and their products find place in our meals and diet. Human body requires vitamins, minerals, proteins, energy etc. for its health. All these are supplied by horticultural crops. Fruits and vegetables are the chief sources of vitamins, minerals, carbohydrates, fats, proteins etc. are recognized as protective foods as they are necessary for the maintenance of human health. No doubt these can be obtained by consuming meat, fish, egg etc. but for vegetarians the consuming of vegetables and fruits is the only solution for getting these essential nutrients for making a sound body with appropriate health.

Deficiency of any minerals and nutrients is depicted by the human body by giving typical symptoms. *The great majority of people obtain most of their carbohydrates and proteins from cereals and pulses but their diets must also contain significant amount of fruits and vegetables to ensure that they get the vitamins which are not provided by the staple cereal foods.*

A person should consume atleast120 g of fruits and 300 g vegetables per day as per Indian Council of Medical Research, but the consumption of fruits and vegetables per capta in India is still low. However, the respective availability of fruit and vegetables is 172 g and 350 g per day in our country. In countries like Italy, France and USA the consumption is 308, 232 and 223 g / day respectively.

Vitamins: These are the important constituents of fruits and vegetables and are indispensable part of human diet. Although required in very minute quantities, they are absolutely essential for the maintenance of health. The deficiency of any vitamin from the diet for considerable period may lead to diseased state or disorder conditions. Fruits and vegetables supply several vitamins.

Vitamin-A: It is essential for normal growth, reproduction and maintenance of health and vigour. It affords protection against cold and influenza and prevents night blindness. The deficiency of this vitamin results in cessation of growth in young children, night blindness, drying up of tear glands in the eyes, eruption of skin (Rashes on the skin) and brittleness of the teeth

Sources: ***Fruits-***Mango, Papaya, Dates, Jackfruit, Walnut etc. ***Vegetables-***Greens like palak, spinach, amaranthus, fenugreek, carrot, cabbage, lettuce, peas, tomato etc.

***Vitamin B1 (Thiamine)* :** Tones the nervous system and helps in proper functioning of the digestive tract. Its deficiency in human diet results in Beri-beri, paralysis, loss of sensitivity of skin, enlargement of heart, loss of appetite ,loss of weight and fall in body temperature.

Sources: ***Fruits-***Orange, pineapple, jack fruit, cashew nut, walnut, dry apricot, almond, banana etc,. ***Vegetables-***Green chilli, beans, onion, sweet potato, tomato (red), leaves of colocasia.

Vitamin B2 (Riboflavin): This vitamin is required for body growth and health of the skin. The deficiency of this vitamin causes sore throat, anorexia cataract, and loss of appetite and body weight and also development of swollen nose.

Sources: ***Fruits-*** Bael, papaya, litchi, banana, apricot, pomegranate, pear etc. ***Vegetables-*** Cabbage, cauliflower, potato, peas and beans, methi, lettuce, asparagus, green chillies, leafy vegetables etc,.

Vitamin -C (Ascorbic Acid): This vitamin promotes general health and healthy gums, prevents scurvy disease which is characterized by pain in the joints and swelling of limbs (rheumatism), bleeding of gums, tooth decay and keeps the blood vessels in good condition.

Antioxidants are naturally occurring substances found in most plants and have the potential to help combat heart diseases and fight cancer

Sources: ***Fruits:*** Amla, guava, ber, citrus, strawberry, pineapple etc. ***Vegetables:*** Tomato, palak, menthi, cabbage, green chillies, spinach, potatoes, peas and beans and carrot etc,.

Vitamin-D: This vitamin is necessary for building up of bones, preventing rickets and diseases of teeth.

Sources: All green leafy vegetables are rich in this vitamin.

Vitamin-E: Ithas an important effect on the generative functions and promotes fertility.

Sources: Green lettuce and other green vegetables, as well as almonds, cashewnut, walnut etc.

Vitamin-K: This vitamin prevents blood clotting.

Sources: All green leafy vegetables and nuts are rich in this vitamin.

Minerals: Human body requires minerals like P, Ca, Iron, and Iodine etc. for maintaining good health.

Calcium: It is essential for development of bones, regulation of heartbeat, controlling blood clots.

Sources: ***Fruits-*** Acid lime, Orange, Fig, Dried apricots, wood apple etc. **Vegetables-** Cabbage, greens, beans, carrot, onions, peas, tomatoes, agati, spinach drumstick leaves etc.

Iron: It is required for production of haemoglobin and it is constituent of red blood corpuscles. Its deficiency causes anaemia, smooth tongue, pale lips, eyes and skin and frequent exhaustion.

Sources: ***Fruits-*** Custard apple, Guava, Pineapple, Straw berry, Grape, Black currents, dried dates etc. and **Vegetables** like Carrot, Drumstick leaves, beans and agave etc.

Phosphorus: It is essential for maintaining the moisture content of tissues and for development of bones.

Sources: ***Fruits-***Guava, Grape, Jackfruit, Passion fruit, Orange and ***vegetables*** like Carrot, Chilli, Drumstick leaves, Beans, cucumber and onion.

Proteins: These are body building foods. These are essential for growth of the body. The deficiency of proteins in the body causes retarded growth and increases susceptibility to diseases and causes lethargy.

Sources: ***Fruits-*** Cashewnut, almond, pecannut, walnut etc. ***Vegetables*** like peas and beans are rich in proteins.

Enzymes: These are required for controlling several metabolic activities in the body.

Sources: Papaya-Papain and Pineapple-Bromelin.

Fibre and roughages (Cellulose and pectin): Fruits and vegetables supply roughages. These are required for digestion and prevention of constipation.

Sources: Fruits contain low content of fibre. Guava and anola are better sources compared to other fruits. Leafy vegetables are rich in fibre content

Energy foods: Fruits and vegetables contain Carbohydrates and fats there by supply energy to human body. Those fruits (Banana, Dates, Apple etc.) and vegetables (Potatoes, Sweet potato, Beans, Peas etc.), which contain carbohydrates, are called as energy foods. Nut fruits like Walnut, Cashew nut and almond etc. supply proteins besides energy.

IMPORTANCE OF HORTICULTURE IN THE NATIONAL ECONOMY

India is the 2nd largest producer in the world, with 76 million tones of fruits occupying an area of 6.70 million hectare and 156 million tones of vegetables from an area of 8.98 million hectare. In all, horticulture crops occupy an area of 23 million hectare and are said to annually yield 257million tones of crops. Horticulture sector not only impact the immediate life but play a very important role in the Indian economy by proving to be an important source of income for the rural population. Fruits and vegetables are not only used for domestic consumption and processing into various products(Pickles, preserves sauces, jam, jelly squashes, etc.) but also substantial quantities are exported in fresh and processed form, bringing much-needed foreign exchange for the country. These groups of crops also provide ample scope for achieving bio-diversity and diversification to maintain ecological balance and to create sustainable agriculture and can make an impact on the national economy in the years to come.

Presently, the horticulture sector contributes around 31 % of the GDP and 38% of the total exports of agricultural commodities from around 14% of area.

- Globally, second largest producer of fruits and vegetables
- Largest producer of mango, banana, coconut, cashew, papaya, pomegranate etc.
- Largest producer and exporter of spices
- Ranks first in productivity of grapes, banana, cassava, peas, papaya etc.

Table: Area and production of Horticultural Crops.

Particulars	Area (million hectare)	Production (million tones)
Fruits	6.70	76.4
Vegetables	8.98	156.3
Flowers	0.25	76.7
Plantation Crops	3.58	16.36
Spices	3.21	5.95
Aromatic Plants	0.50	0.56
Total	23.22	257.3

Source: www.nhb.org.in

1. Horticultural produces contribute to national wealth. They are the important exportable commodities in many countries. Through export of horticultural produce, our country is earning foreign exchange. India is exporting flowers to America, Netherlands, Germany, Japan, UK; Onionsto Malayasia, UAE, Singapore, Sri Lanka and Bangladesh; vegetables to Sri Lanka, America, UAE, Spain, Saudi Arabia, Bangladesh, U.K., Kuawait,; Fresh grapes to UK,Netherlands, UAE, Bangladesh, Germany; Fresh fruits to Bangladesh, UAE, Saudi Arabia, UK and Sri Lanka.; Processed vegetables to Egypt, Srilanka, UAE, America and Turkey and Mango pulp to Saudi Arabia, UAE, Netherlands, Kuwait and Germany and Pickles and Chutneys to UK, America, UAE, Spain etc.

Export growth of fresh fruits and vegetables in term of value is 14% and of processed fruits and vegetables is 16.27%

Table: Export of Horticulture Produce in India (APEDA Website)

Product	Quantity (MT)	Value (Rs. Lakhs)
Floriculture	30926.02	36532.15
Fruits / Vegetable Seeds	15205.81	28776.35
Fresh Onions	1309924.82	172299.80
Other Fresh Vegetables	729810.62	129893.77
Walnut	5841.56	23108.40
Fresh Mangoes	63441.29	20974.30
Fresh Grapes	108584.56	60288.15
Other Fresh Fruits	271347.82	73586.20
Dried and Preserved Vegetables	138464.03	70018.80
Mango Pulp	150499.06	62082.91
Other Processed Fruits & Vegetables	459514.68	211785.85

2. Increased production of horticulture crops is possible in comparison to other agronomical crops because trees have a longer life and their production increases with advancement in age provided a proper care is taken. Similarly vegetables can also be grown 3 to 4 times each year giving the products all the time they are grown. More number of crops can be grown from same piece of land, whereas, cereal crops bind the land for a longer time. Furthermore, spices, medicinal, aromatic and flower crops are high value crops as these crops fetch more prices in the market.

3. Horticultural crops are more profitable since the average income per unit area is more in comparison to agriculture crops. One hectare area of horticultural crops may generate income to the tune of Rs. 10,000 to Rs. 1,00,000 and even more, depending upon nature and value of crops.

4. With the support of horticulture, many agro-industries can spring up in villages itself. It is an acceptable fact that horticulture can come in a big way to solve the problem of unemployment. Source of other industries such as rubber, oil, gum, dyes, chemicals etc. raw material for fruit and vegetable-processing plants, hence becomes a solution to reduce unemployment.

5. Horticultural crops provide gainful employment for small farmers and agricultural labour in doing field operations like fruit picking / harvesting, grading, packing, selling etc.through out the year. One hectare of fruit production generates 860 man-days per annum as against 143 man-days for cereal crops. Some industrial attribute crops and cultural intensive crops like grape, banana and pineapple, generate much large employment ranging from 1,000 to 2,500 man-days per hectare. The processing industries are labor intensive and offer high employment potential in collection centers, grading, packing, loading / unloading, storages (ware houses and cold storages) transport, marketing and processing units.

Entertainment

Roaming in the gardens, orchards or places well planted with flowerbeds etc. gives mental peace to the people. One enjoys fresh air and natural beauty, sheds of tension making him fresh. Paradise means garden. The hanging garden of Babylon (one of the 7th wonders of the world) and the Versailles garden of 17th century are unique examples.

Medicines

The parts like stem, leaf, flowers, roots and even the fruits of horticulture plants are used to make drugs, chemicals, insecticides, germicides etc. For example, rose water is used to cure eyes ailments. Similarly saffron is imported ingredient of many medicines, papain is a digestive enzyme, citrus fruit like sweet lime is used for liver ailment, rind of pomegranate and pectin from guava used for stomach upset, bark of arjun trees for heart troubles, neem water for skin irritation and allergies etc.

Aesthetic value and religious importance

Aesthetic value and religious importance is the unique factor distinguishing it from agricultural activities. Mango leaves, wood, banana leaves etc. are used for religious functions. Similarly the plantation of banana tree in the court yard or tulsi plantation is said to bring prosperity as per Hindu religion. Leaves of bael are famous for offering to Lord Shiva. Worshiping tree is considered pilgrimic action. This aspect of horticulture has lead to its universal popularity.

ACTIVITY/EXERCISE

Make a check list of fruits and vegetables being consumed by you in your daily diet and write the observations on the important fruits and vegetables required to meet daily requirement from nutrition point of view.

CHECK YOUR PROGRESS

1) Fruits and vegetables are protective food. Justify the statement.

2) What is the importance of horticulture in Indian economy?

3) Write an account on the medicinal properties of horticultural crops.

4) Discuss in brief the importance of fruits in daily diet of human beings.

5) Identify the causes due to which the following disorders develop and enlist the fruits and vegetables as their remedial measures:

Sr. No.	Disorder	Causes	Remedial measures
1.	Paralysis		
2.	Pain in joints and swelling of limbs		
3.	Night blindness		
4.	Sore throat, loss of appetite		
5.	Anaemia		

FILL IN THE BLANKS

1. Per capita consumption of fruits and vegetables in India is ……g and ……g respectively.
2. Night blindness is due to the deficiency of……and can be corrected by taking ……..fruits and vegetables.
3. Energy providing fruits are …… and ……
4. ……vitamin prevents blood clotting.
5. India is the largest producer and exporter of ……
6. Total area under fruits in India is …… and production is……
7. India ranks ……in the production of fruits and vegetables.
8. ……..and……are required for digestion and prevention of constipation.
9. Proteins are called as ……food.
10. ……fruit is the richest source of vitamin C and can be used to avoid scurvy.

SUGGESTED FURTHER READINGS

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http://www.angrau.ac.in

CHAPTER 3

Principles of Horticulture Crop Production Technology

OBJECTIVES

After studying this chapter, students will be able to:

- Select the appropriate location for raising desirable horticultural crops under a given climatic conditions.
- Select the suitable lay out plans for different horticultural crops.
- Plan various key operations for establishing new orchard/garden.
- Manage the horticultural crops by making efficient uses of available resources.
- Decide on the most appropriate cultivation system for a given situation.

INTRODUCTION

As you might be aware after studying chapter I that, 'Horticulture' deals with a large number of plant species. Traditionally, it includes fruits, vegetables, and ornamental plants. It deals with a combination of the botanical and agricultural aspects of plants. Thus, one may define horticulture as the culture and biology of garden crops, including both the aesthetic and the scientific dimensions. Basic principles of physics, chemistry, and biology are used by horticulturists to understand and manipulate plant life. Therefore, it is essential to understand the fundamental principles of horticultural crop production in order to grow them successfully and fetch economic returns.

PRINCIPLES OF FRUIT PRODUCTION

The commercial production of fruits is known as orcharding. Grape plantations are called vineyards, and the cultivation of grapes is called viticulture. Similarly, citrus orchards are typically called citrus groves and the cultivation of citrus is known as citriculture. Orcharding and other types of fruit growing require high capital investment for years on a fixed site, without immediate return.

SELECTION OF SITE

Selection of suitable site is the first step for establishing an orchard on commercial scale. Selection may be made based on the following criteria;

- The land chosen for orchard should be in proximity to main road and market.
- It should have proper irrigation facilities and have a good soil and climate suitable for growth and production of fruit trees.
- Experience of the fruit growers and research stations in the locality should be taken into account for the acclimatization of the fruits under consideration.
- Adequate water supply should be available round the year.

Any mistake in selection of site cannot be altered after planting while modifications in other factors are possible.

Preliminary Operations for establishing an orchard

After selecting the suitable location and site, some preliminary operations have to be done. Trees are felled without leaving stumps or roots. The shrubs and other weedy growth are also cleared. Deep ploughing is essential to remove big roots. The land should be thoroughly ploughed, leveled and manured. Leveling is important for economy of irrigation and preventing soil wash. In the hills, the land should be divided into terraces depending upon the topography of the land and the leveling is done within the terraces. Terracing protects the land from erosion. If the soil is poor, it would be advisable to grow a green manure crop and plough it in situ so as to improve its physical and chemical conditions before planting operations are taken up.

Planning of an orchard

A careful plan of the orchard is necessary for the most efficient and economic management. The following points should be considered in preparing the plan.

1. Optimum spacing to accommodate maximum number of trees per unit area.
2. Stores and office building in the orchard should be constructed at the centre for proper supervision. .
3. Wells should be located at convenient places in different parts at the rate of one well for 2 to 4 hectares.
4. Each kind of fruit should be planted in a separate block.
5. Fruits ripening at the same time should be grouped together.
6. Pollinizers should be provided in deciduous fruits.
7. Irrigation channels should be laid along the gradients for most economical conduct of water.

   For every 30m length of channel, 7.5 cm slope should be given.

8. Roads should occupy minimum space for the economy of transport. The clearance between wind break and first row of trees is advantageous for the road.

9. Short growing trees should be allotted at the front and tall at the back for easy watching and to improve the appearance.

10. Evergreen trees should be in the front and deciduous ones behind.

11. Fruits attracting birds and animals should be close to the watchman's shed.

12. A good fence is essential. Live fencing is economic and cheap to other kind of fences. The plants suitable for live fencing should be drought resistant, easy to propagate from seed, quick growing, have dense foliage, should stand severe pruning and should be thorny. *Agave, Prosopis juliflora, Pithecolobium dulce* and *Thevetia* if closely planted in 3 rows would serve as a good live fencing.

13. Wind breaks, rows of tall trees planted close together around the orchard, are essential to resist velocity of wind which causes severe ill-effects particularly moisture evaporation from the soil. Since the wind breaks are very effective in reducing the wind velocity and minimizing the damage to the fruit trees and to other crops, their presence in regions where strong winds prevail is of paramount importance. A wind break ordinarily has its maximum effectiveness for a distance about four times as great as its height but has some effect over twice about that distance.

The most effective windbreak is a double row of tall trees alternately placed. There should be at least as much as space between the windbreak and the first row of the fruit trees as between fruit trees. It is preferable to dig a trench of 90 cm deep at a distance of 3m from the windbreak trees and prune and cut all the roots exposed and again fill up the trenches. This may be repeated for every 3 or 4 years in order to avoid the competition between the wind breaks and fruit trees for moisture and nutrition. Trees suitable for windbreak should be erect, tall and quick growing, hardy and drought resistant and mechanically strong and dense to offer maximum resistance to wind. The trees which are suitable for growing as wind breaks are *Casuarina equisetifolia, Pterospermum acerifolium, Polyalthia longifolia, Eucalyptus globulus, Grevillea robusta, Azadirachta indica* etc.

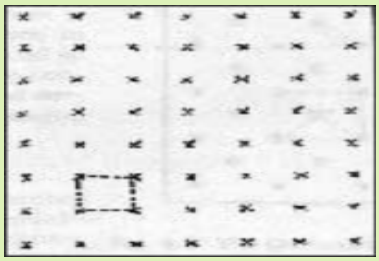
LAYOUT SYSTEMS OF PLANTING

Lay-out means locating the position of trees, roads and buildings in the orchard being established, and systems of lay-out refer to the orderly ways of planting the trees. It is desirable to have the trees planted in systematic way because

- Orchard operations like interculture and irrigation are carried out easily.
- It enables equal distribution of area under each tree.

- It results in least wastage of land.
- It makes supervision more easy and effective.
- There is room for systematic extension of the orchard.

There are mainly five systems of planting of fruit trees. In all these systems, trees are planted in rows.

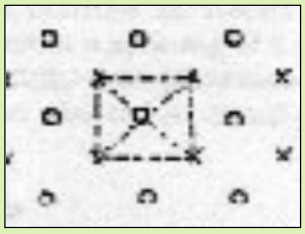


A. Square system

In square system the trees are planted in four corners of a square keeping the same distance between row to row and plant to plant in the same row. This is the most commonly followed system and is very easy to layout. This system permits inter cropping and cultivation in two directions.

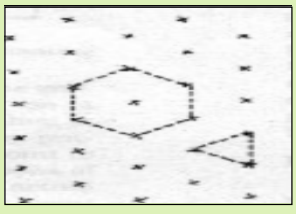
B. Rectangular system

In rectangular system the trees are planted in the same way as in a square system except that the distance between rows to row will be more than the distance between plant to plant in the same row. The wider alley spaces available between rows of trees permit easy intercultural operations and even the use of mechanical operations.



C. Quincunx or Diagonal system

Basically, quincunx or diagonal system is the same as the square system except for the addition of a tree in the center of each square. This will accommodate double the number of plants, but does not provide equal spacing. The central trees are known as filler crop and the others as main crop. The central (filler) tree chosen may be a short lived one. Papaya, Guava, Lime, plum and peaches are a few examples of filler crops in orchards with trees like mango, jackfruit and tamarind. This system can be followed when the distance between the permanent trees is more than 10m. As there will be competition between permanent and filler trees, the filler trees should be removed after a few years when main trees come to bearing.



D. Hexagonal/ septuple system

In the hexagonal system, the trees are planted at the corners of an equilateral triangle. Six such triangles are joined together to form a hexagon. Six trees are positioned at the corners of this hexagon with a seventh in the center all arranged in the three rows.This system provides

equal spacing but it is difficult to layout. This system accommodates 15% more trees than the square system. The limitations of this system are that it is difficult to layout and the cultivation is not so easily done as in the square system.

E. Contour system

In a hilly area, a lot of depressions, ridges, furrows and place surface are found. But when plating is done a line is made by connecting all the points of same elevation across the slope from a base line. Thus spacing is maintained on this row.

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. 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.

In the recent past, a new trend has been observed among the growers i.e. adoption of high density planting system. This has gradually becoming imperative due to shortage of land and labour.

High density planting system

High density planting (HDP) can be defined as "accommodation of the maximum possible number of the plants per unit area to get the maximum possible profit per unit of tree volume without impairing the soil fertility status". 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.

Examples of successful HDP in fruit crops: There are quite a good number of success stories of HDP in fruit crops under Indian conditions. Some of them are being listed below with their technical details;

Table 1. Performance of fruit crops under HDP.

S. No.	Crop	Variety	Density	Spacing (m) (Plants/ha)	Yield (t/ha)
1.	Banana	Basarai	4,444	1.5x1.5	78.0
2.	Papaya	PusaNanha	6,400	1.25x1.25	103.6
3.	Pineapple	Kew	63,758	0.22x0.6x0.75	118.8
4.	Guava	Lalit	5,000	1x2	55
5.	Mango	Amrapali	1,600	2.5x2.5	22

CHOICE OF FRUIT TREES

The next step of orchard establishment is choice of fruit crops. The choice of fruit crops is governed by various soil and climatic conditions as indicated in Table 2;

Table 2. Choice of fruit crop as affected by soil and climatic conditions.

Climatic/soils conditions	
Climatic conditions	
Temperate region	Apple, pear, peach, walnut, apricot, almond etc.
Tropical region	Papaya, banana, sapota, coconut, cashewnut, mangosteen, citrus
Subtropical region	Mango, litchi, pomegranate, loquat, grape, pomegranate
Temperate fruits in subtropical region	Low chilling peaches, apples, plums and pears
Arid region	Ber, bael, mulberry, aonla, date palm, phalsa etc.
Semi-arid region	Jamun, woodapple, fig, custard apple, khirni
Cold desert	Apricot, Pistachionut, apple, chilgoza, prunes
Cold sandy desert	Chilgoza nut
Arid temperate zone	Oleaster
Soil conditions	
Coastal sands	Coconut
Sandy soils	Ber, date palm, fig, mulberry, phalsa
Loamy soils	Most of the major fruit crops
Clayee soils	Jamun
Alkaline soils	Guava, date palm, coconut, olive, phalsa
Acidic soils	Raspberry, blueberry, fig, gooseberry
Salt affected soils	Date palm, ber, aonla, bael

All major fruits are clonally propagated by means of cutting, grafting, budding and micropropagation. In modern orcharding, fruit crops are grown as a composite plant. The upper part, which forms aerial part is called as scion, while the lower part, which makes the root system is termed as rootstock. In some cases a third part i.e. interstock, which is used for overcoming incompatibility between the scion and stock is also employed. In most cases, the commercial varieties are used as scion, and the rootstock is of a different species or variety. Rootstocks are known to influence vigour, yield, early bearing, fruit size, and impart tolerance to various soil, climatic and pests & diseases. Some of the important rootstocks of fruit crops are being mentioned below;

Table 3. Rootstocks of fruit crops.

Fruit crop	Rootstocks
Apple	M9, M27, MM111, MM106
Ber	Jharber (*Ziziphusnummularia*), Boradi (*Z. rotundifolia*)
Citrus	Rangpur lime, KarnaKhatta, Rough lemon, Trifoliate orange, Flying Dragon
Grape	Salt Creek, Dogridge, Ripario, Temple
Guava	*Psidium friedrichsthalianum, P. pumilum*
Mango	Kurukkan, Olour, Vellaikolmban
Sapota	Khirni
Walnut	Paradox (*Juglans hindsi x J. regia*)
Fig	*Ficus glomerata*

Spacing

The distance between trees and rows varies with climatic conditions, soil type, rootstock, cultural practices, training & pruning, system of planting, fruit crop and varieties to be planted. The most commonly followed spacing for commercial fruit crops are given below;

Spacing (m)	Tree number/hactare	Fruit crop
2x2	2500	Dwarf papaya, dwarf banana
3x3	1111	Tall papaya, Tall banana, grape
4x4	625	Hazel nut
5x5	400	Peach, pomegranate
6x6	277	Citrus, apricot, almond

7x7	204	Plum, guava
8x8	156	Aonla, ber, bael, litchi
9x9	121	Sapota
10x10	100	Mango, walnut, cherry
12x12	68	Tamarind, pecan nut, jamun

Farm operations like pruning and training of trees and thinning of fruits are unique to pomology and are regular features of an orchard.

Training: It is a physical technique that control the shape, size, and direction of plant growth

Pruning: It is a judicious removal of plant part to improve shape, influence growth, improve flowering, fruitfulness and fruit quality or to repair injuries.

Training systems

Training is practiced to give the shape or build strong framework of the tree in order to support maximum crop of good quality. Selection of training systems depends upon the agro-climatic situation of the region. Generally, three training systems viz., Open Centre or Vase, Central Leader and Modified Leader System are followed for canopy management of fruit plants in different regions.

Orchard cultivation

Orchard cultivation refers to the careful management of the orchard soil in such a way that the soil is maintained in a good condition suitable to the needs of the tree with least expenses.

METHODS OF SOIL MANAGEMENT PRACTICES

a. Clean culture

This type of cultivation is extensively followed in India. This involves regular ploughing and removal of weeds.

b. Clean culture with cover crops

This type of soil management involves raising of a cover crop or green manure after removing the weeds. In India, green manure crops like Sunhemp, Cowpea, Daincha, Lupins etc. are more commonly used. Legume cover cropping in grape, mango, guava and other fruit crops is becoming a common practice in the management of orchards. Cowpea and French beans grow well under guava and sapota tree.

c. Mulching

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

d. Sod

In this method, permanent cover of grass is raised in the orchard and no tillage is given. This type of orchard cultivation is followed in USA and Europe.

e. Sod mulch

This is similar to sod with the only difference is that the vegetation is cut frequently and the cut material is allowed to remain on the ground.

Intercropping

Most of fruit crops are a slow-growing tree and takes at least three-four years to come to flowering and fruiting. Intercrop like legumes in pre-bearing stage of trees not only provide more income but also improve health of the trees. Vegetables or leguminous crops like pulses, beans, berseem, etc. can be successfully grown during the initial stages. The recommended intercrops for some important horticultural crops are given as under.

Crop	Age	Intercrop
Mango	Upto 7 years	Leguminous vegetables, Papaya (filler)
Grapes	Upto 8 months	Snake gourd or bitter gourd in pandal
Apple, pears	Upto 5 years	Potato, Cabbage
Banana	Upto 4 months	Sunhemp, onion
Tapioca	Upto 3 months	Onion, beans, lab-lab, black gram
Turmeric	Upto 3 months	Small onion, coriander
Arecanut	Upto 10 years	Pineapple
Coconut	Upto 3 years	Banana, tapioca, vegetables

Multi-tier system of cropping

The system comprise of a combination of perennial and annual plant species as different components in the same piece of land arranged in a geometry that facilitates maximum utilization

of space in four dimensions (length, width, height and depth) leading to maximum economic productivity of the system. Certain horticultural plants like coconut and arecanut are grown for about 50 years in a particular land. It takes nearly 4 to 7 years for the above trees to reach the bearing stage. Adequate alley spaces (nearly 75%) are available in between these trees. Hence, these vacant spaces can be profitably used for raising other crops, thereby increasing the employment opportunities and profit. An ideal combination of crops for multitier cropping in coconut and arecanut plantations is as follows.

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

Crop regulation

Fruit crops like guava and pomegranate has three main flowering and fruiting seasons or bahars, ambebahar (spring season flowering), mrigbahar (June-July flowering) and hasthbahar (September-October flowering). Theses crops flowers continuously when watered regularly. For commercial production, only one crop in a year is desirable. Therefore, by crop regulation, the tree is forced to rest and thereby produces profuse blossoms and fruits during the required bahar. Selection of the bahar depends mainly on the availability of irrigation water, risk of damage by diseases and pests and market factors.

For bahar treatment, operations like withholding irrigations, root exposure, root pruning and spray of chemicals (thiourea, NAA or potassium iodide) are practiced to induce leaf drop and cessation of growth during the period of the unwanted bahar. The recommended doses of fertilizers are applied immediately after pruning and irrigation is resumed. This leads to profuse flowering and fruiting. The fruits are ready for harvest 4-5 months after flowering.

PRINCIPLES OF VEGETABLE CULTIVATION

As compared to orcharding, the vegetable industry is characterized by its flexibility. Because most vegetables are grown as annuals, shifts in cultivars and crops can be readily made. There are three main categories of vegetable production: home gardening, market gardening, and truck gardening. In addition, there are several small, specialized production types including vegetable forcing, production for processing and seed production.

From ease in recommending the general cultivation practices, vegetable crops have also been classified based on method of cultivation. In this method all the crops, which have similar

cultural requirements are grouped together. For instance, cucurbits (musk melon, water melon, bottle gourd, ridge gourd, cucumber etc.), cole crops (cauliflower, cabbage, broccoli), root crops (beet root, carrot, radish), bulb crops (onion and garlic) not only have similar cultural requirements for the group but the crops in each group usually belong to same family.

There are some principles required in the production of vegetable crops which are very important and well known to the grower. These principles are:

1. Production of vegetables does not involve a long time investment as does in the orchard of guava, mango, or apple.
2. Vegetable growers/farmers are not bound to produce the same crop each year like his counterparts, who grow fruit crops.
3. Vegetable growing lacks the stability which is methodically developed over a period of years like an orchard thus, getting into vegetable production is a fast process and getting out may even be faster.
4. Vegetables can be grown by people with limited experience. Only skillful farmers sustain their vegetable production.
5. The land for production of vegetable crops is flexible and adjustable. It is much easier for vegetable growers/farmers to change production from one crop to another than for fruit crop grower.
6. Cooperative efforts and organizations are somewhat more difficult with vegetable crop producers than fruit growers. Vegetable/grower/farmers have no long period for making plans. Vegetable production is seasonal.
7. Vegetable production requires more intensive production management per unit area and time.

Vegetable nursery raising

Most vegetable species are grown from seeds, but some important ones (e.g. pointed gourd, colocasia, basella, ivy gourd etc.) are propagated by vegetative methods. Among those grown from seeds, a significant number mainly those with small seeds (e.g. tomato, brinjal, cauliflower, cabbage etc.) are usually first sown in nursery beds, boxes or containers and are transplanted at a later stage. Nursery raising have several advantages like economy of seeds, uniformity of growth and selection of vigorous & healthy seedlings for transplanting.

Field establishment

Land Preparation: In preparing land for vegetable production, factors such as ecological location, mode of cropping, season, crop disposition, and the type of vegetables to be grown

should be taken into consideration. The land should be first cleared off of existing vegetation followed by leveling and suitable tillage operations

Planting: Vegetables can be propagated either by direct sowing or by transplanting methods.

Direct sowing: Vegetables are sowed either by broadcasting or by seed drilling methods. In broadcasting, seeds are spread over the prepared land by throwing small quantities of the seeds into the air close to the surface of the prepared land. This is followed in *Celosia* and *Amaranthus*. Seed drilling method is followed for planting small seeded vegetables in rows. Shallow furrows are made at the spacing recommended for the crop and the seed drilled along the furrows. This method can also be used for some leafy vegetables such as *Celosia* and *Amaranthus*.

Transplanting method: Vegetable seedlings are first raised in the nursery for a required period of time before they are transplanted on the field. Seedlings are transplanted in the morning or in the evening to avoid transplanting shock.

SOME ROUTINE OPERATIONS

Thinning: Thinning of vegetable is done to reduce the number of seedlings per stand.

Supplying or gap filling: This is the practice of providing missing stands of vegetables planted by direct sowing as a result of poor emergence or when seedlings are damaged by pests.

Staking: This is usually required for vegetables with climbing growth habit such as fluted pumpkin, or those with weak stems such as tomato. Stake can be made from bamboo or other available wood. The support allows the plant to carry more load without touching the soil thus enhancing the quality of the fruit.

Mulching: A mulch is a layer of plant residue or other materials like plastic or paper, which is applied to the surface of the soil in order to reduce evaporation, run-off or to prevent weed growth. The purpose of mulching is to conserve soil moisture.

Watering: Young vegetable seedlings in the nursery or in the field should be watered in the early morning or in the evening. Watering should be done before transplanting particularly in the evening. Likewise, over-watering can be very harmful and can encourage the development of pathogenic diseases and also cause mechanical damage to the seedlings.

Fertilizer application: Vegetables must be provided with ample supplies of nutrients such as nitrogen. Application of N fertilizer has been shown to increase yield. In some tropical leafy vegetables, fertilizers such as FYM and other sources of P and K can be applied as pre-plant basal dressing or after the plants have become established as post planting application.

Weeding: Weeds can be managed using cultural, physical, chemical and biological methods. Weed seeds and rhizomes can be killed using physical method during land preparation by burning. Mulching of soil can also smother weeds. Hoeing, pulling and roguing are carried out during the early stages of growth. Chemical weed control is applied in commercially grown vegetable crops.

PRINCIPLES OF FLOWER CULTIVATION

In a garden there are certain operations that are to be followed judiciously for successful cultivation of ornamental plants. Most of these operations, such as transplanting, pruning, pinching, etc., are of vital importance for the growth of the plants. Some other operations, such as topiary or shearing of hedges, are designed to enhance the ornamental or aesthetic value of the plant material.

Some routine operations

Soil Sterilization: This is an essential operation to eliminate soil-borne diseases, caused mainly by fungi. Soil can be sterilized with 2 per cent formalin (or formaldehyde). The formalin solution is mixed thoroughly with the soil and this is covered with tarpaulin or gunny bag for 48 hours. Some fungicides such as benlate, captan, bavistin, brassicol, and blitox (0.1 to 0.2 per cent solution) are also used for soil sterilization.

Seed Sowing: Sowing of seed is an important operation for annuals, biennials, and some herbaceous perennials, as seeds of most of them are very minute and need special care during sowing. The seeds of trees are quite bold and do not require as much care as is required for annuals.

Pricking: Pricking out, also known as thinning out, means removing the seedlings from their original container and replanting into individual pots or transferring into beds to give them more growing space.

Planting and Transplanting: Planting and transplanting are two important operations. The time of planting depends on the climate of the area. Deciduous plants are transplanted during the dormant season when they are in leafless condition. This is done only on the hills and at places having cold winter. The other season of planting is spring when new growth takes place, provided the plants can be given sufficient care and irrigation during the ensuing summer. Under Indian conditions, the best period is to transplant during the rainy season, provided there is no water-logging. The pits should be dug before the rains start.

Planting of shrubs and trees: During digging the pits for planting, the surface soil should be kept separately and not to be mixed with the rest of the soil. After digging the pit, the soil is

returned to the pit mixed with the requisite quantity of manure, the surface soil going on the top. While planting, a small hole is made at the centre of the pit and the plant is placed with the ball of earth. The plant should not be placed deeper than when it was in the nursery. After transplanting, the earth around the root should be finned thoroughly. A basin should be made on the ground around the plant for watering.

Transplanting: There are generally four types of transplanting in a garden: (1) Transplanting a potted plant to ground, (2) Transferring a potted plant to another pot, (3) Potting a ground plant, and (4) Transplanting of large trees and shrubs from the ground to another suitable location poses problems. For lifting very large trees, the help of tree-lifters or cranes and trucks will be needed.

Shading: Shading and protection of plants is an important operation in a garden, especially in places having hot summers and severe winters. The newly planted seedlings or plants need shade from the scorching summer sun. In places, where frost is likely to kill the plants these should be given proper protection. The seedlings in the nursery also need shading.

Stopping or Pinching: The operation of pinching or stopping involves the removal of the growing-point of a shoot along with a few leaves. The two main purposes of this operation are to encourage branching to produce a bushy growth, and/or the production of flower-buds on the branch which is pinched. Pinching is done mostly in annuals and herbaceous perennials and is hardly required for any flowering trees. The plants which need pinching include dahlia, chrysanthemum, carnation, brachycome and marigold.

Deshooting: Deshooting involves the removal of shoots that are not wanted. Some flowering annuals and herbaceous perennials produce numerous side shoots and if all of them are allowed to flower, the size and quality of the flowers will be greatly reduced. Deshooting of carnations grown for cut flower trade and chrysanthemum for exhibition purposes are common practice.

Defoliation: The removal of foliage is known as defoliation. This is done mainly with a view to induce flowering in certain plants. Sometimes, this can also be done to reduce transpiration loss during periods of moisture stress and also during transportation of certain plants such as roses. Defoliation can be achieved by the removal of leaves by hand or by the use of chemicals and by withholding water. In jasmine, it is a common practice to defoliate the plants after pruning just prior to the flowering season.

Staking: Plants in the garden, either in pots or on ground, need support at least for a part of, or throughout, its life. Stakes may be of various kinds. The most common stakes used in India are made of either whole bamboo or split bamboo of various sizes depending upon the type of plants to be staked. Some other types of stake which are commonly available under Indian

conditions and can be used as stakes for herbaceous plants are the dried stems of jute, cotton and pigeon pea.

Pruning: The planned removal of branches, twigs, limbs, shoots, or roots is termed as pruning. Even the removal of a dried flower can be termed as pruning. Each pruning is done with a view to increase the usefulness of a plant.

Wintering: This may be considered as an alternative to root pruning. In hotter parts of India, it may not be wise to resort to root pruning. In such places ornamental plants are "wintered". During resting period, the water supply to the plant to be wintered is stopped for a few days and the roots are exposed to the sun by removing the surface soil around the trunk. After wintering, the roots are covered with the same soil enriched with farm yard manure and copiously watered.

Clipping or Cutting of Hedges and Edges: To keep the hedges in symmetry, good health, and beauty, constant vigilance and regular shearing or pruning are needed. A sharp pair of pruning shears is used for clipping the herbaceous twigs. But to cut woody branches, secateurs or pruning saws will be required.

Topiary: The art of clipping and shearing shrubs and small trees and sometimes even herbaceous perennials into ornamental or abstract shapes is known as topiary. The term is derived from the ars *topiaria* meaning ornamental gardening. Shapes such as globe and dome can be given without the help of any pre-fabricated moulded wire model. But difficult shapes such as bird, animal, etc., are to be obtained by preparing a rough outline with wires and then training the shrub along the frame and clipping carefully over years to get the desired shape.

ACTIVITY/EXERCISE

1. Visit orchards situated in your area and try to find out which system of planting is being followed there. Compare the practices being followed in those orchards with modern practices, which you have learnt in this chapter.
2. Plan a suitable scheme for an orchard, along with important fruits and their varieties, suitable intercrops, on 10 hectare of land in your region.
3. You can visit vegetable gardens of your locality and try to find out, which system of vegetable growing is practiced, predominantly.
4. Choose some ornamental flowering plants like marigold or carnation and separate them in two sets. Apply pinching and deshooting practice to two different sets of plants, separately. Compare the size of flowers formed as a result of such practice.

CHECK YOUR PROGRESS

1) Name the important systems for layout of fruit orchard. Explain each briefly.

2) What is high density planting? Cite some successful examples of HDP in fruit crops.

3) Write the most commonly followed spacing for different commercial fruit crops.

4) Enlist different methods of soil management practices in fruit crops.

5) Enlist different types of vegetable production system.

6) Name vegetable crops, which are usually transplanted in field for cultivation.

7) Differentiate between pinching and deshooting.

8) What do you mean by topiary?

9) How soil is sterilized to get rid off of fungi and other pests?

10) Name an ornamental crop, which is defoliated for improved flowering.

FILL IN THE BLANKS

1. Quincunx system of laying out orchard is also termed as……system.

2. Recommended spacing between two tamarind plants is…….m.

3. …….. is judicious removal of plant part to improve shape, influence growth, improve flowering, fruitfulness and fruit quality or to repair injuries.

4. Bahar is practiced in fruit crops like…… and ……

5. Vegetatively propagated vegetable crops are……., ……. and ……

6. The purpose of mulching is to conserve ……

7. Pricking out is also known as …….. out.

8. The removal of …… is known as defoliation.

CHAPTER 4

Principles of Plant Propagation, Methods of Propagation for Horticultural Crops

OBJECTIVES

After studying this chapter, students will be able to:

- Gain knowledge of basic plant propagation techniques
- Gain a greater understanding of plant processes and lifecycles
- Develop skills in the art of budding and grafting
- Start agribusiness in nursery production of horticultural plants.

INTRODUCTION

Propagating new plants is both a science and an art. The study of it can provide a lifetime of challenges and opportunities to learn more about this fascinating craft, or a basic knowledge of it can provide the students with the skills and techniques to start their own business in nursery production of horticultural plants since the demand for planting material of horticultural plants is ever increasing. It can be of great fun to grow your own plants. You may already have some experience growing different plants. Plant propagation is the multiplication of plants by both sexual and asexual means. To start with, start growing a few tomato plants from seeding in kitchen garden, to the conservationist growing endangered species of orchids in test tubes, to the commercial nurseries that grow the millions of annuals, perennials, bulbs, shrubs and trees sold every year, a working knowledge of plant propagation makes all of these endeavors possible. This chapter will give the students greater confidence in producing plants from seed, cuttings, grafting, budding, layering and specialized vegetative structures along with essential skills to work in the horticulture industry.

What is Plant Propagation?

Plant Propagation is defined as the multiplication of plants by both sexual and asexual means.Propagation is an art of multiplication of plants. The horticultural plants are propagated both by sexual and asexual methods.

Most of the horticultural plants are now propagated through grafting and budding,few through cuttings, layering, seeds and micro-propagation. The propagation methods are broadly classified as sexual,asexual and micro-propagation.

The study of plant propagation has three different aspects:

- **A Knowledge of mechanical manipulations and technical skills-** ***art of propagation.***
- **A knowledge of plant growth and structures-** ***science of propagation.***
- **A knowledge of different kinds of plants and their methods of propagation**

The details of methods are presented below:

Sexual Propagation

Sexual propagation is the raising of plants by means of seed which is formed due to the fusion of male and female gametes within the ovule of a flower. Plants that are produced from seeds are called seedlings. In ancient times when the asexual methods of plant propagation were not known, this was the only commercial method for plant propagation. Papaya, phalsa and mangosteen, vegetable crops and flowers are still being propagated by seed.

Advantages

- Seedling trees are generally long-lived, bear more heavily and all comparatively more hardy.
- This is the only means of reproduction, where asexual propagation is not possible or economical e.g. Papaya, phalsa, mangosteen etc.
- To develop new varieties, hybrids are first raised from seed and it is essential to employ this method in such cases.
- It has been responsible for the production of chance seedlings of highly superior merits.
- Polyembryonic character exists in many fruit plants such as in some citrus species and some mango varieties which give rise to more than one seedling from one seed. The nucellar seedlings are true to type. Therefore, polyembryomic varieties can be propagated by seeds.
- Rootstocks upon which the fruit varieties are budded or grafted are mostly raised from seeds.
- Seedlings are cheaper and easy to raise.

- Easily transported to distant places e.g. seeds
- Does not require high technical knowledge and skilled labour.

Limitations/disadvantages

- Seedling trees are not uniform in their growth, yielding capacity and fruit quality.
- Seedling trees have long juvenile period and take more years to bear the first crop.
- Seedlings become large for economic management.
- It is not possible to maintain the exact character of any superior selection.
- Seed propagation can not be applied in many plants e.g. banana
- It is not possible to avail the modifying influence of rootstock on scion or scion on rootstock.
- Since seed-borne viruses exist in a number of fruit plants and the multiplication of such plants by seed is not recommended.

Asexual propagation

Propagation of plants through any vegetative parts is called vegetative or asexual propagation. The goal of vegetative propagation is to reproduce progeny plants identical in genotypes to a single source plant.

Advantages:

- Vegetatively propagated plants are true to type, uniform in growth, yielding capacity and fruit quality.
- Vegetatively propagated plants come into bearing earlier.
- Uniformity in fruit quality makes harvesting and marketing easy.
- Modifying influence of rootstock on scion can be profitably availed off.
- It is possible to regulate the tree size, fruit quality, precocity etc. according to one's requirements by using different rootstocks.
- Cross pollination can be effected by grafting shoots of other suitable varieties (pollinizers) on some of the branches of self-unfruitful variety.
- Grafting can be used to encourage healing of tree wounds caused by rodents, implements.
- Composite tree can be raised.
- One can correct to some extent the initial mistakes of planting inferior or unsuitable varieties.

- Fruit plants producing seedless fruits such as banana can only be multiplied through vegetative means.

Limitations

- No new variety can be evolved by means of the vegetative method of propagation.
- Sometimes, it is more expensive.
- Vegetatively propagated plants are comparatively short lived.

Methods of Asexual Propagation:

Plant Propagation by Cutting: A portion of a stem, root or leaf is cut from the parent plant and is placed under certain favourable environmental conditions to form roots and shoots. Thus a new independent plant is produced which in most cases identical with the parent plant.

Stem-cuttings: Propagation by hardwood cuttings is simple and cheapest method of multiplication. Hardwood cuttings are easily handled and transplanted. One-year-old mature shoots are collected during November-February. Grape, fig, pomegranate, currant,gooseberry, some plums and apple are propagated by hardwood cuttings. Many deciduous ornamental shrubs are started readily by this type of cuttings. Some common ones are privet, forsythia, wisteria, honeysuckle, willow, poplar, dogwood, Potentilla, Sambucus, and Spiraea. Rose rootstocks are propagated by hardwood cuttings.Weak and fast growing shoots with long internodes should not be used for this purpose. Length of

> Naphthelene Acetic Acid (NAA) and Indole-3-Butyric Acid (IBA) are the two most commonly used root promoting hormones used.

cuttings should be between 10 and 45cm. It should contain at least 2 buds. Just on the base of shoot below the node a straight cut is given while on the top of the cutting, 1-2cm above the bud a slanting cut is given. This helps maintain the polarity of the shoot and if rain occurs, water does not accumulate on the tip of cutting.

Semi-hardwood cuttings are mostly used in evergreen fruit plants-mango, guava, lemon and jackfruit. Many broad-leaved evergreen shrubs such as *Camellia, Pittosporum, Rhododendron, Euonymus,* evergreen azaleas and holly are commonly propagated by semi-hard wood cuttings. The available shoots during June-July have not attained the full maturity and are 5-9 months old. Such shoots are used for propagation purpose. Length of cuttings should be 7-20cm. It is better to retain 2-4 leaves on the top of cuttings. Treating cuttings with 5,000ppm IBA gives better results.

A novel technique for rooting semi-hardwood cuttings has been perfected. It is known as bottom heat technique. Semi-hardwood cuttings of mango, guava and aonla are prepared during December and treated with IBA 5,000ppm. These cuttings are inserted in rooting medium in a chamber maintained at 30±2°C, and 30-90% cuttings get established in this method.

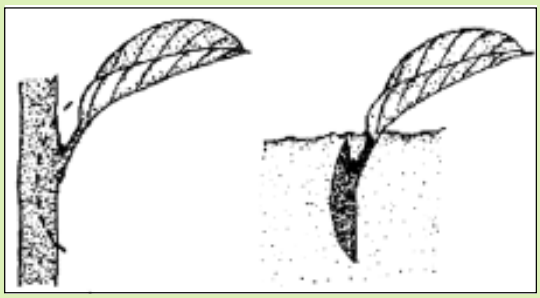
Soft wood cuttings: Cuttings are prepared from the soft succulent new spring growth of species which are 4 to 6 months old. Many ornamental woody plants can be propagated by softwood cuttings. Typical examples are the hybrid French lilacs, Foresythia, Magnolia, Spiraea, maples. Nerium, crotons, Eranthemum, Graftophyllum etc can also be multiplied through this type of cuttings.

Herbaceous stem cuttings: This type of cuttings is taken from succulent herbaceous green house plants. For example, Chrysanthemum, Coleus, Carnations, Geraniums, Cactus and many foliage plants are multiplied through herbaceous cuttings.

Softwood cuttings and herbaceous cuttings are not used to propagate fruit plants. Only 2-3 months old shoot and very tender shoots are utilized.

Leaf Cuttings: Certain plants with thick and fleshy leaves have the capacity to produce plantlets on their leaves. In leaf cuttings, the leaf blade with or without petiole and axillary bud is used for starting new plants. Adventitious roots and shoots form at the base of the leaf and form in to a new plant. However, the original leaf does not become a part of the new plant. Frequent watering and high humidity and bottom heating are desirable for better and rapid rooting of leaf cuttings. Sand or sand and peat moss (1: 1) are satisfactory rooting media for leaf cuttings. For leaf cuttings, depending on the species the whole leaf blade, leaf blade sections or the leaf with petiole is used. Begonia, African violets and peperomia are propagated by leaf cuttings.

Leaf-bud cutting: A leaf-bud cutting consists of a leaf blade, petiole and a short piece of stem with attached axillary bud of actively growing leaf Black raspberry, blackberry, boysenberry, lemon, camellia, maple and rhododendron are readily propagated by leaf-bud cuttings as well as many tropical shrubs and most herbaceous greenhouse plants usually started by stem cuttings.



Root cuttings: As the name indicates, roots of the plant are utilized as propagating material. Roots 1 cm thick and 10-15cm tall are used. In temperate fruits, such kind of roots are prepared

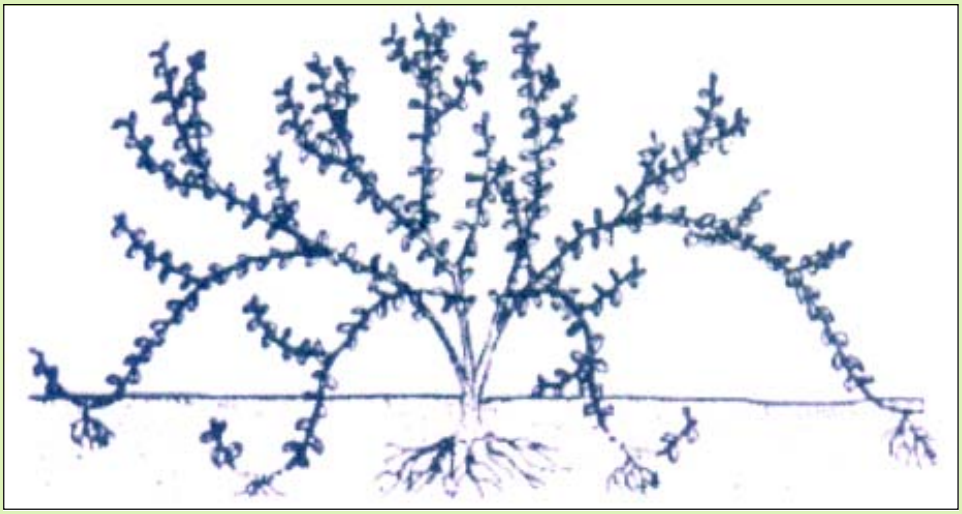
in December and kept in warm place in moss grass or wet sand for callusing and transplanted during February-March in open beds. Blackberry and raspberry are commercially propagated by this method. This method is also advocated in pecan nut, apple, pear and peach.

Propagation by layering

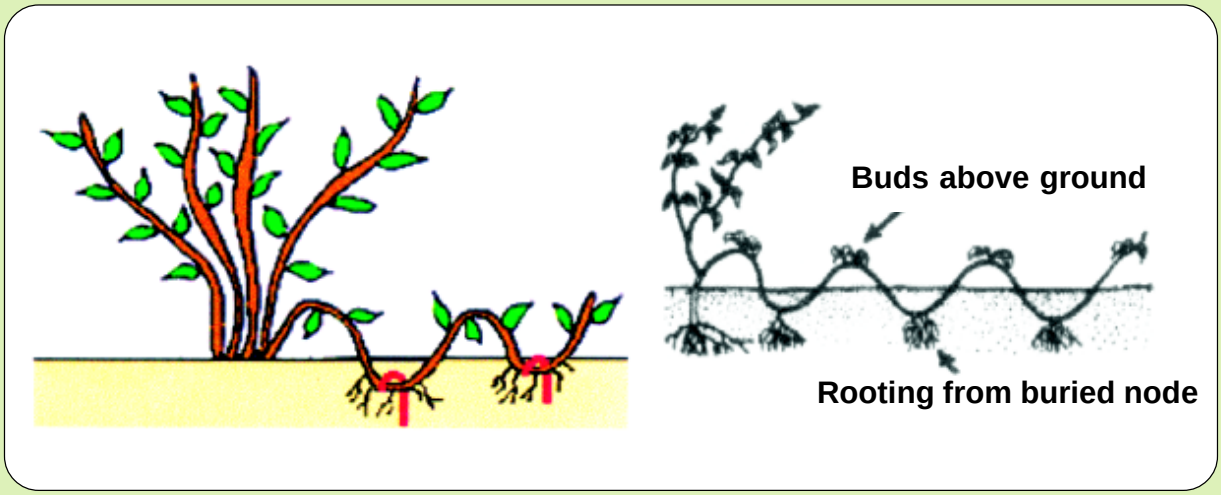
Layering is the method of propagation in which roots are developed on a stem while it is still attached to the parent plant. After proper rooting, the stem is detached and becomes a new plant for growing on its own roots. The high success of layering is obtained by ringing or wounding, etiolation (absence of light), use of rooting hormone (IBA, NAA) and favourable environmental condition (temperature and humidity).

The layering can be natural means of propagation as in black raspberries and trailing blackberries or can be artificially created by different means. The layering techniques generally employed in fruit plants are:

Tip-layering: In tip-layering, rooting takes place near the tip of current season's shoot which is bent to the ground. It is commonly followed in black berries, raspberries and dewberries. The stem of these plants complete their life in two years. During first year, vegetative growth takes place while in the second year fruiting takes place. After harvesting plants are heavily pruned which give rise to number of lateral shoots. The tips of these shoots are buried 5-10 cm deep in soil. Rooted layers are detached and planted in soil during spring.

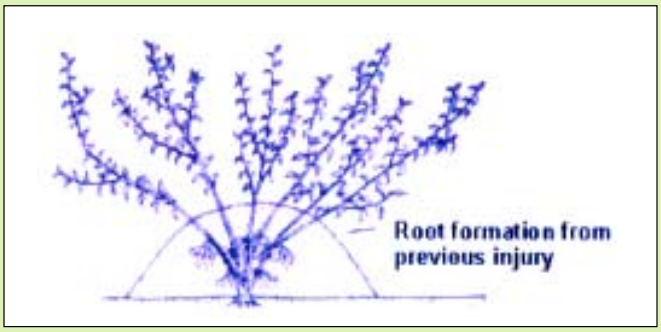


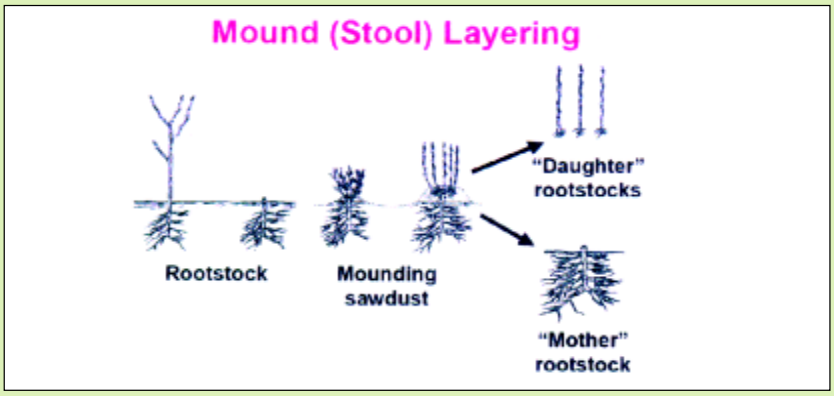
Serpentine layering: It is modification of simple layering in which one-year-old branch is alternatively covered and exposed. The stem is girdled at its lower part. The exposed part of stem should have at least one bud to develop a new shoot. After rooting, the sections are cut and planted. Muscadine grape is commercially propagated by this method.



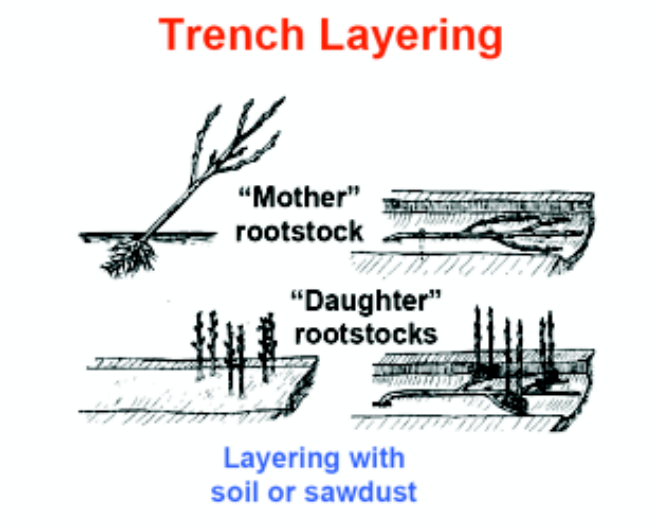
Air-layering: In this method, roots are formed in the aerial part of the plant. The stem is girdled and rooting hormone (IBA) is applied to upper part of cut. The moist rooting medium (moss grass) is wrapped with the help of small polythene strip (200-300 gauze, transparent). This method is commonly known as goottee. Many plants like litchi, kagzi lime, jackfruit, guava and cashewnut as well as Ficus species, Croton, Monstera and philodendron are propagated through air-layering. February-March and June-July are the ideal periods for air-layering. Rooting in air layers generally commences within 25-30 days and layers are ready for transplanting within 3 months.

Mound layering/stooling: In this method, the plant is headed back to 15cm above the ground level during dormant season. The new sprouts will arise within 2 months. These sprouts are then girdled near base and rooting hormone (IBA), made in lanolin paste is applied to the upper portion of cut with moist soil. These shoots are left as such up to two days for proper absorption of rooting hormone (IBA) before they are covered with moist soil. The concentration of rooting hormone varies from plant-to-plant but in general 3,000-5,000ppm is most commonly used. The rooting of shoots is observed within 20-30 days. After 2 months, the rooted shoots are separated from mother plants and planted in nursery. Apple and pear root stocks and guava are commercially propagated by this method. However, this method is also advocated in other fruits like plum, cherry, hazelnut, pecannut, mango, jackfruit and litchi.





Trench layering: Trench layering consists of growing a plant or branch of a plant in a horizontal position in the base of trench and filling in soil around the new shoots. Roots are developed at the base of new shoots, so produced. Rootstocks of apple, pear and walnut are usually propagated by trench layering.



Plant propagation by grafting

Grafting is an art of joining parts of two independent plants in such a manner that they unite and grow together into single independent plant. The part of graft combination which is to become the upper portion or the shoot system or top of the new plant is termed as scion and the part which is to become the lower portion or the root system is the root stock or under stock or some time stock.

In case of grafting, a bud stick consisting of two or more buds is inserted into the stock whereas in budding only single bud with or without wood is inserted into the stock.

Methods of grafting: There are two main types of grafting- attached scion methods of grafting and detached scion methods of grafting.In attached scion methods of grafting, the scion is still attached to the mother plant till the graft union takes place where as in detached scion methods of grafting the scion is separated from the mother plant just before grafting. Inarching or approach grafting is most important method under attached scion methods of grafting.

Inarching/ Approach grafting: The distinguishing feature of this method of grafting is that two independent plants on their own roots (self sustaining) are grafted together. This method provides a means of establishing a successful union between certain plants which are difficult to graft by any other method as the two plants will be on their own roots till the formation of successful graft. Examples are Guava, mango, sapota.

Veneer grafting: This method of propagation holds promise for large scale commercial propagation. The method is simple and can be adopted with success. Eight months to one year old seedlings are used as rootstocks. In this method, a downward and inward 3-4 cm long cut is

made in the smooth area of the stock at a height of about 20 cm. At the base of cut, a small shorter cut is given to intersect the first so as to remove the piece of wood and bark. Proper selection and preparation of scion are of utmost importance. The scion should be of matching thickness with the stock, preferably a terminal non-flowered shoot of 3 to 4 months maturity. Remove the leaf blades from the selected scion shoot on the mother plant keeping the petiole intact, about 7 to 10 days prior to detaching. This helps in forcing the buds to swell and in increasing the grafting success. The scion stick is given a long slanting cut on one side and a small short cut on the other so as to match the cuts of the rootstock. The scion is inserted in the rootstock and the graft union is then tied with polythene strip. The rootstock should be clipped in stages when the scion takes and remains green for more than 10 days.It is used widely for grafting plants such as Avocado, Mango etc.



Epicotyl (Stone) Grafting: This method of grafting is done on the epicotyl region of the young seedlings; hence the name epicotyl grafting. This method is simple, economical and useful for multiplication of mango plants in large number in a less time. Fresh mango stones are sown in the nursery beds. Germinated seedlings of 10-15 days old with tender stems and coppery leaves are lifted along with stones. The roots and stones are dipped into 0.1 per cent Carbendazim solution for 5 minutes after washing the soil. The seedling stems are headed back about 6-8 cm above the stone. A vertical split (about 3-4.5 cm longitudinal cut) is made into the middle portion of the seedlings. A wedge shaped cut is given on the lower side of scion. The scions should be 4-5 months old and 10-15 cm long containing plumpy terminal buds. The scion is then inserted in the cleft of the seedlings and tied with polythene tape. Immediately thereafter, the grafts are planted in polybags filled with the mixture of soil and farmyard manure (1:1). The polybags are watered and then kept in the shade protecting from sun and heavy rain. The successful grafts

should be shifted to open space or may be planted in nursery beds when their leaves become green. The most suitable time for stone grafting is July. Examples are Cashew, mango etc.



Soft wood grafting: This method is similar to that of cleft or wedge grafting. In the past, this technique has been used for in situ orchard establishment under dry land conditions as the grafting operation is performed using cleft/wedge method on the newly grown top portion of the plant one year after the establishment of rootstock in the field. In this method, 3 to 8 months old seedlings are used as rootstocks. The scion shoots of the thickness equal to that of rootstocks are defoliated 7-10 days prior to grafting. The graft should be secured firmly using 1.5 cm wide, 150-gauge polythene strip. The best time for the success of softwood grafting is July and August.

Cleft grafting: This method is employed in the nursery when the rootstock is quite thicker than the scion. It can be done successfully in the rootstock having a diameter of 3-10 cm. A vertical split (5 cm) is made in the rootstock with a sharp knife. The scion should be one year old, about 15-20 cm long and having 3-4 buds above the slanting cuts. For preparing the scion, two slanting cuts (5-6 cm) each are given on the opposite sides. The scion is inserted into the split of the rootstock in such a way that the cambium of both stock and scion coincides. Careful tying is necessary to avoid displacing the scion and separating the cambiums. The graft union is then tied with the help of 150 gauge polythene strip. Sprouting of scion shoots starts within 3 weeks of grafting. The polythene strip is removed after about 6-8 weeks of grafting. The sprouts arising below the graft union should be removed periodically. The best time for cleft grafting is December- February in temperate fruits.

Steps in cleft grafting

Tongue Grafting

This method is highly effective and widely employed for the propagation of peach and pear. In this method, the diameter of the scion and the rootstock should be equal. In this method, a flat slanting cut, about 5 cm long is given at the base of the scion so that the lowest bud is about midway along the cut but on the opposite side. A downward pointing tongue is made in the upper half of the slanting surface. A slanting cut, corresponding in length to that of the scion, is made upwards through the stock 15-20 cm above the ground. An upward pointing tongue is made in the upper half of this slanting surface. The cut surfaces of the scion and stock are now placed together so that the tongues interlock and the cambial regions are in close contact. This interlocking of tongue gives greater surface for the root stock and scion come into contact with each other to make the strong union. Careful tying is necessary to avoid displacing the scion and separating the cambiums. The graft union is then tied with the help of 150 gauge polythene strip. Sprouting of scion shoots starts within 3 weeks of grafting. The periodical removal of sprouts below the graft union should be carried out. The polythene strip is removed after about 6-8 weeks of grafting. Examples are apple, pear, peach, plum, apricot, almond, cherry, kiwi fruit, pecan nut etc.The best time for tongue grafting is December- Februaryin temperate fruits.

Steps in Tongue grafting

Plant Propagation by Budding

Budding is also a method of grafting wherein only one bud with a piece of bark and with or without wood is used as the scion material. It is also called as bud grafting. The plant that grows after union of the stock and bud is known as budding.

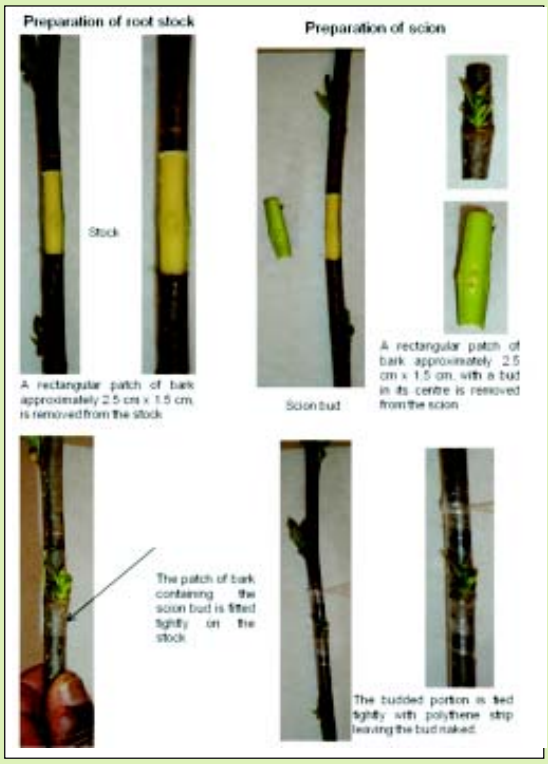
Generally grafting is performed during dormant season whereas budding is done during active growing season

Methods of budding:

T-Budding (Shield budding): This method is known as T-budding as the cuts given on the stock are of the shape of the letter T, and shield budding as the bud piece like a shield. This method is widely used for propagating fruit trees and many ornamental plants. This method is generally limited to the stock that is about 0.75 to 2.50cm in diameter and actively growing so that the bark separate readily from the wood. Example is Rose and Citrus.

Inverted T- Budding: In heavy rainfall areas, water running down the stem of the stock may enter the T cut, soak under the bark and prevent healing of the bud piece. Under such conditions, an inverted T budding may give better results as it is more likely to shed excess water. Inverted T budding procedure is same as that of T-budding except the horizontal cut on the stock is made at the bottom of the vertical cut rather than at the top.

Patch Budding: In this method a regular patch of bark is completely removed from the stock plant and is replaced with a patch of bark of the same size containing a bud from the desired mother plant. For this method to be successful the bark of the stock and bud stick should be easily slipping .The diameter of the stock and bud stick should be preferably by about the same (1.5 to 2.75cm). Examples are Pecan nut and walnut.



Steps in patch budding

Ring budding: The bud is prepared by taking a ring of a bark, 3cm long with the bud in the centre. In the root stock, two transverse cut 1.5cm apart are made and these are connected with a vertical cut and a ring of bark is removed. The prepared scion bud with the ring of bark is fitted in the exposed portion of the rootstock and tied. Example is ber.

Double working: It is practiced for several purposes (i) to over come incompatibility between the stock and scion. Incompatible stock and scion may be united by means of a piece of interstock that is compatible to both (ii) to secure resistance to drought or cold by providing a disease or cold resistant trunk by means of double working. (iii) To obtain resistance to pest and dwarfing effect by using a pest resistant stock and a dwarfing stock and (iv) top working of grafted orchard trees is essentially a double working; here the tree trunk as an intermediate stock may exert certain influences on the new top.

Top working: Top-working for changing a variety is generally done on long lived species, growing in a healthy condition. Short lived species, old trees or diseased trees are not suitable for top working; in such cases new planting is considered more economical and useful than top working.

Micro-propagation

Micro propagation (tissue culture or invitro culture) refers to the multiplication of plants, in aseptic condition and in artificial growth medium from plant parts like meristem tip, callus, embryos anthers, axillary buds etc. It is a method by which a true to type and disease free entire plant can be regenerated from a miniature piece of plant in aseptic condition in artificial growing medium rapidly throughout the year. This method is gaining popularity because of advantages over other conventional methods.

Advantages

- Large-scale multiplication in lesser time and space
- Production of virus-free plants
- Year-round production of plants
- Highly beneficial in those fruits where vegetative propagation is difficult
- In dioecious fruit plants, production of female plants is possible through micro-propagation. Papaya, is a good example.

Under micro-propagation, different plant parts are cultured. Based on explant, different in-vitro methods are used for propagating fruit plants. They are shoot-tip culture, meristem-tip culture, embryo culture and ovule culture.

Tissue culture technique has been perfected in banana. Shoot tips excised from rhizomes of sword suckers are suitable explants and MS medium supplemented with sucrose (3%), and gelite (0.25%) is the best. Shoot tips and micro-cuttings are highly suitable explants for faster and disease-free production of grape. Salt-tolerant rootstock of grape has increasing demand and in-vitro propagation has been successfully used. Seed-propagated papaya often shows high variability, undesired ratio of male and female plants. Shoot tip culture technique has been successfully used in producing female plants in papaya.

Micro-propagation has been referred to as the most ideal method for propagation of strawberry and blackberry. Scientists in India and abroad are trying hard to perfect micro-propagation in mango, coconut, litchi. However, the success is limited.

Micro-propagation, however, has its limitations. The facilities required are very costly. It requires technical skill, pathogen/disease if appeared in culture may be multiplied to very high levels in a short time and establishment of laboratory produced plants in field is a difficult task until properly hardened.

APOMOXIS

The embryo is generally produced by sexual reproduction but there are certain cases in which the embryo is produced by an asexual process. This is of great value as the resulting plant can be reproduced by seed propagation in almost the same manner as it would be by any other vegetative method. The seedlings produced through apomixes are known as apomictic seedlings. Apomictic seedlings are identical to their mother plants and similar to the plants raised through other vegetative means, as it has the same genetic make-up as that of the mother plant. Hence, propagation by means of apomictic seedlings is equivalent to vegetative propagation. The phenomenon in which an asexual reproductive process occurs in place of the normal sexual reproductive process of reduction division and fertilization is known as apomixis.

Kinds of apomixis:

Obligate apomixis: Plants that produce only apomictic embryos are known as obligate apomicts.

Facultative apomixis: Plants that produce both apomictic and sexual seedlings are called facultative apomicts.

Types of apomixis:

Recurrent apomixis: In this the embryo develops from the diploid egg cell (diploid parthenogenesis) or from some other diploid cells of the embryo sac, with out fertilization (diploid

apogamy). As a result, the egg has the normal diploid number of chromosomes, as in the mother plant. e.g, Onion, raspberry, Apple etc. In some plants apomixis occurs without the stimulus of pollination, in others pollination is necessary for embryo development.

Non-recurrent apomixis: In this type, the embryo develops directly, either from the haploid egg cell (haploid parthenogenesis) or some other haploid cells of the embryo sac (haploid apogamy). In this case haploid plants are always produced. As the plants produced by this method contain only one set of chromosomes, these are sterile and the process is not continued for more than one generation. Non-recurrent apomixes does not commonly occur and is primarily of genetic interest. e.g. *Solanum nigrum, Lilium* spp.,etc.

Adventitious apomixis (Adventitious embryony or nucellarembryony): In this type of apomixis the embryo does not develop from the cells of the embryo sac, but develops from any diploid sporophyticcell, eg.,cells of the nucellus (usually), integument etc. Hence, the diploid cells of the sporophyte giverise directly to diploid new embryos. This type of apomixis is found in citrus, where fertilization takes place normally and a sexual plus a number of apomictic (nucellar) embryos develop. In opuntia also this type of apomixis occurs.

Vegetative apomixis (Bulbils): In this case the flowers in an inflorescence are replaced by bulbils or vegetative buds, which often sprout into new plants while they are still on the mother plant. This type of apomixis is found in some species of *Allium, Agave, Diascorea, Pao* etc.

Poly embryony: This is a type of apomixis.The phenomenon in which two or more embryos present with in a single seed is called polyembryony. When such seeds are sown, more than one seedling arises from the seed. Of them one is from the zygote (Sexual seedling).The others are asexual or apomictic seedlings. The reasons for this phenomenon are many. The origin of these extra embryos or seedlings varies.

a) From nucellus-Nucellarmbryony as in citrus and mango

b) From seed coats (integuments) or antipodals or synergids -rare-mango.

c) Occasionally more than one nucleus develops with in the embryo sac (in addition to the usual and regular nucleus).

d) Cleavage of the embryo during the early stages of development is common occurrence.

What ever may be the place of origin, the common thing is, these embryos arise from the maternal tissue of the plant. Example are Citrus, Mango, Jamun, Rose, apple etc. The poly embryonic seedlings are uniform and true to parent like other vegetatively propagated plants. They are derived by mitosis, and come from maternal tissue (not by meiosis), but they have the characteristics of sexual seedlings like juvenility, vigour, freedom from virus diseases. Examples are Citrus, Mango, Jamun, Rose apple.

How to differentiate the poly embryonic and sexual seedlings: It is difficult to differentiate in the nursery. Generally more vigorous seedlings are considered to be polyembryonic. By rejecting about 10% of weaker and weakest seedlings, one can have fairly uniform poly embryonic seedlings.

Standardized and commercial methods of propagation in fruits

Name of fruits	Methods of propagation	
	Standardization	Commercial
Acid lime	Seed, budding, air layering	Seed
Avocado	Grafting (cleft, side, whip), chip budding and cutting	Layering, T-budding
Aonla	Budding (patch, shield)	Patch budding
Bael	Root cutting, budding, (Patch and Shield), air layering	Patch budding
Ber	Cutting, air layering, budding, (T, I, ring and forkert)	Ring and T-budding
Carambola	Seed, approach grafting	Seed
Custard apple	Soft wood grafting	T-budding, Inarching, Offshoots
Date palm	Seed, Offshoots	Offshoots
Fig	Cutting, budding and air layering	Hard wood cuttings
Grape	Hard wood stem cutting, chip budding, layering and micropropagation	Hard wood stem cuttings
Grapefruit	Seed and budding (patch, shield)	T-budding
Guava	Cutting, air layering and budding	Stooling, Inarching
Jamun	Seed and budding	Shield and Patch budding
Karonda	Seeds, soft wood stem cuttings in mist	Seeds, Air layering
Lemon	Seed and layering	Air layering, hard wood stem cuttings
Litchi	Air layering, splice grafting, budding	Air layering

Longan	Seeds, inarching, tongue grafting, air layering	Air layering
Loquat	Budding, grafting, seed and air layering	Inarching
Mandarin	Seeds and budding	T/shield budding
Mango	Inarching, side and Veneer grafting, budding, stool layering and cutting, cleft grafting	Inarching, Veneer grafting
Passion fruit	Stem cutting, cleft grafting	Seeds
Persimmon	Grafting and budding`	Crown grafting
Phalsa	Seeds and cutting	Seeds
Pomegranate	Budding (chip, patch and forkert), air layering, inarching	Hardwood stem cuttings and Air layering
Pummelo	Seed and budding	Seed, T-budding
Sweet orange	Seed and budding	T-budding

Propagation by specialized vegetative structures

Some fruit plants have natural structures-runner, sucker, offset, rhizome and crown-for propagation.

Runner: It is a specialized stem which is produced from the leaf axil at the crown of plant and prostrate horizontally. The roots appear at one of the nodes having contact with soil. After root formation in the new plant, the contact with the mother plant is automatically detached and new plant can be separated and planted. Strawberry is the typical example which is commercially propagated through runners.

Suckers: A sucker is a shoot which arises on a plant below the ground. However, in practice, shoots which arise from vicinity of the crown are also referred to as suckers. Pineapple is usually propagated through suckers. In banana, 2 types of suckers are produced-water sucker and sword sucker. Water suckers are broad leaved while sword suckers are pointed and in the shape of a sword.

For propagation purpose, sword suckers are preferred over water suckers.

Offset: It is a lateral shoot or branch which is developed from base of the main stem. The date palm and pineapple produce such type of lateral shoots by which they can be propagated.

Plant propagation by division: It is a method of propagation of plants using cut section of a particular part like rhizome, tuber and tuberous root etc.

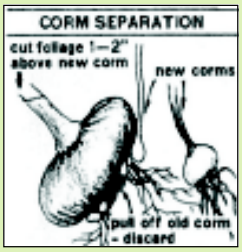
Rhizome: A rhizome is a modified stem structure in which the main axis of the plant grows horizontally just below or on the surface of the ground. Banana is a typical example where rhizome is cut into pieces in such a way so that each piece contains at least 3 lateral buds (eyes) for propagation.

Ginger rhizome

Turmeric rhizomes

Crown: It designates that part of a plant at the surface of ground from which new shoots are produced. In strawberry plant, where leaves are seen in groups, is offenly referred to as 'crown' of plant. Similarly, at the top is the crown of pineapple plant, which can be used for propagation purpose.

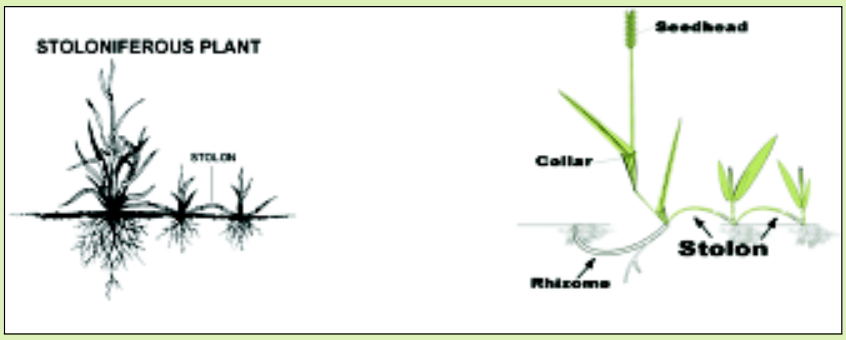
Corm: The bulb consists predominantly of modified leaves; the corm is a modified stem. Food is stored in this compact stem, which has nodes and very short internodes and is wrapped up in dry, scaly leaves. When a corm sprouts into a new shoot, the old corm becomes exhausted of its stored food and is destroyed as a new corm forms above it. Several small corms, or cormels, arise at the base of the new corm. The cormels may be separated from the mother corm at maturity (die back) and used to propagate new plants. e.g. Amorphophallus, Colocasia, Gladiolus etc.



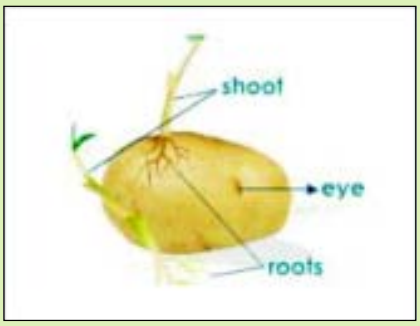
Gladiolus corm

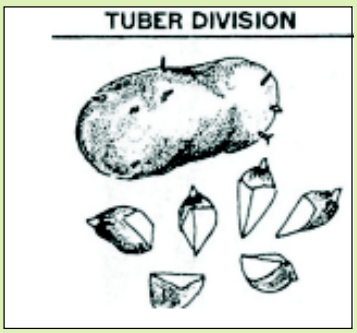
(Source: Plant facts Ohio state university)

Stolon: It is a term used to describe various types of horizontally growing stems that produce adventious roots when come in contact with the soil. These may be prostate or sprawling stems growing above ground. In propagating plants by stolon, the stolon can be treated as a naturally occurring rooted layer and can be cut from the parent plant and planted separately. For example, Mint, Bermuda grass etc.

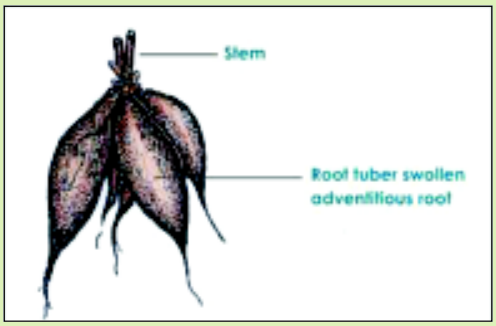


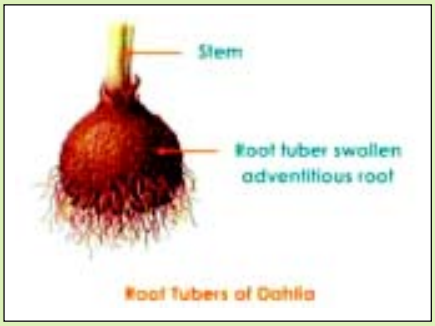
Stem tuber: A tuber is specialized swollen underground stem which possesses eyes in regular order over the surface. The eyes represent the nodes of the tuber. The arrangement of the nodes is spiral, beginning with the terminal bud on the stolon to produce a new plant, the tuber is divided into sections so that each section has a good amount of stored food and a bud or eye. Propagation by tubers can be done either by planting the tubers whole or by cutting them into section, each containing a bud or eye. For example, Potato.





Stem tuber of Potato





Root tuber of Sweet potato

Tuberous roots: These are thickened tuberous growth that functions as storage organs. These differ from the true stem tuber, in that they lack nodes and internodes. Buds are present only at the crown or stem end. Fibrous roots are commonly produced towards the opposite end. Most plants with fleshy roots must be propagated by dividing the crown so that each section bears a shoot bud. For example, Dahlia, Begonia, Sweet potato.

Offset: It is a short thickened horizontal branch growing out of the crown ending at the apex with a tuft of leaves and a cluster of leaves below. These are special type of branches or lateral shoots which are produced from the base of main stem of parent plant. The offset often breaks away from the mother plant and the daughter starts a new independent life. For example,Pistia, Agave, Water hyacinth, Cycas, Dracaena etc.

Propagation by seed

Papaya, phalsa, kagzi lime and jamun are usually propagated by seeds. Seeds are also used to raise rootstock seedlings in many fruit crops such as citrus and mango. This method being the easiest and cheapest is generally employed on a commercial scale in the fruit crops. In mango and citrus, nucellar seedlings can be used to raise true-to-type plants. Seed propagation is essential for breeding new plant type, conserving gene pools. Propagation by seed requires a thorough knowledge of seed viability, its storage, time of sowing, factors responsible for germination and care of germinated seedling is essential.

The condition in which the seed can germinate immediately upon the absorption of water in the absence of any internal germination barrier, the embryo (or seed) is said to be quiescent. While those seeds which fail to germinate even though the embryo is alive, moisture is absorbed and favourable condition are provided are known as dormant seeds.

In most of the fruit crops, there may be natural or chemical dormancy. The dormancy in seeds of ber, guava and walnut is due to presence of hard seed coat which inhibits penetration of water and oxygen required for germination. Presence of chemical inhibitors (abscisic acid) is responsible for dormancy in seeds of most of temperate fruits (apple, pear, peach and walnut). Besides ABA, higher concentration of pectin, gum, tannin and amino acids (trypophan) are also responsible for dormancy in seeds of temperate fruits.

How to overcome dormancy

Seed dormancy due to hard seed coat can be overcome by softening the seed coat and other covering. It can easily be done either by scarification, stratification or by use of chemicals and hormones.

Scarification: It is the process of breaking, scratching, altering or softening the seed covering to make it permeable to water and gases. Scarification can be achieved mechanically, or by hot water and acid.

In mechanical scarification, cracking of seed with hammer, rubbing with sand paper or cutting with a file without injury to embryo is generally employed to break the dormancy (ber, peach and walnut).

Impermeable seed coat of guava can be softened by hot water scarification. Seeds are placed in hot water at 77°-100°C. They are immediately removed from hot water and allowed to soak gradually in cool water for 12-24hr.

Acid scarification consists of treating guava seeds with concentrated sulphuric acid for 3 minutes, ber for 5-6 hr and strawberry seeds with 0.25% nitric acid or hydrogen peroxide results in higher germination.

Stratification: It is the method of handling of dormant seeds, in which, the imbibed seeds are subjected to a period of chilling to after-ripen the embryo. This term originated as the nurserymen used to place seeds in stratified layers interspaced with a moist medium such as soil or sand out of door or in pits during winter. The term moist chilling has been used as synonym to stratification. Stratification can be achieved by refrigeration of dormant seed.

Dormant seeds of temperate fruits like apple, cherry, pear and apricot are generally placed in layers of sand in a box at a temperature of 1°-5°C. Depending upon the seed type, treatment time varies from 1-5 months for breaking dormancy of seeds.

The seed dormancy due to presence of growth inhibitors can be broken by placing the seeds in running water. It results in leaching of inhibitors. The freshly extracted seeds of strawberry and grape if placed in running water for 7-12 days result in increased germination.

Chemical treatments: Many freshly harvested dormant seeds usually respond to soaking in potassium nitrate solution. This technique is largely used in seed testing laboratories where seeds are placed in petri-dishes containing 0.2% solution of potassium nitrate. The seeds of peach and grape, treated with 5,000ppm of thiourea show enhancement in their germination.

Use of hormones: The seed dormancy can also be overcome by the treatment of growth regulators. Treatment of seeds of apple, cherry, peach, strawberry and hazelnut with 100-500ppm of GA3 for 24-48hr improves germination and better growth of seedlings. Ethrel (5,000ppm)-treated seeds of guava and strawberry also show better germination and growth of seedlings.

Treatment of apple and peach seeds with 10-20ppm solution of benzyle adenine (BA) is effective for higher seed germination.

Seed sowing

The fruit seeds are sown in seed bed, polythene bags or in situ. Seeds of tropical and subtropical fruits are sown during monsoon (June-July) or in the beginning of spring (February-March). Generally seeds of mango and jackfruit are sown during June-July while those of guava, ber and aonla during February-March. Seeds of temperate fruits are generally available during June-October and their sowing should be done after the dormancy period is over. In citrus, mango, loquat, litchi and jackfruit, seed viability is very less, so these should be sown immediately after extraction. In north India, seeds of different citrus types are available during winter months. Germination of seeds is low due to prevailing low temperature. Hence use of polythene sheet on seed beds during December-January is useful in increasing germination percentage and faster growth of seedlings.

The seeds are usually sown at a depth 3-4 times of their size. It should be a little deep in light soils while shallow in heavy soils.

Nowadays, sowing of seeds in polythene bags, earthen pots and pans is becoming popular. It is usual practice to sow papaya seeds in polythene bags. For epicotyl grafting, mango stones are also sown in polythene bags.

While raising the plants in polythene bags, care should be taken that root system develops properly. It has been observed a number of times that the roots get twisted and there is difficulty in establishment of the plants in field due to poor anchorage.

In-situ sowing: In walnut, pecan nut, jackfruit and ber, the tap-root system is very vigorous. So during the process of transplanting, root system is disturbed which ultimately affects their establishment in the field. Therefore, for these fruits, sowing of seeds in-situ is recommended. In rocky soils, in-situ sowing of mango seeds and grafting later on is recommended.

Seed storage: Based on storage behaviour, seeds are classified as orthodox or recalcitrant. The orthodox seeds can tolerate loss of moisture and their longevity can be increased by preserving them at low temperature. These include the seeds of apple, ber, custard-apple, date palm, fig, grape, guava, lemon, lime, mandarin, mulberry, papaya, passion fruit, peach, pineapple, plum, phalsa, pomegranate and sweet orange. Recalcitrant seeds do not withstand desiccation and need a critical level of moisture to survive. Such seeds can be stored for relatively short period ranging from a few weeks to a few months. Seeds of fruits which show recalcitrant behaviour are avocado, barbados cherry, carambola, breadfruit, durian, jackfruit, litchi, mango, mangosteen

and rambutan. Seeds of most of the tropical and subtropical fruits cannot be stored for a long period. However in controlled temperature and humidity, storage period can be prolonged.

Cryopreservation: It is the method of storage of material in liquid nitrogen maintained at a temperature of -196°C. Successful cryopreservation of material involves the application of chemicals known as cryoprotectants. The most commonly used chemicals are glycerol and DMSO (Dimethyl sulphoxide). This method has recently been used in preservation of embryos of coconut and jackfruits under in-vitro systems.

ACTIVITY/EXERCISE

1. Describe and explain the conditions needed for successful plant propagation from stem and leaf cuttings
2. Make three different types of stem cuttings.
3. Demonstrate knowledge of propagating plants by layering/grafting/budding in fruit plants growing in your farm/nearby orchard.
4. Visit nearby fruit/flower nursery and find out the methods of propagation being used by nurserymen for the multiplication of various fruits and flowers.

CHECK YOUR PROGRESS

1) Define asexual propagation. How does it differ from sexual propagation?
2) Asexual propagation is advantageous in horticulture, why? Also write its limitations.
3) Enlist different types of layering and describe air layering giving suitable examples.
4) Differentiate between the followings:
   a. Grafting and budding
   b. Softwood and herbaceous cuttings
   c. Leaf cuttings and leaf bud cuttings
   d. Stratification and scarification
   e. Mound layering and trench layering
5) How seed dormancy can be overcome?

FILL IN THE BLANKS

1. Two most commonly used rooting hormones are ……and ……
2. Strawberry is commercially propagated through ……..

3. Grafting is generally performed during.....season and budding during.....season.

4. Seed germination can be improved by the application of .....growth regulators.

5. Inverted T budding is generally done in areas experiencing.....rains.

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CHAPTER 5

Essential Plant Nutrients, Their Deficiency Symptoms and Toxicities in Horticultural Crops

OBJECTIVES

After studying this chapter, the students should be able to learn about:

- Essentiality of plant nutrition
- Classification of essential nutrients on the basis of their requirement to plant
- Identify and diagnose common plant nutrient deficiency andtoxicity symptoms

INTRODUCTION

Plants, like all other living things, need food for their growth and development.The plant nutrients are essential for optimum plant growth. Nutrients are naturally present in the soil. Now, certain questions may arise in your mind. Why does plant need nutrients? How many nutrients are required for the growth and development of the crop? What are their functions and effects on plant growth and development? What will happen if there is deficiency of these nutrients? How will we identify and diagnose the deficiency symptoms of a particular nutrient in the soil? You can face several questions of this category. Each nutrient assists with different plant functions that allow the plant to grow and reproduce. Each plant nutrient is needed in different amounts by the plant, and varies in how mobile it is within the plant. It is useful to know the relative amounts of each nutrient that is needed by a crop in making fertilizer recommendations. In addition, understanding plant functions and mobility within the plant should prove useful in diagnosing nutrient deficiencies. The knowledge of the specific role of the essential elements in normal growth and development of the plant, their deficiency symptoms and amount required for the optimum crop production is considered necessary to understand soil fertility better and to adopt scientific use of fertilizers. Plant nutrients taken up by crops during the growing season may come from many sources including soil, synthetic fertilizers or manure, and also crop residues. Most soil conditions across the world can provide plants with adequate nutrition and do not require fertilizer for a complete life cycle. However, man can artificially modify soil through the addition of manures and fertilizer to promote vigorous growth and increase yield. It is essential to apply balanced quantity of nutrients through man-made fertilizers. An element present at a low level may cause deficiency symptoms, while the same element at a higher level may cause toxicity.

What is Plant nutrition?

Plant Nutrition is the study of the chemical elements and compounds that are necessary for plant growth, and also of their external supply and internal metabolism.During the first half of the 19th century, it was found that element are absorbed by roots principally as inorganic ions in soils and these are derived mostly from mineral constituent of soil. The term **Mineral Nutrition** generally refers to an inorganic ion obtained from soil and required for plant growth.

The process of absorption, translocation and assimilation of nutrients by the plants is known as mineral nutrition. Nutrients are chemical elements, which are absorbed by the plants in more and less large quantities to transform light energy into chemical energy and to keep up plant metabolism for the synthesis of organic materials.

Difference between plant nutrition and fertilization

Plant nutrition means need for basic chemical elements for plant growth whereas fertilization refers to the external application of synthetic plant nutrients to supplement the nutrients naturally present in the soil.

Criteria of Essentiality:

Arnon& Stout proposed criteria of essentiality, which was refined by Arnon (1954). According to this criterion, an element is considered as essential when-

1. A deficiency of the element makes it impossible for the plant to complete its life cycle.
2. Its deficiency can be corrected or prevented only by supplying this element.
3. The element is directly involved in the metabolism of the plant.

Essential Nutrients: An essential nutrient is one required by an organism for normal growth and development, but which it cannot manufacture on its own. There are 17 elements which are essential for plants namely, carbon (C), hydrogen (H), oxygen (O), nitrogen (N), phosphorus(P), potassium(K), calcium(Ca), magnesium(Mg),sulphur(S), Iron(Fe), manganese(Mn), zinc(Zn), copper(Cu), molybdenum(Mo), chlorine (Cl), boron (B) and Nickel (Ni) . Ni is recently added as an essential nutrient. There is a dispute among plant physiologists concerning the role of nickel in plant nutrition. Since many physiologists exclude it as essential, in some textbooks, lists consist of only 16 essential inorganic nutrients.

Classification of essential elements: Over 95 percent of the dry weight of a flowering plant is made up of three elements namely, carbon, hydrogen, and oxygen which are taken by the plant from the air and water. The remaining 5 percent of the dry weight comes from chemicals

absorbed from the soil. Roots absorb the chemicals present in their surroundings, but only 14 of the elements absorbed are essential for plant growth. These 14 elements, along with carbon, hydrogen, and oxygen, are called the 17 essential inorganic nutrients, or elements. All elements are needed in specific amounts.

Therefore, depending upon the quantity of nutrients present in plants, these elements can be grouped into three categories:

1. **Basic Nutrients-** Of the 95% of total dry matter of plants, carbon and oxygen constitute 45% each. Example:- total dry matter produced by rice crop in one season is about 12 t/ha in which 5.4 t is oxygen, 5.4 t is carbon and 0.7 t is hydrogen.

2. **Macronutrients -** The nutrients which are required in larger quantities for better growth and development of the plant are known as macronutrients. They include N, P, K, Ca, Mg, and S. Among these, **N, P and K** are called primary nutrients whereas **Ca, Mg,** and **S** are known as secondary nutrients. They are known as secondary nutrients due to their secondary importance to the manufacturer of primary nutrient fertilizers.

3. **Micronutrients-** The nutrients which are required in small quantities are known as micronutrients or trace elements. They are Fe, Zn, Cu, B, Mo, Mn and Cl. These are also known as trace/minor/rare elements which are very efficient. Their deficiency and excess can be harmful to the plants.

Plants use elements in differing amounts and forms e.g. some as cations and others as anions. Almost all elements are used in a variety of ways-

1. Catalysts for enzymatic reactions (either as part of the enzyme structure or as regulators or activators),

NON-MINERAL NUTRIENTS

Three elements, carbon (C), hydrogen (H), and oxygen (O), are considered to be non-mineral nutrients because they are derived from air and water, rather than from soil minerals. Although they represent approximately 95% of plant biomass, they are generally given little attention in plant nutrition because they are always in sufficint supply.

2. Regulators of the movement of water in or out of the cell and maintenance of turgor pressure

3. Regulators of membrane permeability,

4. Structural components of the cell or of electron receptors in the electron transport system, or as buffers (which maintain the pH within cells).

Based on the functions, the nutrients are classified into four groups:

1. Elements that provide basic structure to the plant- C, H, O.
2. Elements useful in energy storage, transfer and bonding- N, S, P. These are accessory structural elements which are more active and vital for living tissues.
3. Elements necessary for charge balance- K, Ca, Mg. These elements act as regulator and carriers.
4. Elements involved in enzymes activation and electron transport- Fe, Mn, Zn, Cu, B, Mn, Cl. These elements are catalyzers and activators.

The importance of all the 17 essential elements lies in their specific function or roles in various biochemical or biological system essential for growth and development of plant. As each nutrient perform specific function, its adequate and deficient supply lead to development of visual deficiency symptoms in plants. The deficiency symptoms generally appear on specific plant parts i.e leaves, stem or roots. Deficiency symptoms are the first indication of non availability of nutrients in soil and hence the specific and general functions and visual deficiency symptoms of the essential plant nutrients will help in better understanding of fertilizer or nutrient need of plants. The major functions and deficiency symptoms of essential plant nutrients are as under:

Mobile nutrients are nutrients that are able to move out of older leaves to younger plant parts when supplies are inadequate. Mobile nutrients include N, P, K, Cl, Mg, and molybdenum (Mo). Because these nutrients are mobile, visual deficiencies will first occur in the older or lower leaves and effects can be either localized or generalized.

Immobile nutrients(B, Ca,Cu, Fe, Mn, Ni, S, and Zn) are not able tomove from one plant part to another and deficiency symptoms will initially occurin the younger or upper leaves and be localized. Zn is a partial exception to this as it is only somewhat immobile in the plant, causing Zn deficiency symptoms to initially appear on middle leaves and the naffect both older and younger leaves as the deficiency develops.

Functions, deficiency symptoms and toxicities of essential plant nutrients:

Carbon, hydrogen and oxygen: These are the major constituents of organic compounds like carbohydrates and fats found in the plants and provide energy required for growth and development. They are rarely limiting as a nutrient and there are no specific symptoms

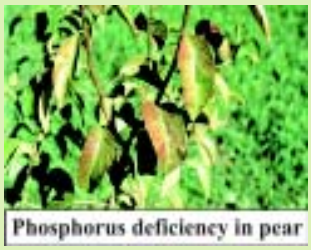
Nitrogen

It is a constituent of proteins, enzymes, vitamins and plant hormones. It imparts vigorous

vegetative growth and dark green colour to plants, produces early growth, delays maturity of plants, and governs the utilization of potassium, phosphorus and other elements. Its deficiency results in drastic reduction in vegetative growth, stunted shoots and roots with thin, upright and spindly appearance. Chlorosis is first observed on older leaves. Leaves are thin, fragile, small, pale- yellowish in colour and defoliate prematurely. Flowering, fruit-bud formation and fruit setting are reduced. Woody fruits without any flavour are formed. Excess levels result in abundant foliage with dark green colour, making plants more susceptible to pest and disease attack. Yields are low. Fruits are poorly coloured with poor eating quality and storage properties. It delays fruit maturity. P uptake is low.


Severe nitrogen deficiency in citrus

Phosphorus


Phosphorus deficiency in pear

It is found in younger parts-flowers, maturing fruits and seeds. It enhances maturity of crop, root growth and development, activity of rhizobia and formation of root nodules. Its deficiency leads to stunted roots and shoots with abnormally small leaves with dull dark green colour, which later turns into bronze colour. Older leaves prematurely defoliate. Flowering is delayed, fruit-bud formation is reduced, and yields are with poor quality. Excess of P results in interveinal chlorosis in younger leaves and marginal scorch of older leaves followed by necrosis, tip die back, heavy leaf shedding and death of shoots. It results in Zn, Cu, Mn and Fe deficiency.

Potassium


Potassium deficiency in banana

Young leaves, root tips and meristematic tissues are very rich in K. It is involved in cell division, synthesis and translocation of carbohydrates and synthesis of proteins in meristematic tissues. K plays a unique role in osmotic regulation, opening and closing of stomata. It has a beneficial effect on symbiotic N_2 fixation by leguminous plants and increases resistance of plants to various abiotic and biotic stresses. It improves the colour, flavour and size of fruits. Deficiency symptoms first appear on recently matured leaves. Marginal burning of leaves starts from tip which turns reddish-brown in colour and eventually die giving a scorched, ragged appearance. Shoots are thin with poor growth. Excess of K leads to Mg, Mn, Zn and Fe deficiency by affecting their uptake.

Calcium

Calcium occurs mainly in the leaves as calcium pectate. It plays an important role in cell division, elongation, maintenance of membrane integrity, development and functioning of roots and root apices, respiration, uptake of N, Fe, B, Zn, Cu and Mn. Since Ca is not freely mobile, its deficiency first appears on the shoot tips. Terminal buds fail to grow and eventually die. Leaves are distorted with margins curled downwards or upwards, Fruits crack, roots are abnormally short, thick and crooked. Excess Ca produces alkalinity and reduces the availability of nutrients such as P, K, Mn, Fe and Zn.

Magnesium

It is a constituent of chlorophyll, protoplasm, chromosomes, etc. It is a catalyst in several enzymes and is essential for formation of carbohydrates, oils, fats and vitamins. Deficiency symptoms first appear in older leaves. The most prominent symptom is yellowing of leaf margins that progresses through the interveinal tissue towards the rib. The veins and adjacent tissues remain green. Excessive Mg levels may result in either K or Ca deficiency in plants.

Magnesium deficiency in peach leaves

Sulphur

Sulphur is present abundantly in leaves. It is a constituent of cystine, methionine, proteins and fatty acids. It increases root growth, nodule formation and stimulates seed formation. Chlorosis is first observed on the young leaves in sulphur deficient plants. Shoot growth is restricted. Leaf area and fruiting is reduced. Leaves fall early. Excess of Sulphur results in reduced leaf size, leaf burning or mottling with a yellow or bronzed colouration, accompanied by leaf abscission.

Sulphur deficiency in banana

Iron

Iron acts as a catalyst in formation of chlorophyll and in several enzymes. It is a key element in various reactions of respiration, photosynthesis and reduction of nitrates and sulphates. In its deficient plant interveinal chlorosis is first seen in young terminal leaves. In severe cases, the new leaves unfold completely, devoid of green colour but veins usually turn green later. The fine network of veins is distinctively green against a

Iron deficiency symptoms- yellowing of youngest leaves

yellow back ground. Plants seldom show Fe toxicity symptoms as solubility of Fe in the soil solution is rather low.

Zinc

Zinc deficient mango shoots have shortened internodes, resulting in leaf rosetting.

It is required for synthesis of tryptophan, a precursor of auxin, Indole acetic acid. It is essential for carbon dioxide evolution and utilization, carbohydrate and phosphorus metabolism, and synthesis of proteins. Its deficiency leads to short internodes, small narrow leaves, interveinal chlorosis and shoot and branch dieback. In advanced stage, small, narrow, terminal leaves are arranged in whorls giving rise to a typical 'rosette' or little leaf symptoms. Root growth is restricted. The symptoms disappear as the season advances. Soils derived from parent material rich in zinc or impregnated with seepage water from Zn ore, excessive fertilization with Zn in acid soils causes toxicity in plants. Toxicity of Zn can be reduced by liming or by adding superphosphate to the soil, thus reducing the solubility and absorption of Zn.

Manganese

Manganese deficient orange; leaves develop a mottled pattern of light and dark green.

Manganese accumulates in leaves more than seeds and stalk tissue. It plays an essential role in respiration, nitrogen metabolism, chlorophyll synthesis and breakdown. Deficiency symptoms appear soon after the leaf is fully expanded and persists throughout its life. It is characterised by a pattern of leaf chlorosissome what between that caused by magnesium and iron deficiency. High acidity leading to greater solubility of Mn; addition of acid forming fertilizers and regular application of $MnS0_4$ over many years or poor soil aeration cause Mn excess in soils.

Copper

It is required in oxidation-reduction reactions, photosynthesis, respiration, carbohydrate/ nitrogen balance, chlorophyll and vitamin A formation, biosynthesis and activity of ethylene in fruit ripening. Dieback, gum pockets at nodes of twigs and brownish excrescence on fruits, twigs and leaves are common in copper deficient plants. Chlorotic and small leaves sometimes also show brown or bronze areas. Fruits have thick peel, lack juice and are insipid with a tendency of cracking or splitting of rind. Excess of copper results in reduced plant and root growth with less branching, more thickening and abnormally dark root-lets.

Boron

It plays a part in flowering, fruiting, photosynthesis, hormone movement and action, cell division, differentiation and development, sugar translocation, pollen germination, pollen tube growth, rooting and active salt absorption. In its deficiency, terminal buds fail to open or abort and twigs die-back. Leaves are darker green, boat like, brittle and abscise early, starting from the shoot tips. Fruits are malformed, hard, misshapen with rough skin. Corky areas develop in cortex and browning in core region. In some cultivars, fruits crack. Available B content of 0.5 ppm in soil may cause a deficiency in some plants but leaves (>5 ppm) become toxic for normal plant growth.

Boron deficient papaya fruits develop bumps.

Molybdenum

The Mo plays an important role in nitrogen metabolism. It is constituent of two major plant enzymes namely, nitrogenous and nitrate reductase. It helps in fixation of atmospheric nitrogen in legume crops. Deficiency symptoms develop on leaves as yellow spots. In late summer, large yellow spots are apparent with gum and corky cells forming on the lower leaf. Fruit yield is adversely affected. Mo toxicity is not reported in plants

Molybdenum deficient grapefruit leaves have interveinalchlorosis.

Chlorine

It is involved in the oxygen evolution in primary reactions of photosynthesis, cell multiplication and turgor production in guard cells. Chlorosis, necrosis, unusual bronze discolouration of foliage and wilting of plants is seen in Cl deficient plants. High levels of Cl result in depressed growth, chlorosis, burning of tips and margins of leaves, bronzing, premature yellowing and abscission of leaves.

Nickel

It is an essential part of enzyme in nitrogen metabolism. Leaf tips with dead spots.

These deficiency symptoms can be overcome by supplying nutrients artificially. Nutrients can be supplied to vegetables by organic manures and chemical fertilizersin appropriate quantities. Organic manures not only add the essential nutrients to the soil but they also improve the soil texture and structure. Nitrogen is applied in the form of farmyard manure and inorganic fertilizers such as urea, ammonium sulphate, calcium ammonium nitrate (CAN) etc. Phosphorus is applied in the form of phosphate such as single super phosphate, rock

phosphate, di-ammonium phosphate etc. Potash is applied in the form of sulphate or chloride of potassium etc. For controlling of micronutrient deficiency, several water soluble fertilizers specific to micronutrients are available like borax (for boron).

Activity

Visit nearby fruit and vegetable farms and collect samples of plants showing some abnormalities. Try to diagnose the symptoms associated with nutrient deficiency and prepare herbarium.

CHECK YOUR PROGRESS

1. Write the criteria of essentiality of an element. Classify all essential nutrients on the basis of their requirement.
2. Write five nitrogenous andphosphatic fertilizers along with their percent N and P2O5 contents.
3. Classify all essential nutrients on the basis of their mobility in plant system.
4. Write the functions and deficiency symptoms of nitrogen, calcium, zinc and boron in plants.
5. Define the following terms

   a) Mobile nutrients b) essential nutrient c) Macro nutrient

   d) Secondary nutrient e) Fertilization f) Mineral nutrition

FILL IN THE BLANKS

1. Deficiency symptoms of nitrogen first appear on……leaves.
2. Ca, Mg, and Sare known as _____ nutrients.
3. A nutrient which plays a unique role in osmotic regulation, opening and closing of stomata is ……
4. Elements that provide basic structure to the plant are……, ……and……
5. Nutrient required for synthesis of tryptophan, a precursor of auxin, Indole acetic acid is……
6. Deficiency of……. causes 'little leaf" in citrus.

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CHAPTER 6

Organic and Inorganic Manures and Their Methods of Application in Horticultural Crops

OBJECTIVES

After studying this chapter, students will be able to:

- Gain basic knowledge about organic and inorganic manures and fertilizers.
- Understand the importance and principles of fertilizer application to horticultural crops
- Learn about different methods of fertilizer application.
- Decide on the most appropriate manures and fertilizers and their suitable method of application for a given situation.

INTRODUCTION

For optimum growth and production of horticultural crops,application of fertilizers is most important. Horticultural crops require nutrients for its growth and development which are absorbed through soil. In order to get maximum benefit from manures and fertilizers, they should not only be applied in proper time and in right manner but there are many other aspects, which should also be given due consideration. Different soils react differently on fertilizer application. Similarly, the N, P, K requirements of different crops are different and even for a single a crop, the nutrient requirements are not the same at different stages of growth.Now, certain questions may arise in your mind. What are the different methods of fertilizer application? Is there a choice to practice a particular method fertilizer application? Can any chemical fertilizer be sprayed on crops?

As we learnt about essential plant nutrients, their deficiency symptoms and various types of manures and fertilizers in chapter 5, let's revise it. There are 17 elements which are essential for plants namely, carbon (C), hydrogen (H), oxygen (O), nitrogen (N), phosphorus(P), potassium(K), calcium(Ca), magnesium(Mg),sulphur(S), Iron(Fe), manganese(Mn), zinc(Zn), copper(Cu), molybdenum(Mo), chlorine (Cl), boron (B) and Nickel (Ni) . Manures and fertilizers are major nutrient supplying sources to plants. In this chapter we will learn about various methods of fertilizer application employed for optimum growth and yield of horticultural crops. A deficiency of any of these nutrient elements can limit plant growth and development and, ultimately, yield. Most soils contain sufficient amounts of the micronutrients needed to support

plant growth. However, soils may be lacking in some of the macronutrients, particularly nitrogen, phosphorus and potassium. Therefore, it becomes necessary to ensure the presence of all the essential elements supplied by the soil in the right quantities and the right chemical forms for plant use. This is done by supplying organic matter and by the judicious use of fertilizers and manures in order to supplement the nutrients required by the plants from soil to increase crop yield *vis-a-vis* to maintain/ improve the soil fertility. Continuous cropping and several other factors necessitate the use of manures and fertilizers. The dose, method and time of application depend on crop, soil, fertilizer/manure and climatic factors of the region.

Inorganic and organic manures

Inorganic manures: These are industrially manufactured chemicals containing higher nutrient content than organic manures, while fertilizer grade refers to the guaranteed minimum percentage of N, P_2O_5 and K_2O contained in the fertilizer material. Composition of different fertilizers commonly used in horticultural crop production is given in Table 1. Nutrient input is lost either through leaching, runoff, volatization, fixation by soil or consumption by weeds, etc. Coated fertilizers namely, urea supergranules, tar-coated urea and sulphur-coated urea make nutrients available slowly and prevent wastage. Use of nitrification inhibitors can also be an approach for increasing the nitrogen-use efficiency.

In India, fertilizers consumed are of 5 types:

1. Nitrogenous fertilizers
2. Phosphatic fertilizers
3. Potassic fertilizers
4. Complex fertilizers
5. Fertilizer mixtures

Any natural or manufactured material, dry or liquid added to soil in order to supply one or more plant nutrients other than lime or gypsum is known as fertilizer.

1. Nitrogenous fertilizers

These fertilizers supply nitrogen. The common nitrogenous fertilizers are ammonium sulphate, calcium ammonium nitrate and urea etc. Ammonium sulphate and urea are by far the most important nitrogenous fertilizers used by Indian farmers.

2. Phosphatic fertilizers

These fertilizers are chemical substances that contain nutrient phosphorus in absorbable form. The primary material of phosphatic fertilizers is rock phosphate. The commonly used phosphatic fertilizers are Single super phosphate(16% P_20_5, 20% calcium and 12% sulphur), Dicalcium phosphate(32-36% P_20_5) triple super phosphate (46-48% P_20_5).

Bone meals have been used as manures for time immemorial. Bone meals are of two kinds (i) Raw bone meal and (ii) Steamed bone meal. Raw bone meal contains about 25% P_20_5 and 4% N which is in the slow acting organic form. Steam bone meal contains 25-30% total phosphorus(P_20_5) and about 1-2% N. It contains about 25% citrate soluble phosphorus (P_20_5). Steam bone meal is applied to soil few days before sowing of crop.

Basic slag: It is a by product of the steel industry where the original iron ores contain appreciable amounts of phosphorus. It is a grayish black powder with a very high specific gravity. It contains 8-12% P_20_5.

3. Potassic fertilizers

These fertilizers are applied to soil to supply the plant with potassium (K) one of the essential elements for plant growth. Main potassic fertilizers used today are Muriate of Potash(60% K_2O), Sulphate of Potash(48 to 52% K_2O).

4. Complex fertilizers

Straight fertilizers versus Complex fertilizers:

Straight fertilizers supply only one of the primary fertilizer elements, either N or P or K for plant growth, e.g., urea. Complex fertilizers supply more than one fertilizer elements needed for crop growth. When they supply any of the two of the fertilizer elements needed for plant growth, they are called incomplete fertilizer, e.g. Mono-ammonium phosphate (11.0% N and 48.0% P_20_5) and Diammonium phosphate (21% N and 52% P_20_5). When they supply all the three fertilizer elements for crop growth, they are called complete complex fertilizer, e.g., Nitrophosphate (15% N, 15% P_20_5 and 15% K_2O).

5. Mixed fertilizers:

A mixed fertilizer means a mixture of more straight fertilizers, e.g., ammonium sulphate and single super phosphate may be thoroughly mixed to get a mixed fertilizer.

Advantages of mixed fertilizer

- Two or more fertilizer elements are added together to make a mixed fertilizer to be applied m the field. Less labour is, therefore, required for application of a mixed fertilizer.
- Fertilizer elements can be more uniformly applied to the field especially when they are required in small quantities.
- Mixed fertilizer can easily be drilled because of good physical condition.

Disadvantages of mixed fertilizer:

- The use of mixed fertilizer does not permit the use of single nutrient which may be required by the crop at a certain stage.
- The illiterate farmers cannot effectively control the quantity of plant food nutrients present in the mixture.

Types of mixed fertilizers:

Mixed fertilizers are of two types(i) Open formula mixture and (ii) Close formula mixture

In open formula mixed fertilizer, manufacturer discloses the name and quantities of the straight fertilizers that are constituents of the mixed fertilizer whereas in close formula mixed fertilizer, firm does not disclose the constituents of the fertilizer.

Sulphur containing fertilizers

These are the chemical substances containing the nutrient 'S' in the nutrient form of absorbable sulphate anions $S04^{-2}$ .The important 'S' containing water soluble fertilizers are Ammonium sulphate (24% S), Potassium sulphate (18% S), Ammonium sulphate Nitrate (15%S) and Super phosphate (12%S).

Micronutrient fertilizers:

Iron fertilizers: These are generally water soluble substances predominantly sprayed as foliar nutrients on the crops. Plants absorb iron in the form of Fe^{-2}. Commonly used iron fertilizers are Ferrous sulphate ($FeS0_4$. $7H_20$) contains 20% Fe (water soluble).

Manganese fertilizers: Manganese sulphate ($MnS0_4$. $4H_20$.) is pink salt containing 24% Mn, suitable for foliar application.

Zinc fertilizers: Zinc sulphate ($ZnS0_4$ $7H_20$) is water soluble salt whitish in colour containing 23% Zn. It can be applied as foliar or in soil.

Boron fertilizers: Borax (Na_2B0_4. $10H_2O$) is water soluble white salt which can be applied as soil dressing/foliar spray. It contains 11% boron.

Other micronutrients like copper and molybdenum are supplied through copper sulphate and sodium molybdate, respectively.

Table 1. Composition of common inorganic manures.

Fertilizer	Composition (%)			
	N	P_2O_5	K_2O	Miscellaneous
Anhydrous ammonia	82			
Ammonium sulphate	20.6			
Calcium ammonium nitrate	25			
Urea	46			
Single superphosphate	-	16		12 S
Diammonium phosphate	16 and 18	48 and 46		
Rock-phosphate		20-40		
Muriate of Potash			60	
Ferrous sulphate				19 Fe
Borax				11 B
Boric acid				17 B
Manganese sulphate				26 Mn
Basic zinc sulphate				55 Zn
Copper sulphate				21 Cu

Organic manures: These are plant and animal wastes that are used as nutrients after decomposition. Plants are directly or indirectly the source of recyclable materials. They provide various types of crop residues. When crushed, seeds of oil crops leave behind oil cakes. Biomass of several uncultivated plants is also recyclable. Human and animal wastes are largely the residues of plant products ingested either by humans or by domesticated animals. Organic manures and leguminous green manures are most valuable from crop nutrition point of view, whereas farmyard manure, crop residues and composts are most important from utilization and organic recycling point of view. Organic resources reduce the mining of soil nutrients and improve soil productivity, by improving soil tilth, aeration, water-holding capacity and activity of microorganisms. Organic manures are classified into bulky organic manures and concentrated organic manures depending on the nutrient content in them. Nutrient content of commonly used organic manures have been given in Table 2.

Bulky organic manures

Farmyard manure: The decomposed mixture of dung and urine of farm animals along with litter and left over materials from roughages or fodder fed to cattle is farmyard manure.

Quality of farmyard manure can be improved by concentrated feeds given to the cattle. Cotton seed, cotton seed cake, linseed meal, wheat bran, grain husk, ground nut cake etc. are rich in N, P, Mg, and S.

Compost: Composting is a process in which both aerobic and anaerobic micro-organisms decompose organic matter under medium to high temperature and low carbon-nitrogen ratio of refuse. Farm compost is mass of rotted organic matter made from farm waste like sugarcane trash, paddy straw, weeds and other plants, while town compost is mass of rotted organic matter made from town refuses like night soil, street sweepings and dustbin refuse.

Sewage and sludge: In modern system of sanitation adopted in cities, water is used for removal of human excreta and other wastes, called as sewage. Solid portion is sludge while the liquid portion is sewage water. Both sludge and sewage water are separated and given preliminary fermentation and oxidation treatments to reduce bacterial contamination and offensive smell and also to narrow down the C: N ratio.

Vermi-compost: It is the compost prepared with the help of earthworms. Earthworms consume large quantities of organic matter, excrete soil as casts which have several plant growth promoters, enzymes rich in plant nutrients, beneficial bacteria and mycorrhizae. Vermicompost is a rich mixture of major and minor plant nutrients. It increases total microbial population of nitrogen fixing bacteria, actinomycetes and symbiotic association of mycorrhiza on plant root system. Earthworm casts harbour a large number of vesicular arbuscularmycorrhizal (VAM) propagules which survive for about 11 months. Increased microbial activity improves soil phosphorus and nitrogen availability. It also improves by using residues as surface mulches.

Concentrated organic manures

Oil cakes: Oil cakes can be grouped into edible oil cakes which are suitable for cattle feeding and non-edible oil cakes which are unfit for cattle consumption.

Blood meal: An adult cattle gives about 13.6kg blood meal and goat or sheep about 1.36kg. It is effective for all horticultural crops and all types of soils.

Meat meal: The meat is converted into meat meal. It is quick acting and suitable for all types of horticultural crops and soils.

Fish meal: Non-edible fish carcasses and fish offal are used to prepare fish meal. These are crushed and powdered before use.

Table 2. Nutrient content of organic manures

Organic manures	N (%)	P_2O_5 (%)	K_2O (%)
Poultry manure	3.03	0.63	1.40
Farmyard manure	0.75	0.20	0.50
Vermi-compost	3.00	1.00	1.50
Neem cake	5.22	1.08	1.48

Bio-fertilizers

These are inputs containing micro-organisms capable of mobilizing nutritive elements from non-usable form to usable form through biological processes. They are less expensive, eco-friendly and sustainable and do not require non-renewable source of energy during their production. They improve plant growth and fruit quality by producing plant hormones. They increase the sustainability of soil and make it more productive. They are also useful as bio-control agents since they control many plant pathogens and harmful microorganisms. Some of the beneficial microorganisms are capable of fixing atmospheric nitrogen, while some can increase the availability of N and P. Different bio-fertilizers available for use for horticultural crops are given in Table 3.

Table 3. Biofertilizers commonly used for horticultural crops

Biofertilizer	Organisms	Fixed nutrient
Saprophytes	Aspergillus,Trichoderma	Decomposes organic matter at a faster rate
Legume inoculants	Rhizobium species	Fixes atmospheric N in association with leguminous crops
In association with plants	Azospirillum	High N fixation capacity
Free-living organism	Azotobacter	Fixes N in neutral to alkaline soils
Phosphorus solubilizers	Pseudomonas striata, Bacilluspolymixa, Aspergillusawamoriand Pencilliumdigitatum	P
Endotrophic mycorrhizae (VAM)	Glomus, Gigaspore,	Higher N, P, K, Ca and Mg

Integrated nutrient management

It is the use of chemical fertilizers, organic manures, slow-releasing fertilizers, nitrification inhibitors, vesicular-arbuscular mycorrhizae and nutrient efficient rootstocks either singly or in combination, all at a time in a definite sequence during the growth developmental stages of plant for economic and efficient use of nutrients without having any adverse effects on soil health and environment.

Principles of fertilizer application

The basic principle of fertilizer application is to make the nutrients readily available to the plants as per their requirement without much wastage and harmful effects on soil. Usually larger quantities of fertilizers are added to clayey soils at longer intervals than to sandy soils because clayey soils are richer in humus than sandy soils and both clay and humus have a high capacity to retain nutrient ions by a phenomenon called Base Exchange. These adsorbed nutrient ions are not lost by leaching, can be gradually taken up by the plant roots. If a heavy dose of water soluble fertilizer is applied to sandy soils, most of it will be leached down by high rainfall in the humid regions.

Difference between manures and fertilizers

Sl. No.	Characteristics	Manures	Fertilizers
1.	Origin	Plant, animal, human residue	Chemically manufactured
2.	Type	Natural product	Artificial product
3.	Nutrient content	Low / less concentrated	High / more concentrated
4.	Availability of nutrient	Slow releasing	May or may not be readily available
5.	Effect on soil health	Improves physical property of soil	Do not improves physical property of soil

Quantities of fertilizers to be applied

Different crops require different quantities of nutrients. Fertilizer dose is calculated on the basis of requirement of plants for its various physiological activities. While applying fertilizers, nutritional status of soil is taken into account. After deducting contribution of soil, rest amount is replenished externally by the application of fertilizers.

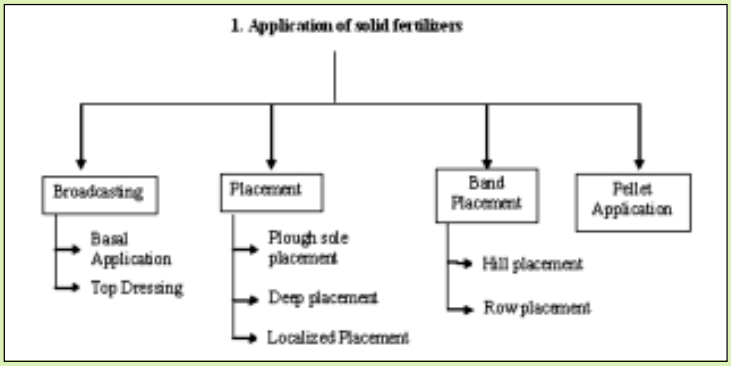
Time of application of fertilizers

Generally, the manures are applied in the field before the onset of monsoon. With the appearance of rain, the manures are decomposed well and their nutrients become readily available

to plants. The fertilizers are applied at the time of active growth of plants so that the nutrients may be absorbed by the roots. Generally, the plants remain active during February- March and July and new growth emerges on the plant. During these times, fertilizers must be applied. In case of bearing plants, the manures and fertilizers are applied to cope with nutritional requirement. Under such circumstances, the manures and fertilizers must be applied one month before the commencement of flowering in plants. Phosphatic fertilizers being less soluble should be applied about 20 days before the commencement of new growth. Nitrogenous fertilizers being highly soluble and hence prone to leaching losses should be applied in split doses. Half of the recommended dose of nitrogen should be given before commencement of flowering and rest half dose is given after fruit set. This holds true especially in case of fruits. In case of vegetables, the recommended doses of fertilizers are applied at the time of sowing, transplanting and also during growing. Nitrogenous fertilizers are given in splits to support production.

Methods of application

For maximized efficiency, fertilizer should be applied in root zones of the plants. The methods by which fertilizers can be applied are discussed as under:



1. Broadcasting: It refers to spreading fertilizers uniformly all over the field. Suitable for crops with dense stand, the plant roots permeate the whole volume of the soil, large doses of fertilizers are applied and insoluble phosphatic fertilizers such as rock phosphate are used. Broadcasting of fertilizers is of two types.

(i) Broadcasting at sowing or planting (Basal application): The main objectives of broadcasting the fertilizers at sowing time are to uniformly distribute the fertilizer over the entire field and to mix it with soil.

Advantages: Fast and economical.

Disadvantages: High nutrient losses, low uniformity. P efficiency is only 1/3 to 1/4 that of banding

(ii) **Top dressing:** It is the broadcasting of fertilizers particularly nitrogenous fertilizers in closely sown crops like paddy and wheat, with the objective of supplying nitrogen in readily available form to growing plants.

Disadvantages of broadcasting

The main disadvantages of application of fertilizers through broadcasting are:

i) Nutrients cannot be fully utilized by plant roots as they move laterally over long distances.

ii) The weed growth is stimulated all over the field.

iii) Nutrients are fixed in the soil as they come in contact with a large mass of soil.

2. Placement: It refers to the placement of fertilizers in soil at a specific place with or without reference to the position of the seed. Placement of fertilizers is normally recommended when the quantity of fertilizers to apply is small, development of the root system is poor, soil has a low level of fertility and to apply phosphatic and potassic fertilizers. The most common methods of placement are as follows:

(i) **Plough sole placement:** In this method, fertilizer is placed at the bottom of the plough furrow in a continuous band during the process of ploughing. Every band is covered as the next furrow is turned. This method is suitable for areas where soil becomes quite dry upto few cm below the soil surface and soils having a heavy clay pan just below the plough sole layer.

(ii) **Deep placement:** It is the placement of ammonical nitrogenous fertilizers in the reduction zone of soil particularly in paddy fields, where ammoniacal nitrogen remains available to the crop. This method ensures better distribution of fertilizer in the root zone soil and prevents loss of nutrients by run-off.

(iii) **Localized placement:** It refers to the application of fertilizers into the soil close to the seed or plant in order to supply the nutrients in adequate amounts to the roots of growing plants. The common methods to place fertilizers close to the seed or plant are as follows:

(a) **Drilling:** In this method, the fertilizer is applied at the time of sowing by means of a seed-cum-fertilizer drill. This places fertilizer and the seed in the same row but at different depths. Although this method has been found suitable for the application of phosphatic and potassic fertilizers in cereal crops, but sometimes

germination of seeds and young plants may get damaged due to higher concentration of soluble salts.

(b) Side dressing: It refers to the spread of fertilizer in between the rows and around the plants. The common methods of side-dressing are:

(i) Placement of nitrogenous fertilizers by hand in between the rows of crops like maize, sugarcane, cotton etc., to apply additional doses of nitrogen to the growing crops and

(ii) Placement of fertilizers around the trees like mango, apple, grapes, papaya etc.

3. Band placement: If refers to the placement of fertilizer in bands. Band placement is of two types.

(i) Hill placement: It is practiced for the application of fertilizers in orchards. In this method, fertilizers are placed close to the plant in bands on one or both sides of the plant. The length and depth of the band varies with the nature of the crop.

(ii) Row placement: When the crops like sugarcane, potato, maize, cereals etc., are sown close together in rows, the fertilizer is applied in continuous bands on one or both sides of the row, which is known as row placement.

Row placement

4. Pellet application: It refers to the placement of nitrogenous fertilizer in the form of pellets 2.5 to 5 cm deep between the rows of the paddy crop. The fertilizer is mixed with the soil in the ratio of 1:10 and made small pellets of convenient size to deposit in the mud of paddy fields.

Seed cum fertilizer drill is an implement used to sow the seed in rows as well as to apply the fertilizers at the same time

Advantages of placement of fertilizers

The main advantages are as follows:

(i) When the fertilizer is placed, there is minimum contact between the soil and the fertilizer, and thus fixation of nutrients is greatly reduced.

(ii) The weeds all over the field can not make use of the fertilizers.

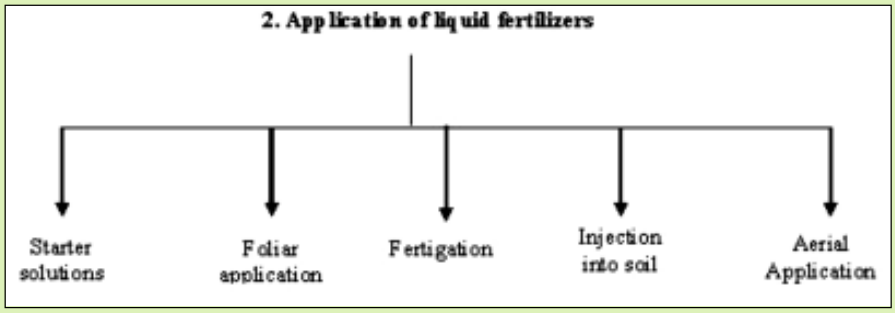
(iii) Residual response of fertilizers is usually higher.

(iv) Utilization of fertilizers by the plants is higher.

(v) Loss of nitrogen by leaching is reduced.

(vi) Being immobile, phosphates are better utilized when placed.

The common methods of applying liquid fertilizers are as follows:



1. Starter solutions

It refers to the application of solution of N, P_2O_5 and K_2O in the ratio of 1:2:1 and 1:1:2 to young plants at the time of transplanting, particularly for vegetables. Starter solution helps in rapid establishment and quick growth of seedlings. The disadvantages of starter solutions are:

(i) Extra labour is required, and

(ii) the fixation of phosphate is higher.

Can any chemical fertilizer be sprayed on crops?

- Only those fertilizers that do not scorch (burn) leaves are sprayed.
- Usually micronutrients, which are required in low rates, are foliar sprayed.
- Urea sprays are used for supplying nitrogen

2. Foliar application:

It refers to the spraying of fertilizer solutions containing one or more nutrients on the foliage of growing plants. Several nutrient elements are readily absorbed by leaves when they are dissolved in water and sprayed on them. The concentration of the spray solution has to be controlled; otherwise serious damage may result due to scorching of the leaves. Foliar application is effective for the application of minor nutrients like iron, copper, boron, zinc and manganese. Sometimes insecticides are also applied along with fertilizers.

3. Application through irrigation water (Fertigation): It refers to the application of water soluble fertilizers through irrigation water. The nutrients are thus carried into the soil in solution.

4. Injection into soil: Liquid fertilizers for injection into the soil may be of either pressure or non-pressure types.Non-pressure solutions may be applied either on the surface or in furrows without appreciable loss of plant nutrients under most conditions.Anhydrous ammonia must be placed in narrow furrows at a depth of 12-15 cm and covered immediately to prevent loss of ammonia.

5. Aerial application: In areas where ground application is not practicable, the fertilizer solutions are applied by aircraft particularly in hilly areas, in forest lands, in grass lands or in sugarcane fields etc.

Precautions in fertilizer use

- It is better to get the soil tested from soil-testing laboratory. The amount of fertilizer(s) should be calculated based on soil test for balanced use of nutrients.
- Secondary nutrients like sulphur should be used either alone or through sulphur bearing fertilizers. In acid soils, calcium and magnesium should be maintained at the optimum level.
- Micronutrient should be applied whenever necessary. In acidic soils boron and molybdenum, and in alkaline soils, iron, zinc and manganese should be made available. Phosphate rich calcareous soils may show zinc deficiency problems.
- Fertilizers should be selected on the basis of soil characteristic. Avoid acid fertilizers in acid soils and basic fertilizers in alkaline soils.
- Improve soil structure through the addition of organic manure and gypsum. Black and alluvial soils should be deep ploughed.
- Use of high yielding varieties, irrigation at an appropriate time and amounts, removal of weeds, spacing and plant population etc. should be given due consideration.

ACTIVITY/EXERCISE

1. Know the manures and fertilizers available and being used in your area by visiting co-operative society and prepare a list of the same mentioning contents of particular nutrient present in them.
2. Apply the available manure and fertilizers in your kitchen garden/farm/orchard by employing a particular suitable method of fertilizer application and record observations in respect of growth and fruiting of the crops being grown.

CHECK YOUR PROGRESS

1) What do you mean by organic and inorganic manures? List five inorganic manures along with their nutrient content.

2) Write the various types of concentrated organic manures.

3) What is vermi-compost? How does it differ from farm yard manure?

4) What is the principle of fertilizer application? Enlist the different methods of fertilizer application.

5) When is broadcasting of fertilizers practiced?What are the drawbacks with broadcast application?

6) What are the different methods of placing the fertilizers? When is placement of fertilizers practiced?

7) What are the advantages of band placement?

8) What is foliar application of fertilizers?

FILL IN THE BLANKS

1. Usually larger quantities of fertilizers are added to…….soils at longer intervals than to sandy soils.

2. Use of ……..inhibitors can also be an approach for increasing the nitrogen-use efficiency

3. Vermi-compost is prepared with the help of……

4. The application of water soluble fertilizers through irrigation water is known as……

5. The fertilizers are applied at the time of……growth of plants

6. The manures and fertilizers must be applied one month before the commencement of …….. in plants.

7. Nitrogen content present in Calcium ammonium nitrate is……percent.

8. The application of water soluble fertilizers through irrigation water is referred to as ……

9. Foliar application is effective for the application of ……nutrients.

10. The application of fertilizers in orchards is done through……..method.

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CHAPTER 7

Water Management in Horticultural Crops

OBJECTIVES

After studying this chapter, students will be able to:

- Learn about water management and various methods of irrigation including micro irrigation techniques
- Select the suitable irrigation system for different horticultural crops.
- Manage the horticultural crops by making efficient uses of available water resources.
- Decide on the most appropriate irrigation system for a given situation.

INTRODUCTION

Horticultural crops require significant amounts of water due to their perishable nature. In fruit trees, water stress not only affects the current season's crop, but future crops as well due to their perennial nature. Since water is such a critical component of the growth and development of horticultural crops, it is recommended that none of these crops be established without assured irrigation facilities. Water requirement of a plant depends on its growth habit and life period. Plants differ greatly in their water requirements. Now, certain questions may arise in your mind. Is there a choice to practice particular method of irrigation? What is the most economic method of irrigation? This chapter will cover the basic information regarding various irrigation systems used in horticultural crops.

Water Requirement:

Water requirement of a crop is the quantity of water needed for normal growth, development and yield and may be supplied by precipitation or by irrigation or by both. Water is needed mainly to meet the demands of evaporation (E), transpiration (T) and metabolic needs of the plants. The water requirement of any crop is dependent upon the following factors:

- Crop factors like variety, growth stage, duration, plant population and growing season.
- Soil factors like texture, structure, depth and topography.
- Climatic factors like temperature, relative humidity and wind velocity.
- Crop management practices like tillage, fertilization, weeding etc.

Irrigation Systems:

Irrigation may be defined as artificial supply of water to support plant growth and production in the absence of adequate supply of water through rainfall. Water is the main constituent of plants. It performs the following important functions in plants:

- Water is essential for the germination of seeds and growth of plants.
- During the process of photosynthesis, plants synthesize carbohydrates from carbon dioxide and water. Therefore, water is one of the essential components for the plant.
- Water acts as a solvent for fertilizers and other minerals, which are taken up by the plant roots in the form of solution. Thus, water serves as the medium in which plants absorb soluble nutrients from the soil.
- Water serves as medium for transport of chemicals to and from cells.
- Water pressure in plant cells provides the firmness to the plants.

Irrigation is very important in horticultural crops as sufficient moisture must be maintained in the soil for obtaining the optimum yield of quality fruits. The aim of irrigating the crops should be to wet the entire root zone without allowing any wastage of water beyond the root zone. The irrigation system has to be properly devised so that the water requirements of the crops are met at the minimum expenditure without any wastage of water. Various types of irrigation techniques differ in how the water obtained from the source is distributed within the field. In general, the goal is to supply the entire field uniformly with water, so that each plant has the amount of water it needs, neither too much nor too little.

Many factors determine the suitability of irrigation system for a particular crop. Several methods are employed for the irrigation of horticultural crops depending on the type of crops grown whether fruit plants or vegetables or flowers or plantation crops, age of the tree, the soil topography and the availability of irrigation water. Thus the system of irrigation must be decided in relation to the varying field conditions. Choose the correct system for a particular crop and situation.

Irrigation is generally applied to horticultural crops by flooding on the field surface (Surface irrigation), applying beneath the soil surface (sub surface irrigation), spraying under pressure (sprinkler irrigation) or by applying in drops in the crop root zone (Drip irrigation). Several water application methods are practiced to suit different soil types, the topography of the land, crops to be irrigated and costs. Different systems of irrigation commonly adopted in horticultural crops are as follows:

A. Surface irrigation: In this method, water is applied to the crop by flooding it on the soil surface. In this system whole of the area is irrigated through one head i.e. without sub-division of the unit area into small plots. Irrigation water used in this case is excessive as the entire field is to be wetted to meet the need of the excessive root system. It provides fully saturation of root zone. In this system, the wastage of water is more and this also leads to excessive weed growth. This method is simple in layout and operation. More than 90 % of irrigated area in India is under surface irrigation. This method may be classified as border, furrow and basin.

1. **Border method:** In this method, border are formed by making number of strips which are separated by ridges. An irrigation channel runs along the upper end of the borders.

2. **Furrow system:** This system is suitable in areas where the orchards are planted in sloppy land. In this system the water moves slowly in furrows in the area between tree rows. The trees are fed through the lateral movement of water. The consumption of water is less in this system and there is no risk of bark diseases. Saturation of root zone is comparatively less. Intercropping or green manuring is not possible in furrow system. This system is suitable for old orchard.

3. **Basin system:** In this method, a small circular basin is provided around the tree trunk. These basins are linked directly with one another through straight channel. There is less wastage of water and it checks weed growth. Water passing through the channel touches the tree trunk directly and hence risk of bark diseases is involved. The water flow also draws away the manure from the tree basins and deposits it at the end of the channel. This system is suitable for young fruit plants below 1- 2 years of age. This system is useful for loamy soils.

4. **Modified basin system:** This system is an improvement over the basin system. In this system, main channel runs in between the tree lines and the basins are linked with it independently through small sub-channels. The only drawback of this system is that this needs more attention to block the sub channels after the basin has received adequate water. The size of the basin is increased with the extension of the leaf drip of each tree every year. Intercropping is not possible in this system. This is a good system of irrigation for the young orchard upto 6-8 years of age and also for the arid- irrigated areas where there is a shortage of water.

In improved modified basin system, the basins are linked with the channel passing through along the side of these basins. This system avoids the risk of bark diseases and intercropping is possible.

B. Sub-surface irrigation: In this system, perforated or porous pipes are laid out underground below the root zone and water is led into the pipes by suitable means. In either case, the idea is to raise the water by capillary movement.

C. Sprinkler system: This system is used where water supply is not adequate. The water is pumped with pressure through the sprinklers attached to pipes and these sprinklers are adjusted in such a manner to overlap upto one fourth area covered by the other sprinklers. These are then moved to the next point after sufficient percolation hastaken place. This system is very costly and is suitable in areas where the sub surface water is not fit and the soil is uneven or sloppy and the water supply is not regular from the canals. There is considerable saving in water used through sprinkler irrigation than surface irrigation. The initial, operational and maintenance costs are high. It is suitable for the full grown orchards and vegetable crops.

D. Drip system: This is system of irrigation which supplies water to the plant equivalent to its consumptive use. This is highly water use efficient system of irrigation. The water is supplied with pressure after filtering it through the pipes with attached drippers designed to supply water in drops. These drippers are placed around the plant in a circular pattern and the percolating water moves down and side ways wetting the root zone. This system requires regular water supply. Advantages of drip irrigation system are:

- Wastage of water through percolation, seepage and evaporation is checked as the water is carried through main lines and laterals. There is 30-70% saving of water.
- Uniform distribution of water
- The labour requirement is minimized considerably.
- Easily adaptable in hilly and undulating lands
- Reduced weed problem.
- Lower quality water of water can be used.
- Increased plant growth and yield.
- Ideal for poor soils and provides better root system to the trees.
- Works at low pressure
- Can irrigate at any time of the day.

- Causes no erosion
- Application of fertilizer can be done.
- Less incidence of diseases

Disadvantages:

- Clogging of drippers due to oxidants and algae
- High initial investment

Fertigation: It is the application of fertilizer or chemicals through the irrigation system. It is a controlled system to supply soluble plant nutrients at the root zone of the irrigated crops. Fertigation is done through tank, ventury or pump systems. The most practical method of applying of fertilizers through the irrigation system is by creating a 10% bypass flow of the main line flow, through an artificial fertilizer mixing tank.

Advantages of fertigation:

1. An opportunity for placement of fertilizer at the vicinity of root zone of the crop along with irrigation water which increases in water and fertilizer use efficiency.
2. Deeper penetration into the soil.
3. Avoids is volatilization from soil surface.
4. Easy coordination with specific crop demand.
5. Decrease in labour and energy cost in fertilizer application by making use of waterdistribution system.
6. Improves the availability of nutrients and their uptake by roots.
7. Trace elements can also be applied along with major nutrients.
8. Saving of fertilizers.

Fertigation Tank Fertilizer injector

Limitations of fertigation:

1. Possibility of clogging emitters if the pH of irrigation water and fertilizer sources is not managed carefully.
2. May result in possible contamination of the drinking water supply if devices are not usedto prevent back flow of nutrients into the well or other water sources.
3. Some of the chemicals are quite corrosive to metal and also cause skin burning is safety devices are not provided to protect the workers against unplanned discharge or spilling of chemicals.

Irrigation Scheduling:

When to irrigate and how much to irrigate, form the schedule of irrigation. In order to avoid water stress in plants and to obtain good yields of quality fruits, proper irrigation schedule should be followed. Scheduling of irrigation in plants is governed by soil, climatic and plant factors. Some practical approaches used to determine schedule of irrigation are soil moisture depletion, cumulative pan evaporation and sensational etc.

Critical Period for Irrigation:

Assured supply of water is required at certain stages of plant growth, which are referred to as critical period for crops. If water is not available at critical stages, yield is greatly reduced. For herbaceous crops, germination is critical stage. Depending upon the crop, critical stages vary such as head development for cole crops, pod development for beans, tuberizationfro potato, bulb development for onion and garlic, flower development for flower crops, fruit setting and development for fruit crops.

ACTIVITY/EXERCISE

1. Visit any orchard/vegetable farm of your locality and find out, which system of irrigation is practiced, predominantly.
2. Prepare a plan for model unit of drip irrigation system along with fertigation unit for one hectare farm area.

CHECK YOUR PROGRESS

1) Define irrigation? Write the important functions of water in plants.
2) Enlist the various systems of irrigation. Discuss the most useful system suitable for areas with water scarcity.
3) Differentiate between flood and furrow systems of irrigation?

FILL IN THE BLANKS

1. Water requirement of a plant depends on its……..and ……..
2. Water serves as the medium in which plants absorb……..from the soil.
3. In ……..system of irrigation, the wastage of water is more and this also leads to excessive weed growth.
4. …….system of irrigation is suitable for young fruit plants below 1- 2 years of age.
5. Application of liquid fertilizer to the root system is possible through…….. system of irrigation

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CHAPTER 8

Weed Management in Horticultural Crops

OBJECTIVES

After studying this chapter, students will be able to:

- Understand the principles of weed management and classification of weeds.
- Describe the different weed control methods.
- Select the suitable method of weed management for different horticultural crops.
- Plan various cultural practices for weed management in different crops.
- Decide on the most appropriate weed management system for a given situation.

INTRODUCTION

Weeds are the most costly category of horticultural pests, causing more yield losses and added labor costs than either insect pests or crop diseases. In particular, weeds are a constant fact of life in annual row crops, vegetables, and other horticultural crops.

Now certain questions may be arising in your mind. What is weed? How will we identify the weeds? What will happen if weeds are allowed to grow? How can we control weeds? You can face several questions of this category.

Horticultural crops are high value crops and the challenge of weed management is one of the important factors to successfully grow them. Weeds compete with crops for light, nutrients and water, resulting in stressed plants, poor fruit quality and yield. Stressed crops are also more susceptible to disease and insect problems, while excessive weed growth itself creates higher humidity in the foliage enhancing disease spread and inviting unwanted insects.

In fruit crops, weed pressure must be addressed throughout the life of the planting. When compared to annual crops, perennial culture is a greater challenge, as fall, spring, summer and winter weeds need to be managed efficiently. Understanding seasonal weed thresholds and integrating cultural and chemical management becomes even more important in year-round culture. However, because of different cultural requirements, each crop should be considered individually. In this chapter, we will study about weeds, their characteristics and harmful effects, classification of weeds and various methods of weed control.

In India, commercial use of herbicides came in 1980. During the period, the herbicides registered a significant growth than insecticides and fungicides. From a mere 2 per cent share of

the totalpesticide consumption in the seventies in India, herbicides now account for about 11 per cent ofthe pesticides market. While this is a very encouraging development, the herbicide consumptionin our country is still much less than that in developed countries, where herbicides constitute 40-50 per cent of the total pesticide consumption.

WHAT IS WEED?

Weeds are unwanted and undesirable plants which interfere with the utilization of land and water resources and thus adversely affect human welfare. They can also be referred as plants out of place.

Weeds compete with the beneficial and desired vegetation in crop lands, forests, aquatic systems etc. and pose great problem in non-cropped areas like industrial sites, road/rail lines, air fields, landscape plantings, water tanks and water ways etc.,

In the world there are 30,000 weed species, out of these 18,000 sps cause damage to the crops. JethroTullfirst coined the term weed in 1931 in the book "Horse Hoeing Husbandry"

Characteristics of weeds

- Weeds are prolific with abundant seed production potentialities e.g. *Chenopodium* spp., *Amaranthus* spp., etc.
- They are persistent and resistant to their control and eradication.
- Weed seeds remain dormant and viable for very long periods e.g. *Chenopodium* spp.
- Some weeds have very deep root system. They store foods in their rhizomes and reappear every year e.g. *Saccharum* spp., *Cyperus* spp.
- Weeds are hardy and can resist any adverse climatic, disease and soil conditions. They result ina severe crop-weed competition.
- Some of the weeds propagate vegetatively e.g. *Cynodon dactylon*.
- Some weed seeds are similar to crop seeds, therefore their separation becomes difficult.

Harmful effects of weeds

- Weeds compete with crop plants for water, space, light and mineral nutrients.
- Weeds reduce the quantity and quality of farm produce.
- Weeds impair the quantity and quality of animal products e g. thorny weeds with hooks entangle with wool of sheep which graze in pastures.

- Weeds harbour insect pests and diseases thus they act as reservoir of infection for cultivated crop plants.
- Weeds increase cost of labour and equipments which ultimately increase the cost of cultivation of crops.
- Weeds reduce the efficiency of farm equipments.
- Presence of some weeds like Saccharum spp. causes depreciation of land value.
- Some weeds are poisonous and cause health hazards to human beings and animals, for example, Parthanium spp.

Aquatic weeds are very harmful because:

- They impede water flow in canal, channels, rivers, etc.
- They impede drainage
- They are menace to fisheries and other aquatic animals.
- They prevent or spoil the recreational value of the water bodies.
- They pose pollution problem in water.

CLASSIFICATION OF WEEDS

Weeds may be classified in many ways. Some of the classifications are mentioned below:

A. Classification according to life cycle

- Annual weeds (a) Kharif (rainy season) weeds (b) Rabi (winter season) weeds
- Biennial weeds
- Perennial weeds

I. Annual weeds

Kharif annuals: These annuals generally appear with the onset of monsoon and the life cycle is completed within the rainy season. Few examples are : *Echinochloa colonum, Echinochloa crusgalli, Setaria glauca, Digitaria sanguinalis*, etc.

***Rabi* annuals:** These annuals start growing up with lowering of temperature in winter and coincide with the life cycle of the rabi crops. These weeds complete their life cycle before the summer season starts. Examples are *Phalaris minor, Avena fatua, Chenopodium album, Aesphodelus tenuifolius*, etc.

In addition to these annuals, there are few plants which complete their life cycle in 2 to 4 weeks. Such annuals are known as short lived annuals e.g. *Phyllanthus niruri* (Hazardana)

II. Biennial weeds

The weeds which complete their life cycle in two years are called biennials. In first year they complete their vegetative growth and store food while in the second year their reproductive growth or seed formation is completed followed by the death of the plant e.g. *Daucus* spp.

III Perennials weeds

These are the weeds which complete their life cycle within 3 or more than 3 years. They are capable of growing/propagating by means of seeds, through under groundstolons, roots andsuckers *e.g. Cynodon dactylon, Saccharum spontaneum*, etc.

B. Classification according to plant family

Graminae: *Cynodon dactylon, Saccharum spontaneum, Echinochloa crusgalli, Phalaris minor, Avena fatua ,etc.*

Solanaceae: *Solarium nigrum, Solanum xanthocarpum, etc.*

Eupkorbiaceae: *Euphorbia hirta, Phyllanthus niruri, etc.*

Liliaceae: *Aesphodelus tenuifolius*

Chenopodiaceae: *Chenopodium album*

Convolvulaceae: *Convolvulus arvensis, Ipomoea spp.*

C. Classification according to cotyledon characteristics

With the discovery of 2,4-D as selective translocated herbicide in 1940's, led to a strong recognition of two great classes, namely, the monocot and the dicot weeds. In general, monocot weeds were found to be resistant to 2,4-Dwhile dicot weeds were susceptible to it. The dicot weeds are often referred to as *broad leaf weeds* and monocot weeds as *narrow leaf or grassy weeds*. The exception to this are *sedges* and cattails which although have narrow leaf yet are not grassy weeds.

Grasses	Sedges
Stem is hollow except at nodes	Stem Angular & solid
Ligulate	Does not posses ligules
Alternate or opposite leaves	Leaves in whorls around the stem
Eg, Digitaria, Cynadon	Cyprus, Scirpus

Character	Monocots	Dicotds
Leaves	Narrow and upright	Broad & horizontal
Venation	Parallel	Reticulate
Retention of herbicide	Less	More
root system	Adventitious	Tap root
Growing point	Open	Open
Cambium (conductive tissue)	Scatered	Intact
Examples	Grasses or Narrow leaved weeds	*Amaranthus spp., Chenopodium album, Convolvulus arvensis, Phyllanthusniruri, Partheniumhysterophorus, Xanthium strumarium*

D. Classification according to habitat

Depending upon the place of their occurrence, weeds can be classified as:

- Crop land weeds
- Fallow land weeds
- Grassland, pasture or rangeland weeds
- Non-cropped land weeds
- Aquatic weeds
- Forest and woodland weeds
- Lawn and garden weeds
- Orchard and vineyard weeds, and
- Plantation weeds.

This classification is important because for each situation different weeds control measures are usually employed even though the target weed species may be the same.

E. Classification according to their seriousness as a pest

Common weeds: Those weeds which can be controlled by ordinary good farm weed controlpractices. These are mostly annuals and biennials.

Noxious weeds: Those weeds which are difficult to control because of an extensive perennialroot system or because of other characteristics that make them persistent.

The noxious weeds are again divided into two categories:

Prohibited noxious weeds : *Circium arvensis* (Canada thistle), *Agropyron repens*

(Quack grass), *Sorghum halepense* (Johnson grass).

Restricted noxious weeds : *Cuscuta* spp. (Dodder), *Convolvulus arvensis* (Field

bindweed), *Allium vineale* (Field garlic), *Cynodon dactylon* (Bermuda grass).

List of common weeds in Horticultural crops:

Echinochloa colonum,Cyperus esculentus, Cyperus rotundus, Digitaria sanguinalis, Eleusine indica,Cynodon dactylon, Amaranthus viridis, Phyllanthus niruri

Ageratum conyzoides, Setaria glauca, Phalaris minor, Avena fatua, Poa annua

Vicia sativa, Medicago denticulate, Ageratum conyzoides, Lantana camara

Imperata cylindrical, Rosa moschata, Berberis, Rubus spp.

Cyperusrotundus

Sorghum halepense

Lantana

Convolvulus arvensis

CRITICAL PERIOD OF WEED CONTROL

This period has been defined as an interval in the life cycle of the crop when it must be kept weed - free to prevent yield loss. The crop yield level obtained by weeding during this period is almost similar to that obtained by the full seasons weed free conditions. Horticulture crops are very sensitive to weed competition, and need to be kept weed-free, from planting, emergence or bud break, until the end of their critical weed -free period. For example, the critical weed free period for bearing apple plants is bud break until 30 days after bloom while in potatoes; it is 4 weeks after planting. If the crop is kept weed-free for the critical period, generally no yield reduction would result. Again, weeds emerging after the critical weed-free period will not affect yield, but control efforts after this time may make harvest more efficient, or reduce weed problems in subsequent years in perennial crops.

WEED MANAGEMENT

Weed control and weed management are the two terms used in weed science. Weed control is the process of limiting infestation of the weed plant so that crops can be grown profitably.

Weed management includes prevention, eradication and control by regulated use, restricting invasion, suppression of growth, prevention of seed production and complete destruction. Thus

weed control is one of the aspects of weed management. The various methods of weed control employed in horticultural crops are described as under:

A. Preventive methods

Prevention of introduction and spread of the weeds in an entirely new locality is termed as preventive method. For the matter, it is essential to know that how weed disseminates. Generally, weed spread through the seeds of previous crop, irrigation water, implements and animals etc. If these are taken into account, there will be a check on the spread of the weed. By taking following measures, weed spread can be prevented from entering into a new locality:

1. Sowing of weed-free clean seed. The seeds, contaminated with weed seed, are a good source of spread of the weed. It becomes hard to separate the weed-seed from the crop-seed. For example, cruciferous crops like radish, cauliflower, cabbage, broccoli etc. are even well mixed with the seeds of satyanashi(Argemone maxicana). Such impure seeds should be discarded for use. Seed act is in force which by imposing laws, help regulates the quality of seed.

2. Use of clean implements. While operating agricultural implement like cultivator, harrow, seed drill etc. in weed infested field, care must be taken that multiplication parts of weeds like rhizome, bulb, tubers, stem etc. are not being carried along. The agricultural implements should be cleaned properly.

3. Removal of weed along canal and irrigation channel. Weed seeds get transported through water and reach the field. Removal of weed growing along the sides of canal or irrigation channel is necessary.

4. Care in transplanting of seedlings/plantlets. Many horticultural plants like all transplanted vegetables, flowers, and fruits are transplanted in the field with soil attached to their roots. Infestation of soil with weed may contaminate a new field.

5. Use of well rotten manure. Weed seeds have good viability. The seeds of hirankhuri *(Convolvulus arvensis)* remain viable for as long as 50 years. Doob *(Cynodon dactylon)* and motha *(Cyperus rotundus)* seeds viability last for two and five years respectively. For making manure, the cowdung is heaped. If the heaping period is short, the seeds do not lose its viability and grow in the field wherever manure is applied. Hence, only well-rotten manure should be used.

6. Avoiding passing of cattle from weed infested area. Grazing in weed infested field followed by allowing passage of cattle in new field, favours dissemination of weed seeds. The weed-seed after passing through alimentary canal of the animal, comes out through dung where it gives rise to weed. Some weed seeds also stick with the legs and skins of the animals and get transported to some other place where they germinate and grow as weed.

7. Crop management practices : All such practices which favour the growth of main crop only disfavour the growth of weed. The following management practices have smothering effect on weed and must find place in crop land to prevent weed spread:

- Proper crop rotation prevents establishment of weeds.
- Higher plant population per unit area smother the growth of weed.
- Proper placement of fertilizer in the root zone of the seed favours the growth of crop. The weeds deprive of nutrients and crop growth is restricted.
- Fast and vigorous growing varieties by virtue of their larger leaf canopy cause smothering effect on the growth of weed. Such crops should receive preference to prevent spread of the weed.

8. Enforcement of weed laws. In India, many noxious weeds grow in the fields and pose great economic and health hazards. Noxious weeds are those perennial weeds which are reproduced by seeds, stem, roots and other reproductive parts as well and are very difficult to *control*. *Parthenium hysterophorus, Striga* sp., *Cyperus rotundus*, *Cynodon dactylon* etc. are noxious weeds that grow in many horticultural crops. In India, no weed laws are in force except in Karnataka where Parthenium has been declared as a noxious weed. Weed laws help the farmers to avoid the use of mislabelled or contaminated seeds and also help in legally prohibiting weed from entering into the country.

9. Quarantine laws. Quarantine laws impose legal restrictions on the movement of agricultural materials. Had there been adequate quarantine laws, the *Parthenium* and *Argemone* which widely grow in vegetable and flower fields may not have been introduced in our country. Creating isolation between widely weeds infested area and new area is essential by enforcing and observing quarantine properly.

10. Use of pre-emergence herbicides. Herbicides which are used before the emergence of weeds either before or after planting of crop, is a good preventive measure for preventing weed infestation. Such herbicides either inhibit seed germination or kill young seedlings before they get established.

B. Curative methods

1. Eradication of weeds

This method implies complete destruction of weeds. Weed eradication is achieved by killing existing plants and destroying the viability of all organs of multiplication. This may be desirable and economical only when the weed is extremely noxious and persistent and makes the cultivation

difficult or precludes bringing new area under cultivation. Eradication is not possible in one season or year as some weed seeds may have viability for as long as 50 years.

The underground parts can be destroyed by tillage or with soil sterilants. A soil sterilant, however, renders the soil incapable to support plant growth for several years.

When weeds are widespread and not feasible to eliminate, control measure would be more practicable and should be given preference.

2. Control of weeds

Weed control refers to minimizing the infestation of weed so that the crop can be cultivated successfully. The various methods of controlling weeds are as under:

(a) Mechanical/Physical method

In this method, weed control is done using tillage, hoeing, hand weeding, digging, cheering, mowing, burning, flooding, mulching etc.

(i) Tillage: It removes the weed from the soil. It causes injury to root and pruning to shoot of weed. The weeds in tilled field lose their regenerative capacity. Weeds are also get buried at the time of tillage. The effectivity of tillage in controlling weed depends upon a number of factors. A field infested with deep rooted perennial grasses like thatchgrass(*Imperata cylindrica*), motha (*Cyperus rotundus*), quackgrass (*Agropyron repens*) having sufficient food reserve in their underground rhizomes and tubers, needs more cultivation with deeper ploughing than a newly infested field with annuals.

(i) Hoeing : Itis widely used weeding tool for centuries. Hoe is quite effective in controlling weed in row crop. It is very useful for annual and biennial weeds. In case of perennials, it destroys the aerial growth. The underground growth is not much affected.

(ii) Hand weeding : It is done by pulling out weeds from the field. Pulling out is done with the help of khurpi. Hand weeding is effective against annuals and biennials. The perennial weeds along with underground portion are not pulled out completely and hence they regenerate in the field. In fields which cannot be sprayed with weed controlling chemicals, can be made weed free using hand weeding.

(iii) Digging : Itis practised especially for the removal of shrubby and stubby woody *perennials. Prosopis juliflora* (Kikar), *Calotropis gigantia* (Aak or Madar), *Zizyphus nummularia* and *Z. rotundifolia* (Jharber) etc. which grow in horticultural crops in arid regions are removed by digging pit. This is ofcourse, costly and time consuming but very useful technique for the removal of very hard perennial woody weeds.

(iv) Cheering : Itis done using cheer hoe similar to a spade with long handle. It cuts and scraps the above-ground weed growth. As the underground part of the weed is left undamaged, cheering is not useful in perennial crops which are regenerated by roots, tubers, rhizome etc. Cheering is widely used in India in plantation crops, particularly in tea.

(v) Mowing : Itis practised to keep the growth of weed under check especially in lawn. The process of mowing is achieved by mower machine and hand blade havinglong cutting edge of about 1 metre. This method is successful only in case of short weeds growing close to the ground.

(vi) Burning : Itis very powerful technique of weed control in uncultivated field. It destroys aerial portion of the weed directly through flame of the fire and underground portion through the heat effect.

(vii) Mulching : It is getting popularity in controlling weed in a variety of horticultural crops. It excludes light from photosynthetic portion and. thus, inhibits the top growth of weeds. Mulching is very effective against annual crops. The mulches of straw, saw dust, paddy husk, paper, plastic etc. are common in use. The mulches should be about 10 to 15 cm thick for better efficacy.

Materials such as black polyethylene have been used for weed control in a range of crops. Plastic mulches have been developed that filter out photo synthetically active radiation, but let through infrared light to warm the soil. These infrared transmitting mulches have been shown to be effective to control weeds

(b) Cultural methods

In this method, attempt is made to control weed by practising agronomic practices. Crop and other practices done to grow the crop are modified in a manner so as to have minimum growth of weeds. The following cultural methods are practised to control weeds:

(i) Selection of crop

- Selection of crop should be such that it may grow fast leaving weed behind.
- The crop should absorb nutrients from lower as well as upper stratum of soil.
- It should have less requirement of nutrients.
- Water requirement should be minimum.
- The crop duration should be less.
- The crop should have dense canopy so that it may smother weed.

(ii) Crop rotation : Crop rotation involves alternating different crops in a systematic sequence on the same land. It is an important strategy for developing a sound long term weed control program. Weeds tend to thrive with crops of similar growth requirements as their own and cultural practices designed to contribute to the crop may also benefit the growth and development of weeds. Monoculture, that is growing the same crop in the same field year after year, results in a build-up of weed species that are adapted to the growing conditions of the crop. When diverse crops are used in a rotation, weed germination and growth cycles are disrupted by variations in cultural practices associated with each crop (tillage, planting dates, crop competition, etc).

Within a rotation, crop choice will determine both the current and the potential future weed problems that a grower will face. Traditionally, potato (*Solanum tuberosum L.*) was included in the rotation to reduce weed problems before a less competitive crop was grown. Crop choice is complicated further by the need to consider soil fertility levels within the cropping sequence and to include fertility building periods in the rotation. Variations in crop and weed responses to soil nutrient levels can also play an important part in weed management. The inclusion of a fallow period in the rotation is known to reduce perennial weeds. It is best to alternate legumes with grasses, spring planted crops with fall planted crops, row crops with close planted crops and heavy feeders with light feeders.

(iii) Use of compost or manure : Decomposition of compost or manure starts after addition in the soil. While decomposition, organic acids like uric acid is produced. Such produce prevents the growth of weed.

(iv) Allowing the land to fallow : In the fallow land the weed is deprived from moisture and nutrients. In the absence of moisture these weeds fail to grow. Now-a-days, with intensive cultivation especially in vegetables, it becomes very hard to leave the field fallow. Continuous cropping favours the growth of weed.

(v) Water management

Effective water management is a key to control weeds in horticultural crops. There are a number of ways that careful irrigation management can help you reduce weed pressure on your crops:

Pre-germination of weeds : In pre-germination irrigation or rainfall germinates weed seeds just before the cash crop is planted. The newly germinated weeds can be killed by light cultivation or flaming. Pre-germination should occur as close a possible to the date of planting to ensure that changes in weather conditions do not have an opportunity to change the spectrum of weeds (cool vs. warm season) in the field.

Planting to moisture is similar to pre-germination irrigation. After weeds are killed by cultivation, the top 2 to 3 inches of soil are allowed to dry and form dust mulch. At planting, the dust mulch is pushed away and large-seeded vegetables such as corn or beans can be planted into the zone of soil moisture. These seeds can germinate, grow, and provide partial shading of the soil surface without supplemental irrigations that would otherwise provide for an early flush of weeds.

Drip irrigation can provide moisture to the crop and minimize the amount of moisture that is available to weeds closer to the surface. If properly managed, this technique can provide significant weed control during dry period.

(vi) Sowing time : Later sown crop grows slowly and resumes less growth due to limited availability of growth period. Such types of growth allow the weed to grow vigorously leaving sufficient space and light for weed.

(vii) Orientation of sowing/transplanting : Sowing or transplanting should be done in such a manner that there may be maximum shade in the field. In shade, weeds fail to grow for want of photosynthesis.

(c) Chemical methods

In this method, chemicals are used for weed control. The chemicals employed for weed control are commonly referred to as weedicides or herbicides. Chemical weed control functions on the basis of the fact that certain chemicals are capable of killing weeds without any significant injury to the crops.

The discovery of 2, 4-D in the early 1940's has revolutionized the chemical method of weed control. ***Marth*** and ***Mitchell*** of U.S.A. in 1944 were the first workers to introduce it as a herbicide.

A large number of herbicides are now available commercially to tackle various weed problems. A herbicide may be selective or non-selective. A selective herbicide kills a particular type of weed or plant. For example, 2,4-D (selectively toxic to broadleaf weeds). A non-selective herbicide (for example, Paraquat, Glyphosate) kills the whole

- Herbicides applied anytime before the weed seedlings emerge through the soil surface are known as pre-emergence herbicides. For example, Simazine.
- Herbicides applied after the crop seedlings (or weed seedlings) have emerged through the soil surface are known as post-emergence herbicides. For example, 2,4-DB, bromoxynil.
- Herbicides that are applied before planting the crop - typically from several days to just before planting are known as pre-plant herbicides. For example, EPTC, Glyphosate

vegetation on which it is applied. Nonselective Herbicides (also known as Broad spectrum) are formulated to control both broadleaf and grass weeds. According to the type of action, herbicides may be classified as contact or translocated. The contact herbicide kills the plant parts where it comes in contact (for example, Simazine), whereas the translocated (Systemic) herbicide goes into the plant system and affects the whole plant (for example, Glyphosate). Use contact herbicides on annual weeds while systemic herbicides are more effective on perennial weeds than contact herbicides

The chemical weed control offers following advantages :

- In crop rows, where harrowing or cultivation is impossible, herbicides can be easily applied to control weeds.
- Herbicides give quick response in terms of checking the growth of weed and by that time crop gets an escape and grow.
- Hand weeding injures the root system of crop also and thus damages the crop.
- Herbicides reduce the need of preplanting tillage. In case of minimum tillage, herbicides are very much successful.
- The use of herbicides reduces the requirement of manual labour.

Control measures of weeds infesting fruit, vegetable and flower crops are given in table below:

Crop	Recommended herbicide	Dose (kg/ha)
Mango	Diuron or	2.25
	Atrazine or	4.00
	Oxyfluorfen	4.00
	Paraquat	12.00
	Glyphosate	6.00
Banana	Diuron or	2.25
	Simazine or	4.00
	Oxyfluorfen	4.00
	Paraquat or	12.00
	Glyphosate	6.00
Apple	Atrazine or	5.00
	Simazine or	5.00
	Diuron	5.00
	Paraquat	3.00

Crop	Recommended herbicide	Dose (kg/ha)
Tomato	Alachlor	3.00
	Fluchloralin	3.00
Brinjal	Fluchloralin	1.50
Onion	Fluchloralin	2.00
Potato	Metribuzin	1.00
Rose	Diuron or	1.20
	Oxyfluorfen or	1.00
	Atrazine	3.00
Gladiolus	Fluchloralin	2.00

(d) Biological methods

Reduction in infestation of weeds by direct or indirect actions of biological entities such as plants, parasites, predators and pathogens is covered under these methods.

(i) Plants as bio-agents of weed control : The differential growth habits, adaptiveness and competitiveness of the plant over weed, forms the basis of weed control by growing a particular crop. Crops which grow vigorously have an advantage over slow growing ones which are sensitive to weed. These competitive crops, also known as smothering crops, are very effective in weed control. Growing of corn and ginger either alone or in combination, has smothering effect on the growth of weed. They grow more rapidly and fill inter-row space with their canopy faster than the weed. This gives smothering effect on the weed growth.

(ii) Parasites, predators and pathogens : In this method, the natural enemies of plants like insects and disease causing organisms are used. Insects kill the weed by exhausting the plant food reserves and through destruction of photosynthetic parts.

Of the wide range of enemies, insects have been proved effective. Parasites like viruses, higher plants and fungi that develop only on live plants are also potent agents of weed control.

Lantana camera weed has been controlled successfully by the larvae of *Crocidosema lantana*- the totricid moth, which bores into flower-stem; *Agromyza lantanae*, the seed fly which eats flower and fruit and *Thecla echion* which destroys flower. *Cuscuta spp.* (dodder) which grows on old fruit plants is controlled successfully by insect *Melanagromyza cuscutae* and *Smicronyx cuscutae*. Nutgrass or Motha (*Cyperus rotundus*), grows in almost all horticultural crops is controlled by insect *Bactra vermosana*.

The larvae of insect *Diacrisia obliqua* feed voraciously on *Parthenium hysterophorus* and destroys the whole plant.

Pathogenic organisms damage the host plants through enzymatic degradation of cell constituents, production of toxins, disturbance of hormone system, obstruction in translocation of food and minerals and malfunctioning of physiological processes. As a result plants die.

The fungi *Alternaria macrospora* and *Puccinia heterospora* control anode (*Anoda cristata*), a weed of malvaceae family. The fungi cause significant reduction in plant height, seed pod per plant, seed per pod and seed per plant. Fungus *Cercospora roclmanii* is effective against water hyacinth (*Eichhornia crassipes*) a problematic aquatic weed for waternut or singhara and lotus.

ACTIVITY/EXERCISE

1. Know the weeds growing on the farms in your locality and prepare a herbarium by collecting samples of different weeds of your area.
2. Summarize the impact of common weeds growing in orchard, vegetable farm and wastelands.
3. Identify possible and potential approaches to practical weed management in predominant horticultural crops of your area.

CHECK YOUR PROGRESS

1) Define weed. What are the characteristics of weeds?
2) What is critical period of weed control? List five commonly found weeds in horticultural crops.
3) Differentiate between the followings:
   a. Annual and biennial weeds
   b. Common and noxious weeds
   c. Selective and non-selective herbicides
   d. Contact and Tran located herbicides
   e. Monocot and dicot weeds
4) Write the various methods of weed control and discuss in brief the chemical method of weed control in horticultural crops.

5) Write short notes on the following

a. Tillage

b. Crop Rotation

c. Biological method of weed control

d. Harmful effects of weeds

e. Water management to control weeds in horticultural crops.

FILL IN THE BLANKS

1. Weeds are …….. and ……..to their control and eradication.
2. The weeds which complete their life cycle within 3 or more than 3 years are known as……
3. Weeds compete with crop plants for……., …… and ……...
4. A ……..herbicide kills a particular type of weed or plant.
5. A herbicide which goes into the plant system and affects the whole plant referred to as……

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CHAPTER 9

Major Pest and Disease Management in Horticultural Crops

OBJECTIVES

After studying this unit the students will be able to:

- Explain the principle of pest management in horticultural crops.
- Explain the importance of various approaches in managing disease and pest incidence.
- Understand the importance of integrated approach of disease/pest management.

INTRODUCTION

Before we delve into the management of major pests and diseases of horticultural crops, we should be aware of what a pest is? The term "plant pest" means any living stage of organisms such as non-human animal (rodent), fungi, bacteria, virus, nematode, any infectious agent (phytoplasma) etc. which can directly or indirectly injure, cause damage to, or cause disease in any plant or plant product. Plant diseases and pests have caused severe losses to horticultural production in several ways. There are several pests and diseases, which cause small losses annually throughout the world; however, collectively constitute sizable losses to growers; besides, reducing the aesthetic values of landscape plants and home gardens.

Management of major diseases and pests

Diseases and pests can damage horticultural crops from the time seeds/saplings are planted until after the crops are harvested, and gardeners/growers who fail to follow good growing practices, which minimize damage from diseases and pests in their gardens/orchard may end up incurring significant losses. The goal of plant disease and pests management is to reduce the economic and aesthetic losses caused by plant diseases and pests.

Many strategies used in disease and pests management can be grouped under two very broad principles of action, prevention and treatment or cure. The first principle (prevention) includes management tactics applied before infection/ infestation (i.e., the plant is protected from disease/pests), the second principle (therapy or curative action) functions with any measure applied after the plant is infected/infested (i.e., the plant is treated for the disease/pest attack). An example of the first principle is enforcement of quarantines to prevent introduction of a disease/pest agent into a region where it does not occur. For instance Ooty (T.N.) has quarantine measures in operation for golden nematode of potato. Similarly, the Ladakh region of J&K had

regulations for quarantine of codling moth of apricot. This implies that potato or apricot from these areas cannot be taken to other areas so as to check the spread of these pests from such areas to other parts of the country.

The second principle is illustrated by heat or chemical treatment of vegetative material such as bulbs, corms, and woody cuttings to eliminate fungi, bacteria, nematodes or viruses, which are established within the plant material. Chemotherapy is the application of chemicals to an infested or diseased plant that stops (i.e., eradicates) the infection/infestation. For example, for elimination of grape fan leaf virus from grapes, chemical compound 'virazole' is employed. Likewise, for elimination of apple mosaic virus from shoot tip, plants are grown at 38 0C for 20 or more days.

There are four general pest management principles viz., exclusion, eradication, protection and resistance.

Exclusion

This principle is defined as any measure that prevents the introduction of a disease-causing agent (pathogen) or pests into a region, farm, or planting. The basic strategy assumes that most pests can travel only short distances without the aid of some other agent such as humans or other vector, and that natural barriers like oceans, deserts, and mountains create obstacles to their natural spread. In many cases pest are moved with their host plants or even on non-host material such as soil, packing material or shipping containers.

Exclusion may be accomplished by something as simple as cleaning farming equipment to remove contaminated debris and soil that can harbor pathogens/insect-pests such as *Verticillium*, nematodes or other soil-borne organisms and prevent their introduction into non-infested fields.

Eradication

This principle emphasises at eliminating a pathogen after it is introduced into an area but before it has become well established or widely spread. It can be applied to individual plants, seed lots, fields or regions but generally is not effective over large geographic areas. Two large attempts at pathogen eradication, in the history of pest eradication, in the United States were the golden nematode *(Globodera rostochiensis)* and the citrus canker (caused by *Xanthomonas axonopodis* pv. citri and pv. *aurantifolii*) programs.

Eradication can also be on a more modest scale such as the removal of apple or pear branches infected by the fire blight bacterium (*Erwinia amylovora*) or pruning to remove cankers (caused by *Coneothecium chomatosporus*) on apples. Or, it can be the sorting and removal of diseased

flower bulbs, corms or rhizomes. Hot water treatment of gladiolus corm 50 °C for 30 minutes before planting is followed to eliminate fungi.

Similarly, for export of fruits such as papaya, mango, mangosteen, and litchi to Japan for consumption purposes the fruit is checked for quarantine pests such as fruit fly, as per Plant Quarantine Law of Japan. As per this law, any fruit that has undergone the process of "vapor heat treatment" (VHT) is eligible for import in Japan, as this process sterilises the pests without the use of chemicals in an environmental friendly way. VHT is a non-chemical process of pest management and control, which utilizes heat and humidity to control and fully eliminate pest growth.

Eradication may also be accomplished by destroying weeds, which are reservoirs of various insects, pathogens or their vectors. Elimination of potato cull piles is an effective method of eradicating overwintering inoculum of the late blight pathogen. Similarly, destruction of *Tinospora* weed, an alternative host of fruit sucking moth, is recommended to contain the pest.

Soil fumigation has been a widely used eradication strategy. This technology involves introducing gas-forming chemicals such as carbon disulfide, methyl bromide, or chloropicrin into soil to kill target pathogens. However, undesirable side effects such as killing beneficial organisms, contamination of groundwater, and toxicity of these chemicals may also occur. Volatile fumigants like methyl bromide are incorporated into soil and covered with a plastic film. Likewise, formaldehyde is also mixed in soil to disinfect it from pathogens.

Crop rotation is a frequently used strategy to reduce the quantity of a pathogen, usually soil-borne organisms, in a cropping area.

Burning is another effective means of eradicating pathogens e.g. flaming potato stems prior to harvest may prevent tuber infection by the late blight pathogen. However, burning agricultural fields is controversial because the smoke creates human health and safety and environmental concerns.

Protection

This principle depends on establishing a barrier between the pathogen and the host plant or the susceptible part of the host plant. It is usually thought of as a chemical barrier, e.g., a fungicide (chemicals used to kill fungi; cide=kill, which has been derived from Latin *caedere i.e.* to kill), bactericide (chemical for killing bacteria), insecticide (chemical for killing insects) or nematicide (chemical for killing nematodes), but it can also be a physical, spatial, or temporal barrier. For example, bananas are covered with plastic sleeves as soon as the fruit are set) to protect the fruit from various pests including fruit decay fungi. Similarly, bagging of pomegranate fruits with butter paper bag is recommended against *anar* butterfly.

Protection often involves some cultural practice, which modifies the environment, such as tillage to bury pest-infested plant residues, drainage, irrigation, or altering soil pH; besides, rotation to non-susceptible crops, selecting pathogen-free planting stocks, orientation of plantings to improve exposure to sun and air currents, adequate nutrition, proper cultivation to improve root growth and avoid plant injury, and sanitation procedures to eliminate sources of inoculum. It may also involve changing date or depth of seeding, plant spacing, pruning and thinning, or other practices, which allow plants to escape infection/infestation or reduce severity of incidence. Raising planting beds to assure good soil water drainage is an example of cultural management of plant diseases such as root and stem rots. A range of fungicides, bactericides, insecticides etc. are available in the market for the management of pest incidence.

Biological control (also known as bio-control) involves the use of one living organism to control another, and this management technology has received much attention in recent times. The examples of biological control in the management of insect-pests are use of *Trichogramma chilonis* against fruit borer in pomegranate; *Chrysoperla* against aphid, thrips and mites; and baculoviruses against *Helicoverpa* and *Cydia pomonella*. Similarly, biological control of pathogen *Erwinia carotovora* by several plant-growth promoting organisms like *Pseudomonas fluorescence* is a usual practice. Another instance is management of soil borne pathogens e.g. Actinomycetes (*Streptomyces lydicus*) reduced root and seed rot severity in peas and resulted in significantly higher final emergence and significantly lower final disease in spinach challenged by *Pythium* and *Fusarium* (soil-borne fungi).

Resistance

Use of disease or pest -resistant plants is the ideal method to manage plant diseases and pests problems. Resistant plants are usually derived by standard breeding procedures of selection and/or hybridization. For instance, pomegranate varieties Jyoti and BedanaBosec are resistant to the attack of fruit borer. Recently, resistant plants have been developed through the use of genetic engineering (e.g., resistance to the *Papaya ringspot virus*). Likewise, genes from the bacterium *Bacillus thuringiensis* have been inserted into plants to protect against insect attacks. Plants with these inserted genes are called genetically-modified organisms (GMOs).

Integrated disease management

Integrated pest management (IPM) is a broad based approach, which integrates a range of practices for economic control of pests. In most cases IPM consists of timely application of a combination of strategies. These may include site selection and preparation, utilizing resistant cultivars, altering planting practices, modifying the environment by drainage, irrigation, pruning, thinning, shading, etc., and applying pesticides, as per requirement. For example, IPM for mango

hopper involves keeping the orchards clean, avoiding overcrowding of trees and water logging to keep the pest at bay and three applications of carbaryl 0.1 % or phosalone 0.05 % at fortnightly interval, or, two sprays of phosphomidon or monocrotophos @ 0.03% at 13 to 18 days interval at flowering and 2 - 3 sprays in June - July. Similarly, IPM of tomato fruit borer (*Helicoverpa armigera*) involves planting marigold as trap crop, sprays of baculovirus, Ha NPV @ 250 LE /ha, mechanical collection and destruction of bored fruit at periodic intervals (3-4 times), chemical spray of Indoxacarb 14.5 SC @ 0.5 ml/l or Thiodicarb 75 WP @ 1g/l. The integrated approach for the management of Panama wilt of banana caused by *Fusarium oxysporum f. sp. Cubense* is controlled by uprooting and burning of affected plants, use of disease-free planting material and resistant/ tolerant cultivar such as 'Gold Finger' and 'Mutiara', crop rotation with paddy followed by banana for 3-5 years once or twice, use of quick lime near the base of the plant and soaking with water and avoiding sunflower or sugarcane in crop rotation, dipping of suckers in Carbendazim (10g/10 litres of water) are recommended. Application of bioagents, such as, *Trichoderma viride* or *Pseudomonas fluorescence* in the soil has also been effective in containing this disease.

ACTIVITY

1. Visit orchards/vegetable farm/ gardens of your area and find out the major diseases and pests of important horticultural crops.
2. Try to collect information on prevalent management practices being followed in your area in different horticultural crops for the control of pests.
3. Visit a Biocontrol Laboratory of AgriculturalUniversity or Research Institution and see how biocontrol agent, Trichogramma/Trichodermais being multiplied and stored under laboratory conditions.

CHECK YOUR PROGRESS

1) What do you understand by term 'pest'? Cite some examples of pests in horticultural crops.
2) Enlist some important biological agents.
3) Differentiate between eradication and exclusion for pest management.
4) What does VHT means? How it helps in killing pests of fruits?
5) Discuss the effects of shoot and root pruning on vegetative growth and flowering of a fruit plant.

SUGGESTED READINGS

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