Agricultural Science - I

A text book based on the first year syllabus of Vocational Higher Secondary Course on Agriculture

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FOREWORD

Restructuring higher secondary level education incorporating vocational courses is a part of the New Educational Policy of the country. In Kerala State, several vocational subjects were introduced at plus two level during 1983-84 in selected Higher Secondary Schools. In this context, the need to make available text books with comprehensive treatise on the subject concerned need not be over emphasised.

The present book entitled 'Agricultural Science-I' is an attempt to provide a standard text book for the first year students in agriculture in the vocational higher secondary schools.

Preparation of text books of this kind needs considerable expertise and earnest effort in the planning, writing and editing of the material. I congratulate the authors for their untiring efforts in making this book very useful.

I hope that this book will meet a long felt need of the agricultural students at Higher Secondary level.

Development of instructional material is a continuous process and needs modification in the light of the experience of the teachers and students. Suggestions to improve this text book are solicited.

Dr. A. G. G. MENON
Director of Extension,
Kerala Agricultural University.

PREFACE

Vocational courses at the Higher Secondary level had been introduced for the first time in Kerala during 1983–84. Vocationalization of education is a part of the National Education Policy, and its main objective is to divert at least 50 percent of the students completing secondary school to one or other vocational courses. Several specific vocations were identified and agriculture is one among them introduced in selected higher secondary schools.

Agriculture is the main stay of Kerala economy and it offers enormous scope for employment both directly and indirectly. Because of this fact, agricultural vocational courses received priority in schools selected for vocational stream. It is hoped that the trainings given at the plus two level would enable the students to find their own employment in some of the selected areas in agriculture. Crop production, fruit and vegetable growing, commercial flower production, garden designing, seed production of various crops (rice, pulses, oil seeds, vegetables, flowers, green manure crops, cover crops etc.), fertilizer and plant protection services, nursery business (of plantation crops, fruits, ornamental plants etc.), mushroom farming, dairying, poultry farming, bee keeping etc. are some of the areas in agriculture in which the student can seek self employment.

It is imperative that the trainings given to the students should develop competencies in theoretical knowledge as well as practical knowledge expected by specific vocations. A thorough knowledge on theoretical skills is a must for acquiring practical skills. Though there are innumerable text books and reference books on specific subjects in agriculture, these are not within the easy reach of the students. Agriculture is a vast area, and information has to be gathered from various sources. For a student of plus two level, this renders the learning process difficult, and in most cases, the student depends entirely on the class notes given by the teachers. This situation prompted us to write a text book for the vocational course in agriculture. The idea of writing a book of this kind was originally proposed by the fourth author, who was then a teacher at the Govt. Vocational Higher Secondary School, Ambalavayal, Wynad. At that time, the first three authors were also stationed at Ambalavayal and were working at the Regional Agricultural Research Station, Ambalavayal. We worked collectively, utilising the library facilities available at the RARS, Ambalavayal. We remember with gratitude the help rendered by the Associate Director, RARS, Ambalavayal in this regard.

This book is prepared in accordance with the syllabus prescribed for the first year of study. However, we made slight modifications in its arrangement in order to have a logical sequence. Moreover, a few topics which do not find a place in the syllabus were added, with the hope that these are useful to the general readers. For instance, the introductory topics were enlarged. This, we hope, would enable the reader to have a wider view of Kerala agriculture and on the weather elements which play a decisive role in the fortunes of agriculture. Similarly, a brief note on 'nursery management' was added. The portions on 'soil survey', 'orchids' and certain other minor details were included based on the suggestions of the Director, Vocational Higher Secondary Education, Govt. of Kerala. We are extremely grateful to him for his valuable suggestions, and also for approving the book as a text book for the first year study of Vocational (Agriculture) Higher Secondary Education.

Though the book is primarily meant for vocational students, we hope, it would also be of use to diploma students in agriculture and as a general reference book for the field level workers in agriculture, progressive farmers and all those who want to have a general awareness in agriculture. The book has been written in a Kerala back ground drawing examples from the land here. This, we hope, would increase the usefulness of the book.

For the preparation of this book, we have referred several books and journals. Important references are listed as books for supplementary reading for those who want to enrich their knowledge further. The recommendations given in the text are mainly based on the Package of Practices, Recommendations (1986) of the Kerala Agricultural University. Many innovations of the Kerala Agricultural University such as 'biological control of African Payal' are included in detail.

Thanks are due to numerous eminent persons both outside and inside the Kerala Agricultural University who have contributed, directly or indirectly, to bring forth this book. It is difficult to single out persons for individual mention, but we do thank them all profusely. The final form of the book, however, is the responsibility of the authors and we apologise for any inaccuracies or inadequacies. We would be highly obliged, if the readers point out any such discrepancies. We also welcome suggestions for improvement.

We wish to record our appreciation to Sri. G. Shanmughan for the help rendered by him in neatly typing the manuscript.

We are deeply indebted to the Kerala Agricultural University for readily agreeing to publish the book as a University publication.

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GENERAL

I. What is Agriculture ?

1:1 Introduction

Food, shelter and clothing are the basic necessities for human life. Without these fundamental needs, man cannot live at all. How does he meet these basic needs ? The only answer is agriculture, the fundamental activity of man to thrive. Food, the foremost among his basic needs, is to be met entirely from agriculture. He cannot go back to the hunting and food gathering stage of pre-history. The food from the nature is not enough to feed even a fraction of the present day population ! So, he has to cultivate crops or rear animals to have food. For meeting the second basic necessity, clothing also, he has to cultivate crops or rear animals. Cotton, silk, and wool still form the clothing for millions. For making a shelter too, he has to depend upon agriculture to an extent. For the construction of houses and for making furniture and furnishings, timber and other plant materials are essential. Agriculture supplies these things. In addition, agriculture along with mining another fundamental activity of man, provide the raw materials for all industries and thus, form the primary sector of the economy. It may be seen that the very existence of human kind depends greatly on agriculture and its prospects.

In earlier days of history, agriculture and farming were synonymous, and were mostly done at subsistance levels. It was a way of life then. However, as agriculture flourished and developed, farming—production of food and fibre—has become only a part of modern agriculture. Agriculture has much wider scope today, and now, it includes the farm supply industries, the product processing industries, and the distribution industries as well. After the commercialisation of agriculture, farming is also running on commercial lines just like any other industries, with the objective of getting more income.

1:2 Beginnings of Agriculture

Scientists believe that man like beings (*Homo eructus*) first appeared on earth appioximately one million years ago. The present day man (*Homo sapiens*) evolved from these ancestors about half a million years ago. The history of man begins from here. Man lived on hunting, fishing, and by collecting .food from the nature. By the end of the Paleolithic Age or the Old Stone Age (50000-10000 BC), with the invention of certain tools and implements made of stone, he became a good hunter, and all the land and forests came under his control. The population of human beings began to increase. This necessitated the requirement for more food. The result was increased hunting and the decline in animal population. The food obtained from the nature also began to be reduced. This situation forced man to think, and he found that it is possible to make food out of some wild grasses, and instead of killing all the animals, some can be reared and its number increased. This happened somewhere around 8000 BC during the end of Mesolithic Age or the Middle Stone Age (10000-3000 BC). It was the Mesolithic people of the Middle East who have first gathered wild wheat and barley, domesticated wild animals like dogs, and took to breeding goats and sheep. The first recorded cultivation is in Northern Iraq and neighbouring region, and was dated at least 7000 BC, the first crops being wheat and barley. This marked the beginning of agriculture. From that humble beginning of agriculture as a way of life, it has grown along with civilizations, and it acclaimed the status of a business in many countries. A wealth of information is available now on various aspects of agriculture and to increase the production potential. More and more are being added every day.

1:3 Agriculture defined

The word agriculture is derived from two Latin terms; *Ager* meaning field and *Cultura* meaning cultivation. This indicate that the term agriculture was originally used to denote cultivation in fields only. However, agriculture now refers broadly to the science of raising plants and animals. We may define Agriculture as the art, the science and the business of production, processing, marketing, and distribution of crops and livestocks for the benefit of human beings. These four activities—production, processing, marketing and distribution—concerning crops and livestocks were previously all farm centred. However, with the improvement in technology, transport, communication developments, and specialisation of labour, some of these activities, perhaps excepting production, have moved away from farm into certain strategic control points outside the farm. Agriculture has, thus, moved out of the farm too.

The definition suggests that agriculture is an art, a science and a business. It is an art, as several of the agricultural operations need skills, which may be either physical or intellectual. Individuals may differ in their ability to acquire such skills. For instance, the techniques of budding and grafting, training and pruning, tapping rubber, preparation of a seed bed, handling and milking animals etc. involve skills, and individuals differ in their ability to do these works. Similarly, decisions regarding the selection of seed, sowing time, fertilizer application, harvesting etc. involve intellectual skills which are also to be obtained through experience.

There is no doubt that agriculture is a science. Scientific principles and methods are freely used in agriculture to increase the production and to have more economic returns. Agriculture is not a simple science, but an assemblage of a number of sciences, including pure sciences and applied sciences. The developments in the fields of physics, chemistry, botany, mathematics, zoology economics etc. and their applied sciences are utilized to build up the science of agriculture.

Above all, agriculture is a business. It is no longer considered as a way of life. The farmer, nowadays, raises crops and livestocks, with the main aim of getting more profit from less investments. In this respect, agriculture is similar to industries and the factors of production—land, labour, capital, and management—are playing their roles in agriculture too.

1.4 Agriculture and its branches

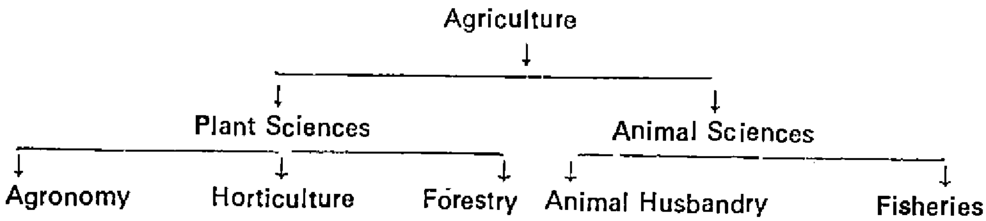
We have seen that agriculture now refers broadly to the science of raising plants and animals useful for human beings. Agriculture is usually divided into five major branches viz. agronomy, horticulture, forestry, animal husbandry and fisheries. Each branch is further divided into so many divisions for convenience and easy understanding. The relationship between these sciences is shown in the Fig. 1.1.

For the study of any agricultural plant science, whether agronomy, horticulture or forestry, a fundamental knowledge on the applied disciplines of plant breeding, plant physiology, agricultural botany, agricultural microbiology, entomology, agricultural zoology, agricultural chemistry soil science, agro-meteorology, seed technology, weed science, agricultural engineering, agricultural economics, agricultural statistics etc. are indispensable. There is yet one more discipline, agricultural. extension, which is primarily concerned with the dissemination of improved technologies in various disciplines.

Agronomy has been defined as a branch of agricultural science, which deals with the principles and practices of crop production and management of land. The crops that are grown under a relatively extensive system of cultivation are known as field crops, and such crops are usually included under agronomy. Crops such as cereals, millets, pulses, oil seeds, tuber crops, fibre crops, sugar crops, forage crops green manure crops, narcotic crops, and any other crop which is grown in an extensive system of cultivation are included under agronomy. In addition, the supporting sciences like agro-meteorology, seed technology, and weed science are considered as parts of this main branch in many circles. Similarly, the areas of study such as soil management, water management, dry land farming, farming systems etc. are part of agronomy which are applicable to other crops as well.

The word 'agronomy' has certain other meanings too. For instance, agronomy of

Fig.1.1. Agriculture and its branches.



Supporting disciplines of Plant Sciences :

Plant Breeding	Soil Science
Plant Physiology	Seed Technology
Agrl. Botany	Agro-Meteorology
Agrl. Microbiology	Weed Science
Plant Pathology	Agrl. Engineering
Entomology	Agrl. Economics
Agrl. Zoology	Agrl. Statistics
Agrl. Chemistry	Agrl. Extension

a crop means its soil, water, cultural, nutrient and weed management aspects as a whole.

Horticulture is that part of agriculture concerned with the so called garden crops, as contrasted with the field crops. Garden crops traditionally include fruits, vegetables, and all the plants grown for ornamental purposes as well as plantation crops, spices, and medicinal plants which are grown under a relatively intensive system of cultivation. Many horticultural products are utilized in the living state, and are thus, highly perishable. In contrast, the products of agronomy and forestry are often utilized in the non-living state, and are usually high in dry matter.

Forestry, another branch of agriculture is concerned with the theory and practices of raising forest crops, and constitute their creation, conservation, and scientific management of the forest resources. Wild life preservation also forms part of forestry.

In the animal science group, *animal husbandry* includes the theory and practices of production, maintenance, and other related aspects of dairy animals, poultry, pigs, sheep, goats, and other useful animals. Another branch, *fisheries* include the science of fish and fish farming.

1:5 Importance of Agriculture

The importance of agriculture in the well being and day to day life of human beings and in the economy of our country could be well understood from the following facts.

Agriculture provide the basic necessities for human life

Food, shelter and clothing are the basic necessities for human beings. As mentioned earlier, man depends upon agriculture for his food and clothing. For this, he has to cultivate or rear animals. The third necessity shelter, though can be met from other sources, too, he has to depend upon agriculture for timber and furnishings.

It is a source of livelihood for millions

Agricultural sector provides livelihood to a vast majority of people. In India, more than 70 per cent of the population is dependant on agriculture.

It provides employment

Agriculture and allied activities provide employment for a large number of people. Crop production, livestock farming and fisheries offer enormous scope for employment. Similarly, agri-based industries, for instance, coir, cotton, fertilizer, pesticides etc. employ a lot of people.

It is the supplier of raw materials for many industries

Agriculture supplies the raw materials for a good number of industries. Cotton, jute, sugar, starch, vanaspathi, cashew, tea, tobacco, rubber, coir, timber, leather etc. are a few examples to mention.

It is a major contributor of national income

The share of agriculture in the national income of a country is important. In India, about 1/3rd of the country's income is derived from agriculture and allied activities. In 1982-83 the national income of India was 1,34,066 crores and the share of agriculture was 35.5 per cent.

It is a source of foreign exchange

The export of agricultural commodities earn the nation valuable foreign exchange. In India, we export tea, coffee, cardamom, pepper, ginger, and several other finished products including fish and dairy products.

It is a source of revenue for the Government

The Government get a substantial income from agriculture and allied activities. eg., Taxes on agricultural commodities and finished products, agricultural income tax etc.

Social importance of agriculture

Agriculture is a way of life and an occupation for millions in our country. It colours our language, culture, and literature. Its influence is well noticed in our rituals and day to day life.

Considering the importance of agriculture, great emphasis is being given to agriculture and its development. In a country like India, where majority of the population live in villages, agricultural development is of paramount importance.

1:6 Agriculture in Kerala

Agriculture plays a key role in the well being of the people of Kerala, and it is the backbone of Kerala economy. Nearly 70 percent of the population live in villages, and about 55 percent of the population depend upon agriculture including livestock farming, fisheries, and forests for a living. In Kerala, the share of agriculture in the national income is about five times as that of industries. On all India level, the share of agriculture in the national income is 2-3 times only as that of industries. The influence of agriculture in the economy of our state is well known from this fact.

Agricultural sector in Kerala shows certain characteristic features. There is high pressure of population on land as compared to any other state. Agriculture is more commercialised in the state than elsewhere in the country, on account of the large number of valuable perennial crops. However, with regard to food production, Kerala has always fallen far short of her requirement. Another notable feature of agriculture in Kerala is the high intensity of cropping, mainly, because of the high pressure of population on land.

1:6.1 Land use and cropping pattern

Table-1.1 indicates the land use pattern in Kerala. The total geographical area of Kerala is 38.86 lakhs. Out of this, the area put under cultivation is 21.84 lakhs An area of 6.90, lakhs is mainly by way of intercropping and multiple cropping. Thus the gross cropped area in Kerala is 28.75 lakhs.

The area, production and average yield of important crops of Kerala are given in Table 1.2.

A perusal of the table indicates certain peculiarities. The predominance of perennial crops, especially non food crops is evident. When seasonal crops contribute 82 per cent of the total agricultural income in India, their contribution is only 30 per cent in Kerala. Similarly, about 64 per cent of the total agricultural income in India is from food crops, whereas in Kerala, it is only 29 per cent.

When we consider the importance of crops, we have to take into account the value of the crop also in addition to its area and production. Here, the value means its share to total agricultural income. The importance of a crop cannot merely be a manifestation of its area. For instance, rice is grown in an area of 7.3 lakh ha. and coconut 6.87 lakh ha. However, an estimate shows that the share of coconut to total agricultural income is 31 per cent and that of rice is only 29 per cent.

Table 1.1 Land utilization pattern in Kerala(1984-85)

Sl.No.	Classification	Area in ha.	Percentage
1	Total geographical area according to village papers	38,85,497	100.00
2	Forests	10,81.509	27.84
3	Land put to non agricultural uses	2,79,703	7.20
4	Barren and uncultivable land	85,688	2.21
5	Permanent pastures and other grazing lands	4 158	0.11
6	Land under miscellaneous tree crops not included in net area sown.	51.039	1.31
7	Cultivable waste	1,30,098	3 34
8	Fallow land other than current fallow	27,221	0.70
9	Current fallow	41,658	1.07
10	Net area sown	21,84,423	56.22
11	Area sown more than once	6,90,220	17.76
12	Total cropped area	28,74,643	73.98

Source: Statistics for planning 1986, Department of Economics and Statistics, Govt. of Kerala.

Table 1.2: Area, production and average yield of major crops of Kerala (1984-85)

Sl. No.	Crops	Area in hectares	Production in tonnes.	Average yield (kg/ha.)
1	Rice			
	Virippu	3,18,611	5,49,027	1.723
	Mundakan	3,26,812	5 39,859	1,652
	Punja	84,956	1,67,050	1,996
	Gross	7,30,379	12,5[illegible],902	1,720
2	Coconut	6,87,483	3,453 (million nuts)	5,023 (nuts/ha.)
3	Rubber	3,10,200	1,72,092	555
4	Tapioca	2,16,742	36,94,270	17,044
5	Cashewnut	1,36,863	72,294 (raw)	528
6	Pepper	1,05,835	17,350 (black)	164
7	Coffee	65,641	43,565	664
8	Arecanut	59,089	8,589 (million nuts)	1,45,357 (nuts/ha.)
9	Cardamom	58,769	2,850 (dry)	48
10	Banana & other plantains	51,417	3,31,192	6,441
11	Tea	35,003	56,329	1,609
12	Cocoa	17,860	4,536 (dried beans)	254
13	Ginger	14,537	41,245 (dry)	2,837
14	Sesame	14,448	3,632	251

Source: Statistics for planning, 1986. Department of Economics and Statistics, Govt. of Kerala.

This type of cropping pattern poses certain problems for us. First, it can create a food problem. Kerala state is not producing enough food grains to feed her people. We depend upon other states for meeting nearly half of our requirements. We need about 35 lakh tonnes of food grains to feed our 250 lakh population. However, our present production is only 13 lakh tonnes. Another problem is wide fluctuation in prices of cash crops. Many of them are not consumed here but consumed elsewhere– we are exporting them. As a result, the market is controlled by external agencies. The cultivator has no influence at all on the market, and the price fluctuation causes severe hardships to the farmers. In the case of domestically used products such as coconut and rubber too the influence of external agencies is evident. Here, the determining factor is North Indian industrialists, since coconut and rubber based industries are very few in Kerala.

1:6.2 Farming systems

Due to the varied soil, land, physiographic and climatic factors, and economic status of farmers, farming systems prevalent in Kerala has certain distinguishing features. The homestead system of cultivation, with a combination of perennial and annual crops along with livestock, is the most common system all over Kerala. Another feature is extensive cultivation of paddy in problem areas such as Kuttanad, Kole, and Pokkali lands of the state. Plantation scale cultivation as monoculture is also seen, especially, with crops such as rubber and tea.

The farming systems prevalent in Kerala can be of four major groups.

Coconut based farming system: In this system, coconut is the major crop. This kind of system is prevalent in uplands and hill slopes of the midlands. It includes a number of intercrops such as pepper, arecanut, cocoa, banana, ginger, turmeric, tuber crops and fodder crops; and in some areas upland rice, pulses, oil seeds, and vegetables.

Rice based farming system: This type of farming system is prevalent in wet lands. A single crop or two crops of rice are grown depending on the availability of water as in the central region of Kerala, or after dewatering of impounded water as in Kuttanad or Kole lands. Seasonal crops like vegetables, pulses, and oil seeds are grown in rice fallows, especially, in the summer season. Sometimes, banana, tapioca, ginger etc. are also grown in rice fields. Fish farming or prawn culture is practiced in the areas of sea water inundation (eg. *Pokkali* lands) after taking a rice crops.

Homestead based farming system: Homestead system of farming is prevalent where the size of the holding is small. The pressure on land and fragmentation of holdings encouraged this type of farming system in Kerala. The farmers choose a wide variety of crop combinations and livestocks, and in certain cases, fish farming, too, according to the conditions available in the region.

Plantation crop based farming system: Plantation crops such as rubber, tea or coffee predominate in this system. In the mid lands and high lands, rubber is a major crop, and grown mainly as a monocrop. However, in the initial growth stages, intercrops such as ginger, banana etc. are also grown, especially by small farmers. Tea is grown only in high ranges, and as a monocrop, that too, in extensive scale. Coffee based farming system is predominantly seen in Wynad. Pepper grown on silver oak is the usual companion in coffee gardens.

1:6.3 Intensity of cropping

The gross area under rice is 7.3 lakh ha. The net area is only 4.8 lakh ha., and an additional 2.5 lakh ha. is also taken by way of double or tripple cropping. Vegetables, sesame, pulses, sweet potato etc. are also cultivated in rice follows; which means, in an area of 4.8 lakh ha., by way of additional rice and other crops about 10 lakh ha. of crops are grown. This means, the intensity of cropping of rice fields is about 2.00. (The intensity of cropping is the ratio between the gross cropped area and the net area sown. It is sometimes expressed as percentage). This indicate another fact about Kerala agriculture. It is very difficult to increase the area under rice, even with improvements i n irrigation and other infrastructure.

More than half of the area under pepper in Kerala is grown as an intercrop in coconut, arecanut, and coffee plantations. A major part of tapioca is also grown as intercrop, especially in coconut gardens. The intensity of cropping as a whole in Kerala is 1.33. If we exclude rubber, tea, and cashewnut, where intercrops are not usually possible, the figure may go upto 1.47. However, the cropping intensity in India as a whole is only 1.15.

1:7 Water resources of Kerala

Kerala State is blessed with a large number of rivers because of the undulating nature of land and heavy rainfall. There are 44 rivers in Kerala which originate from the Western ghats. Of these, 41 rivers flow towards the west and join the Arabian sea; while three rivers–Pampar, Bhavani and Kabani-flow towards the east through Karnataka and Tamil Nadu, and join the Bay of Bengal as river Kavery. The rivers of Kerala are mainly monsoonfed, fast flowing, and comparatively shorter in length.

The South-West monsoon (June-August) contribute about 60 per cent of the annual rainfall in Kerala. About 30 per cent is the contribution of North-East monsoon (September-November) and the balance 10 per cent is from pre- and post-monsoon showers. The average annual rainfall in the state is 3017 mm. it varies from place to place and year to year. There are places (eg. Neriamangalam, Lakkidi) where it exceeds 5000 mm. Similary, there are places such as Chinnar, where it is less than 1250 mm. In Palghat district, rainfall is comparatively low, and areas receiving rainfall below 1250 mm are many. The highest rainfall 5883.8 mm is recorded at Neriamangalam (Ernakulam) and the lowest at Chinnar (Idukki) where it is 651.3 mm.

The total run off all the rivers of the state amounts to 78,041 Mm^3 of which 70.323 Mm^3 is the contribution from catchment in Kerala and the remaining from that of Karnataka and Tamil Nadu. The quantity of water that is considered utilizable is computed as 32,772 Mm^3.

Water resources is one of the most important physical resources of Kerala which is renewed every year. This renewal is by means of rainfall only and cannot be compared to Himalayan rivers where the renewal could also be from ice. In Kerala, a total area of 3.90 lakh ha. (1982-83) is irrigated from various sources. This comes to about 13.6 per cent of the gross cropped area.

Table 1.3 Major and medium irrigation projects
Achievements upto 1985-86

Sl. No.	Name of project	River basin	Command area (ha) Net	Command area (ha) Gross	Cumulative achievements at the end of 1985-86 (ha) Net	Cumulative achievements at the end of 1985-86 (ha) Gross
1	2	3	4	5	6	7
A.	Completed projects					
1.	Chalakudy (diversion)	Chalakudy	26,680	39,380	13,530	27,258
2.	Peechi	Karuvannur	17,555	28,080	15,262	23,918
3.	Malampuzha	Bharathapuzha	29,463	42,090	19,802	40,208
4.	Neyyar	Neyyar	16,042	17,952	8,300	16,716
5.	Pothundy	Bharathapuzha	8,792	10,930	4,685	10,046
6.	Gayathri	Bharathapuzha	7,651	10,930	4,880	10,114
7.	Walayar	Bharathapuzha	4,536	6,470	3,752	6,503
8.	Vazhani	Keecheri	3,565	7,130	2,113	4,226
9.	Mangalam	Bharathapuzha	4,816	6,880	3,313	6,608
10.	Cheerakuzhy (diversion)	Bharathapuzha	2,268	2,828	952	1,746
B.	Ongoing projects					
1.	Kallada	Kallada	61,630	92,000	—	10,610
2.	Pamba	Pamba	21,135	49,456	—	47,778
3.	Muvattupuzha	Muvattupuzha	17,400	52,200	—	—
4.	Periyarvally	Periyar	30,444	32,800	—	76,402
5.	Chimoni	Karuvannur	13,000	26,200	—	—
6.	Chitturpuzha	Bharathapuzha	14.500	28,960	—	25,286
7.	Kanjirapuzha	Bharathapuzha	9,720	21,863	—	15,487
8.	Kuttiadi	Kuttiadi	14.570	35,850	—	34,710
9.	Pazhassi	Valapattanam	11,525	32,374	—	14,220
10.	Vamanapuram	Vamanapuram	8,803	18,014	—	—
11.	Idamalayar	Periyar	13,659	39,318	—	—
12.	Kuriarkutty-Karappara	Chalakudy Barathapuzha	11,736	23,472	—	—

Source: Economic Review, 1986, State Planning Board, Trivandrum

After Independance, to increase the production potential of crops, and also to bring more area under food crops, a number of irrigation proiects have been taken up. Among this, 10 have been completed. This ten completed projects all together irrigate an area of 1.47 lakh ha (gross). Seven ongoing projects, through partial commissioning, irrigate an area of 2.10 lakh ha. (gross). In other words, a gross irrigated area of 3.57 lakh ha is covered by major and medium irrigation projects (1985). The details of the completed and ongoing projects are given in the Table 1.3.

All the major/medium irrigation projects of Kerala are meant for paddy cultivation, especially for the first and second crops. However, Kallada project cater to the needs of garden crops too.

2. Weather and climate

2:1 Introduction

Every living organism, whether plant or animal, is influenced by many known and unknown factors during its growth and development. The final yield of a crop depends on all that had happened to it during the growth and development stages prior to harvest. So is the case of production efficiency of animals. The factors influencing these happenings are both genetic and environmental. Plant growth is primarily governed by the environmental conditions of the soil and climate. Other factors of the environment which exert an influence on the plant are physiography and biotic factors (plants and animals including man). The various factors can be broadly classified as shown below.

The farmer tries his best to manipulate these factors through his skills and knowledge of such factors. However, the modification of climate or its manipulation is not an easy job. It is still in the stages of experimentation. However, it is possible to optimise production by adjusting the cropping pattern and agronomic practices to suit the climate of a locality.

Weather assumes importance in nearly every phase of agricultural activity from the preparatory tillage to harvesting and storage. Even after the produce is stored, weather continues to play its role. The reports of good or bad weather may upset the price level of produces. As weather is the single major limiting factor in crop production, the farmer has to take several decisions on time of sowing, transplanting, scheduling irrigation, time of fertilizer application, time of using pesticides etc based on the prevailing weather conditions. Thus, it could be seen that a sound knowledge of the climatic factors and understanding of the complex processes of interaction between the climate and biological processes of the plants are essential for successful farming.

2:2 Weather and climate

An understanding of the terms weather and climate are important in the study of agro - climatology or agro - meteorology. Weather is the condition of the atmosphere at a given time (from a few hours to about two weeks) of a place or small area. Climate, however, is a much broader term than weather. It is the average of the weather elements for a long time of a particular region. The climate may be defined as the collective probable state of atmosphere within a specified interval of time and space at that locality or area.

Plant growth →
- → Genetic factors
- → Environmental factors →
  - → Soil
  - → Climate
  - → Physiography
  - → Biotic factors

There ere two more terms worth mentioning here-*macro climate* and *micro climate*. Micro climate denotes the weather conditions in close proximity to ground. In other words, it is the climate from the ground surface to the top of the plant and include soil climate upto the depth of maximum root accumulation. Micro climatic conditions may differ based on the growth habit of the crop. For instance, the microclimate of wheat and rice may extend upto about 2m, and that of sugarcane upto about 5m from ground.

The term macro climate is used to express the climatic conditions existing over extensive areas. It is usually expressed only after periodic observations of weather elements in various places representative of the entire region. There is still another term-*meso climate*, which is sometimes used to express the climatic conditions in between macro climate and micro climate.

2:3 Weather elements

The weather etements or the climatic factors which affect the crop growth are atmospheric temperature, precipitation, atmospheric humidity, (RH) wind, sun light, and atmospheric gases.

2:3.1 Atmospheric temperature

Atmospheric temperature is the most important climatic variable affecting the growth of plants. Each and every plant is having certain ranges of temperatures for their normal growth. There is an upper limit, a lower limit, and an optimum limit. These may differ between plant species, cultivars within a species; or it may even differ with the growth stages of a cultivar. The reaction of plants to these limits may also differ. When the temperature approaches the upper limit, normal metabolic activities of the plants are affected, and the plant may even be killed. At the lower limit also, inactivation of plant activities is noticed. At extremely low temperatures, death of plants can occur. Even at temperatures slightly lesser than the upper limit or slightly above the lower limit, the metabolism of plants may not be normal. The plant may be remaining dormant, even though it is still alive. So, there will be an optimum range of temperatures for most crop plants. At this optimum range of temperatures only, the normal rates of photosynthetic activities and other metabolic functions can taken place. These three limits viz., the upper, the lower and the optimum are generally referred as cardinal growth temperatures.

Higher plants can function at a wide range of temperatures, viz., 0–60°C. However for most crop plants, it is 10–40°C, and the maximum dry matter production is at 20-30°C range. We can categories crop plants based on temperature requirements into three groups.

1. Which tolerate low ranges of temperatures—temperate plants. eg., apple, peaches etc.
2. Which tolerate medium ranges of temperatures—sub-tropical plants eg., tea, oranges etc.
3. Which tolerate higher ranges of temperatures—tropical plants eg., sorghum, coconut etc.

Temperature measurements

For recording the temperature of the atmosphere, we use thermometers. There are four types of thermometers used in an ordinary meteorological observatory to suit various requirements. They are maximum thermometer, minimum thermometer, dry bulb thermometer and wet bulb thermometer. These instruments are housed in a specially made wooden box with loavered sides known as 'Stevenson's screen (Fig. 2.1). The loavered sides

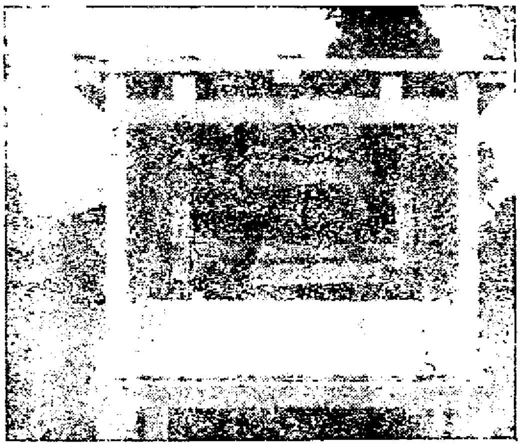


Fig. 2.1 Stevenson's screen

of the box give a standard uniform exposure to obtain reliable measurements from the instruments kept inside.

Maximum thermometer: Using this instrument, the maximum temperature of a day at a place can be recorded. It has got a constriction just above the mercury bulb (as in a clinical thermometer). When the temperature rises, the mercury expands and pushes the pointer up; and it would not come back even if the temperature is reduced, because of the constriction. The thermometer has to be set up daily by violent shaking after recording in order to send the mercury back to the bulb.

Minimum thermometer: The minimum temperature observed in a day is recorded by this thermometer. Instead of mercury and metal pointer, alcohol and a glass pointer is used in this. When the temperature is lowered, the alcohol contracts. Along with the contraction of alcohol, the glass index is also brought back. However, when the temperature rises, alcohol expands, leaving the index in its original position. After recording the temperature, the pointer is to be set up on top of the thermometer stem by tilting the instrument reversely.

Dry bulb thermometer: The reading from the dry bulb thermometer gives the real temperature of the atmosphere at a time, as it is protected from direct heating. In other cases of outside measurements, atmospheric temperature and direct heating of glass is involved.

Wet bulb thermometer: The wet bulb reading is to get a measure of the relative humidity of the atmosphere. Temperature noted in this thermometer will always be less than that of dry bulb thermometer. This chararcteristic is made use of for finding RH at a place. When RH is high, wet bulb reading will be low. The RH is directly obtained from pre-prepared tables (hygrometric tables) against wet and dry bulb readings.

2.3.2. Precipitation

Precipitation is a broader term which includes any sort of liquid or solid form of water falling on earth's surface. Rainfall is the most important of precipitation. Others are:-*drizzle*–rains, but droplets will be very small; *snow*–small ice crystals failing on earth's surface; *hail*-bigger lumps of rice failing on earth; ***sleets***-a combination of rainfall and ice crystals ie., both solid and liquid form.

Rainfall

It is the most important form of precipitation influencing the vegetation of a piece. Most of the crops receive their lion's share of water supply from rain water alone which is the primary source of soil moisture. There are certain characteristics of rainfall, viz., the ***distribution pattern*** and the ***intensity*** which is important in a crop production point of view.

The distribution pattern indicates, how the rainfall is occuring in various parts of the year, or month war distribution of rainfall during a year; and the intensity of rainfall refers to quantity of rainfall in relation to time of its occurance.

In Kerala, in areas north of Trichur, the intensity of rainfall is high and annual rainfall is more. However, some parts of Northern region are drought prone areas, This is because of the fact that the distribution is very poor. The rainfall is mostly received from South-West monsoon periods during May-October. The remaining periods are almost dry. However, in southern region (south of Trichur), North East monsoon and South-West monsoon are almost well distributed, and they are almost equal.

High intensity of rainfall has got its indirect effects as well. If the intensity is high, soils are highly leached and nutrients are lost. Unless rainfall is absorbed as quickly as it is received, there will be run off. As a result soil erosion may occur.

As far as total rainfall is concerned, there is a barest minimum for a crop. Say one crop has the minimum requirement of rainfall as 250 mm, and annual rainfall received is only 225 mm, the crop may fail. When the annual rainfall received is 300 mm, the yield may be doubled. There is an optimum value of rainfall too, just like temperature. If the annual rainfall is going over this value, it has got deleterious effects on crop growth.

Effective rainfall

In simple terms, effective rainfall means useful or utilisable rainfall. Rainfall may not always be useful or desirable at the time, rate, or amount in which it is received. Effective rainfall is, thus the quantity of rainfall received in a particular occasion which is useful for crop production at the site where it falls. Consequently, ineffective rainfall is that portion of the rainfall which is lost by surface run off, deep percolation, and the moisture remaining in the soil after the harvest of the crop, which is not utilisable for next season's crop. The annual effective rainfall commonly amounts to about one-third of the total rainfall.

Monsoons

Rainfall in India is primarily due to summer monsoons. The monsoon is a seasonal wind regime, in which seasonal wind shift occurs as land and sea breeze on a very large scale due to prolonged thermal and physical differences between land and sea.

Based on the region of origin of monsoon winds, two monsoons—the South West monsoon and the North-East monsoon—have been identified in India. With the exception of Jammu and Kashmir in the extreme North and Tamil Nadu in the South, 80-90 per cent of the rainfall over the country occurs mostly during South-West monsoon season. The success of agriculture in India, therefore, depends primarily on the timely set, the proper amount, and the distribution of rains in a season.

Normally, South-West monsoon reaches the Kerala coast by the end of May, advances along the Konkan coast in early June, and extends over the entire country by the end of July. The rains continue upto the end of September, and then, the South-West monsoon recedes. In November-December, the North-East monsoon is the main contributor to the amount of rainfall over the southern portion of the peninsula.

Monsoons in Kerala: Both the monsoons are equally important for Kerala. The South-West monsoon rains in Kerala is popularly called *Kalavarsham* or *Edavapathy*. It starts by the end of May or by the first week of June and continue up to August-September, contributing about 60 per cent of the total rainfall in Kerala.

Kerala receives a share of North-East monsoon rains also. Here, it is called *Thulavarsham*. It starts by the end of September and continues upto November-December, contributing about 30 per cent of he annual rainfall.

From pre-and post-monsoons, we get about 10 per cent of the total rainfall.

There may be a short dry spell in August-September months between SW and NE monsoon. In the Northern Kerala, SW monsoon is important and most of the total rainfall is from SW monsoon. In the Southern regions, SW and NE monsoons are almost well distributed, and they are almost equal.

Fog, smog, mist, dew etc.

In the strict sense, they do not come under the term precipitation. They are localised phenomena. Both fog and mist result from condensation of water vapour in air on the surface of either land or water. This happens, when there is a clear sky, weak radiations, and no winds However, mist is differentiated from fog, due to better and longer distance visibility.

Smog denotes smoke+fog, the term coined in 1905—to describe the greyish fog formed in and around industrial cities.

Dew is condensation of water vapour on solid surfaces that get cooled due to heat loss by night radiation; and temperature is brought below the dew point. At that point, conversion of water vapour to tiny droplets takes place. Dew is found to be beneficial in moisture stressed areas.

Measurement of rainfall

The rainfall is measured by means of rain guages (Fig. 2. 2). Ordinary rain-guages consist of a funnel with a circula brass rim of 12.7 cm diameter. The base

Fig. 2.2 Rain guage

of the rain guage is fixed on a concrete floor. The reservoir to which rain water is collected from the funnel is placed inside the concrete floor. The rain guage is kept at 30 cm above the ground level. Daily rainfall is noted usually at 8.30 am, and measured after transferring the water collected in the reservoir to a graduated measuring flask specially calibrated for this purpose.

Natural syphon rain guages are also available which record the occurrance of rainfall continuously. We could note the total rainfall and period at which it happened from this type of rain guages.

2:3:3 *Atmospheric humidity*

Water in the form of invisible water vapour,is always present in the atmosphere. This water vapour in the air is usually known as humidity of the air. The occurrence of rainfall is largely dependant on humidity of the air which results from vapour contents of the air. This vapour comes from evaporating soil and water surfaces and transpiring plant surfaces. Both this processes—evaporation and transpiration—together is called evapo-transpiration(ET). ET is closely related to changes in temperature and wind effects.

The relative humidity (RH) and the vapour pressure defecit (VPD) are the common parameters used for humidity specifications. *Relative humidity* is the ratio of humidity actually present in the atmosphere, and the maximum that can be present at a particular temperature. RH is expressed as a percentage. The RH of a place is affected by temperature, pressure, wind, exposure, vegetation, and soil water content. The evaporation of water from plants, soil, or a body of water is directly dependant on the RH of the atmosphere. When the RH is lower, the rate of evaporation or transpiration is higher, and vice versa. The difference between the actual vapour pressure and the saturation vapour pressure of air at the same temperature is known as *vapour pressure deficit*. This is comparable to RH, and is much more indicative of the potential rate of evaporation.

Similar to temperature and rainfall, there is an optimum RH also for crop plants for its normal activities. Humid air favours the growth of many fungi and bacteria, and this affect the crop seriously. The blight disease of tea and potato are examples of diseases spread under moist weather. Similarly, many kinds of aphids and jassids thrive well under humid conditions. Low humidity is also deleterious, since it increases the evapo-transpiration, and thereby, increasing the water requirements. Other plant processess are also affected in low humid weather.

Evapo-transpiration

It is actually the loss of moisture from a unit area of cropped fields, both by transpiration through the leaves and evaporation from the underneath soil surface. The ET of crop plants increases with temperature, but decreases with high RH, affecting the quantity of irrigation water. Often, ET is measured for scheduling irrigations or for studying water requirements of crops. Both direct and indirect methods are employed for computing evapo-transpiration.

Pan evaporimenters are widely used, and are simple to handle and less expensive. USWB (United States Weather Bureau) Class-A pan evaporimeter (Fig. 2.3) is the one commonly used for this purpose. Sunken screen pan evaporimeters, Piche evaporimeters etc. are also available.

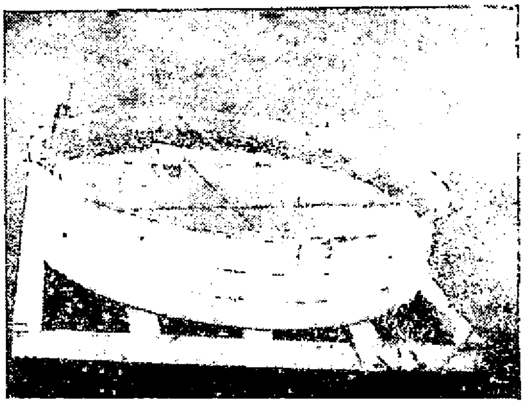


Fig. 2.3 USWB Class—A pan evaporimeter

2.3.4. *Wind*

Wind affects crop growth mechanically and physiologically. The sand and dust particles carried by the wind may damage plant tissues. Emerging seedlings may be completely covered, or the roots of young plants may be exposed by strong winds. Winds may also cause considerable losses by inducing lodging, breaking of stalks, and shedding of grains.

The physiological effects of wind consist mainly of increasing transpiration as well as evaporation from the soil. Hot dry winds may, however, adversely affect photosynthesis, and hence, productivity by causing closure of the stomata even when soil moisture is adequate. Moderate wind has a beneficial effect on photosynthesis by continuously replacing the carbon dioxide absorbed by the leaf surfaces. The favourable effect on photosynthesis is most marked under turbulence of wind at the lower leaf layers.

Wind is also resposible for causing rainfall to a large extent. In India, the monsoon type of rainfall is largely determined by a particular pattern of wind movement. The wind has a powerful effect on humidity of atmosphere also.

For studying wind and its effects, we may have to record its velocity and direction. The wind velocity is usually measured by means of an instrument, named 'Robinson's cup anemometer', (Fig.2.4) in an observatory. The indicator attached to the anemometer will show the wind velocity. For noting the direction of wind the 'wind vane' is useful. The direction from which the wind is blowing is called 'lee ward' side, and the direction to which it is blowing is 'wind ward' side. Both these can be noted from the wind vane (Fig. 2.5).

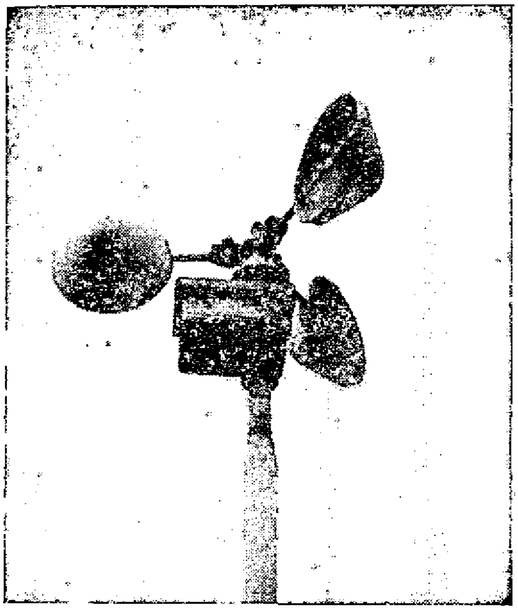


Fig. 2.4 Robinson's cup Anemometer

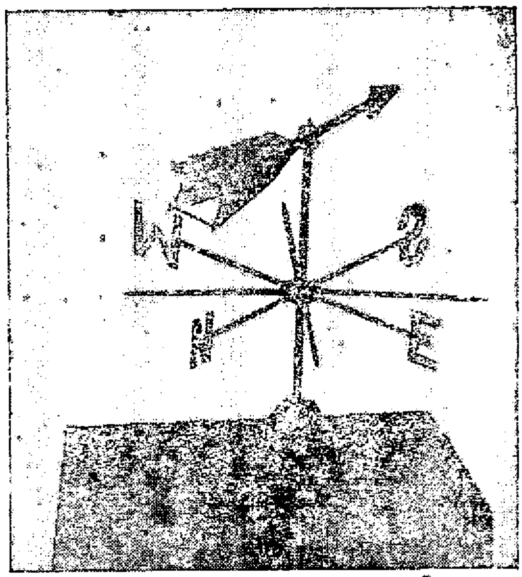


Fig. 2.5 Wind vane

2:3.5. *Sun light*

Sun is the sole source of energy on earth. Solar energy provides two essential needs of plants viz., light required for photosynthesis and thermal conditions for normal physiological functions.

Light is one of the most important climatic factor for many vital processes of plants. The chlorophyll absorbs light and convert it into potential chemical energy of carbohydrates. This is the very fundamental biological activity taking place on earth which supports life.

Light affects the plants in four ways (1) intensity, (2) quality (3) duration and (4) direction.

Light intensity: Light intensity varies greatly under natural conditions. Most of the crops show marked response to changes of light intensities. During cloudy wheather, the production of dry matter is limited. Many plant species produce maximum dry matter under high light intensity, if water is available in plenty.

Quality of light: Red light seems to be the most favourable light for growth, followed by violet, and then blue.

Duration of light: This is of considerable importance from the farmers point of view in selecting crop cultivars. The length of the day has more influence than intensity. The response of plants to the relative length of day and night is known as *photoperiodism*. Plants which develop and reproduce normally, when the photoperiod is less than a critical minimum (more than 12 hrs) are called short day plants. Some plants are found to be unaffected by photoperiods and are called day-neutral plants or photoinsentive plants. Plant characters like floral initiation, floral development etc. are influenced by by photoperiods. If a long day plant is subjected to short days, the internodes may be shortened to give a rosette appearance, and flowering will not take place. In the same way, when a short day plant is subjected to long day periods, the growth of the plant become abnormal, and there is no floral initiation.

Direction of light: Shoots, roots and leaves show different orientation to the direction of light. In temperate region the southern slopes show better growth of crops than the northern slopes, due to the direction of light, contributing more sunlight towards the southern side.

Certain instruments are used to record–the sunshine hours in a day and light intensity. Campbell-stoke's sunshine recorder (Fig. 2.6) is usually used in an observatory to note the period of bright sunshine in a particular day. Light intensity is measured by means of lux meters.

Fig. 2.6 Sunshine recorder

2:3.6 *Atmospheric gases*

The atmosphere surrounding the earth contains a mixture of several gases like carbon dioxide (0.03%), oxygen (20.95%) nitrogen (79.09), and several other miscellaneous gases in almost constant proportion. However, variations from these proportions may be found over industrial areas which releases large quantities of gaseous fumes. This include CO_2, CO, water vapour, and several other toxic gases. All these, in excess of its proportion, may have an adverse effect on normal plant growth. However, it is observed that the rate of photosynthesis is higher, when the concentration of CO_2 in the air immediately surrounding the foliage of the crop is higher.

However, there is one alarm in the increasing amount of carbondioxide and water vapour in the atmosphere. The wide spread use of combustible fuels deplete the vital oxygen supply and increases CO_2 supply. This CO_2 along with water vapour make a huge green house of the earth, because, while they allow sunlight (short wave radiations) to reach earth, they prevent long wave heat radiations from the earth escaping into space. The temperature of the earth is, therefore, certain to rise, as the amounts of CO_2 in the atmosphare increases. This phenomenon is popularly known as *green house effect*.

2:4 Applications of meteorology in agriculture

The information on weather data and their interpretation are highly useful in agriculture for a number of applications. A few of them are briefly mentioned below.

Plant introduction

The knowledge on the climate of different parts of the world facilitate plant introduction. For example, the rice cultivar, IR-8, and the wheat cultivar, Sonora-64 were introduced to India on the basis of the climatic similarity between the countries, where they were evolved and our country. Similarly, the crops like tapioca, rubber, cashewnut etc. were introduced to India based on the analogy of climate.

Selection of crops

The suitability of a crop to a particular region is dependant on mainly the climatic characteristics of that region. For example, in a drought prone area we have to select drought tolerant crops. Similarly, in areas like Wynad or Peerumedu in Kerala where sub-tropical climate prevails, crops like tea, coffee etc. are to be chosen.

Scheduling irrigation to crops

The climatologic approach of scheduling irrigation is becoming more popular in water management. Irrigations are scheduled based on the evaporation data, usually obtained from open pan evaporimeters.

Agro-climatic classification

The average of the climatic parameters all over the word can be used to delineate regions of similar climatic features. There are several systems of classification based on climatic features. The classification of the hemisphere of earth into three zones, viz., Torrid zone (hot), Temperate zone, (medium) and Frigid zone (cold), is an example of climatic classification. Similarly, if we use some other agricultural features like topography or soil type along with climatic factors to delineate the zones, it is called agro-climatic classification. The agro-climatic classification of Kerala into 13 zones is an example.

Forecasting of weather

The forecasting of weather is becoming more and more important nowadays. The Indian Meteorological Department, through a net work of observatories spread all over the country, collect information on weather parameters, and on the basis of this, daily weather forecasts and warnings of adverse weather are given, especially, through 'Farmers' Weather Bulletins'. It usually indicates the periods of the onset of rain, probable rainfall intensity and duration, breaks in rain, spells of heavy rain, and other adverse conditions of weather. These bulletins are broadcast in regional languages and English by the All India Radio, and are telecast by the *Doordarshan*. Weather bulletins will also be issued to Newspapers. The forecasting of weather helps the farmers to plan agricultural operations, so as to take advantage of the favourable weather and mitigate the damages of adverse weather.

Crop yield forecast

The yield of a crop can be predicted based on the weather data collected at the time of sowing and at critical stages. Formulae are available for principal crops like paddy and wheat correlating yield and weather parameters.

Pest and disease forecast

This is done in many countries for important pests and diseases of principal crops. The probable time of occurrence, intensity of attack, and manifestation intensity (maximum attack at what time) are forecast based on the weather parameters.

2.5 Seasons

We observe and feel different seasons in a year. These seasons are caused by the rotation of the earth around the sun. Primarily, four seasons are recognised throughout the world. They are Spring (*Vasanth*), Summer (*Greeshma*), Autumn (*Sharat*) and Winter (*Shishir*). All these seasons have a profound influence on the vegetation all over the world. The plants wake up in spring from its winter sleep, continue through summer and autumn, to grow, flower, and fruit; and again, goes into a kind of hibernation or rest during winter. During the winter, the plants shed their leaves; and wake up again and begin another growth cycle with the onset of the spring.

In temperate and sub-tropical regions, the growth cycle of plants, as mentioned above, strictly follows these seasons, and agriculture is governed by them. There, the seasons are well differentiated, and summer is the principal season for agriculture followed by spring and autumn. Winter is too cold to allow plant growth.

According to Indian traditions, the climatic year is divided into six *Ritus* (seasons) of about two months duration each. They are *Vasanth* (spring), *Greeshma* (summer), *Varsha* (rainy season) *Sharat* (autumn), *Haemanth* (mild early winter) and *Shishir* (severe late winter).

In tropics, however, the differentiation of seasons into four or six, as done above has not much relevance. The temperature at no time of the year goes too low for plant growth, and crops can be raised in all the seasons. However, the crop growth is largely influenced and modified by the monsoons and other climatic factors.

The Indian Meteorology Department has divided the climatic year into four seasons. They are-

1) Summer (March to May)
2) Monsoon (June to September)
3) Post-monsoon (October to November)
4) Winter (December to February)

2.5.1 Crop seasons of India

For agricultural purposes, there are mainly two seasons in India, the season of the South-West monsoon, the '*Kharif*'; and the period of the post monsoon, the

'Rabi'. The *'Kharif'* season is from July to October, and the *'Rabi'* from October to March. A third crop season may also be there, between March and June known as *'Zaid'*, in some parts of the country. However, there are no such distinct seasons all over the country, and some parts have their own classification of seasons. A few examples of Kharif and Rabi crops are given below.

Kharif crops: Rice, Jowar, Bajra, Maize, Groundnut, Cotton etc.

Rabi crops: Wheat, Barley, Oats, Jowar, Gram etc.

The monsoon season is the *'Kharif'* season and the post monsoon and winter together constitute the *'Rabi'*. The summer is the *'Zaid'*.

2.5.2 Crop seasons of Kerala

In Kerala, there are three crop seasons, primarily based on the availability of rainfall. They are-

Virippu: April-May to September-October. (South-West monsoon season)

Mundakan: September-October to December-January (North-East monsoon season)

Punja: December-January to March-April (Summer season)

The above classification of crop seasons is mainly followed for paddy crop. The *Virippu* crop is purely rainfed, and *Mundakan*, though get rains in the initial stages, need irrigation also in the later stages. The *Punja* crop is raised only where irrigation facilities are available.

All the above three seasons are not seen throughout Kerala. For example in Wynad, there are only two seasons viz., *Nanja* (June-December) and *Punja* (December-May) due to the peculiar climatic and physiographical conditions prevalent there.

2.6 Agro-climatic classification of Kerala.

In Kerala, almost all the development programmes of the Government are implemented taking district as a unit. It may be alright for programmes excluding agriculture. However, for agricultural programmes, the agro-climatic conditions of the area should also be considered. In a district, the boundary is fixed for administrative convenience. In the same district itself, there may be differences based on the agro-climatic features. Realising this fact, Govt. of Kerala, in 1973, appointed a committee drawing experts from various fields to identify a basis for agro-climatic zoning and its classification. They have identified four key constraints viz., altitude, rainfall, topography, and soil type. Accordingly, there are 13 agro-climatic zones in Kerala, taking into consideration these four parameters. The description of this 13 zones can be seen from the table 2.1.

Table 2.1: Agro-climatic zones of Kerala

Zone	Name	Area(km²)	Principal crops
I.	Onattukara	519	Rice, Coconut, Tapioca, Sesame Arecanut
II.	Coastal sandy	1564	Rice, Coconut
III.	Southern midland	3224	Rice, Coconut, Tapioca, Arecanut,
IV.	Central midland	2666	Rice, Coconut, Tapioca, Arecanut, Banana
V.	Northern midland	3765	Coconut, Rice, Arecanut
VI.	Northern midland (Malappuram)	4254	Rice, Coconut, Cashewnut, Arecanut
VII.	High land	8361	Rubber, Coconut, Pepper
VIII.	Palghat	1280	Rice, Cotton, Groundnut, Millets
IX.	Red loam	317	Rice, Coconut, Tapioca
X.	Chittur black soil	506	Rice, Sugarcane, Cotton, Groundnut, Millets.
XI.	Kuttanadu	284	Rice, Coconut
XII.	High Ranges	5140	Tea, Coffee, Cardamom, Rice
XIII.	River bank alluvium	—	Rice, Sugarcane, Coconut

(Source: *'Keralathinte Sampathe'* 1984, Kerala Shastra Sahitya Parishad).

Out of the 13 zones, the High lands, the High ranges and the four Mid lands alone constitute about 88 per cent of the total area. The High range region comprises of Idukki, Wynad, and Attappady areas. Below that, the area extending from Perunkatavila in the south to Sreekrishnapuram in the north, is the High lands. Southern midland is from Trivandrum to Kaduthuruthy; and Central midland from Pambakuda to Ottappalam. The Northern midlands include areas extending from Pandalayani to Payyannur; and the Northern midlands (Malappuram) extend from Tirur to Koduvally.

The agro-climatic classification is found to be more appropriate and useful as compared to the traditional classification of Kerala into high lands, midlands, and low lands which takes into account the altitude only. Since this classification takes into account rainfall, topography, and soil type also, in addition to altitude, it increases the reliability and usefulness for agricultural purposes.

3. Soil — An introduction to weathering and soil formation

3:1. Introduction

Soil is the natural medium on which plants grow. Excepting certain plants like epiphytes and aquatics, all the plants depend upon soil for anchorage, water, and mineral nutrients. Different approaches are there towards an understanding of the soil. Soil was considered by many, to be a mixture of rocks and mineral materials with orgnic matter. However, this concept fails to bring about the exact meaning of the word, as it points out only the material from which soil is formed or which constitute the soil. Several other definitions are also there, and they are used in different contexts.

According to a botanist or a farmer, soil is the medium for plant growth. In the view of a pedologist, soil is a natural body of mineral and organic constituents differentiated into horizons, which differ among themselves and from the underlying parent material in morphology, physical make up, chemical properties, and biological characters. A soil physcist, however, view soil as a three phase system, comprising the soil phase made of mineral and organic matter and various chemical compounds; the liquid phase called the soil moisture; and the gaseous phase called the soil air. All these concepts about soil are correct according to their applications for the study of soil.

The concept that the soil is the natural medium for plant growth is generally accepted in crop production. The soil provides anchorage, water, and nutrients for the plants. We may, thus consider soil as a thin layer of earth's crust which serves as a natural medium for the growth of plants.

As already stated, soil consists of three phases, viz., the solid phase, the liquid phase and the gaseous phase. The solid phase, consists of mineral matter and organic matter, the size and shape of which give rise to pore spaces (voids) of different geometry. The pore spaces are filled with the liquid phase (soil moisture) and the gaseous phase (soil air). The volume composition of these three main constituents in the soil system differs widely. A typical soil, for example, contains 50 percent solids, (45 percent mineral matter+5 percent organic matter), 25 percent water and 25 percent air (Fig.3.1).

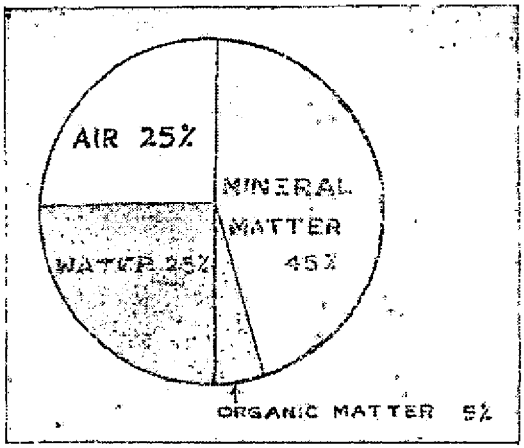


Fig. 3.1 Volume composition of a typical soil

3:2. The mineral matter

The mineral matter content of a soil is primarily responsible for its characteristics. The term *mineral* is given to any inorganic matter occurring on earth's crust having almost a uniform composition and possessing definite crystalline characters. The mineral portion is composed of both primary and secondary minerals. The minerals, which have not undergone much alteration after their formation from the molten magma, are known as *primary minerals*. They are having bigger size and are mainly found in igneous rocks. The sand and silt portion in a soil is chiefly composed of primary minerals eg. quartz, feldspars, micas, olivine etc.

Secondary minerals are formed from primary minerals by the action of climatic factors for a very long time. Due to this action, they undergo both physical and chemical changes and give secondary minerals of different properties. In other words, secondary minerals are the result of decomposition of primary minerals, or the result of recrystallisation of these decomposition products. Secondary minerals are abundantly seen in sedimentary rocks. Examples of secondary minerals include: calcite, dolomite, gypsum, limonite, and clay minerals like montmorillonite, illite etc.

3:3. The rocks

The minerals are formed from rocks of various types. In other words, rocks are the parent materials from which soils are formed. We may define rock as an aggregate of one or more minerals having different chemical composition. Based on the origin, there are three basic types of rocks viz., igneous, sedimentary, and metamorphic.

3:3.1. Igneous rocks (Fire rocks)

Igneous rocks are the oldest type of rocks formed by the cooling and solidification of lava (molten magma) from the interior of earth. They chiefly contain feldspars, maphic minerals and quartz. Two types of igneous rocks are there, based on their origin. The one, formed as a result of slow cooling and within the earth crust is called *plutonic* rocks such as granite; while the other type is formed by the rapid cooling of the materials coming out of the volcano — called *volcanic* rocks. Igneous rocks constitute about 95 percent of earth's crust. They are characterised by a massive crystalline structure. They may also be grouped into *acidic* igneous rocks, for example, granite-which contains a high proportion of quartz minerals (60-70 percent) and *basic* igneous rocks, for example, basalts-which contain less than 50 percent quartz.

3:3.2 Sedimentary rocks

They are formed from igneous rocks by the consolidation of rock materials due to mechanical or chemicals means, or from organic residues. The mechanical sedimentation is mainly due to water and wind. Rocks like sand stone, shale etc. are formed by mechanical sedimentation. Rock salts, gypsum etc. are sedimentary rocks formed from chemical sediments. Lime stone is formed from organic residues or by chemical precipitation. Sedimentary rocks are usually found in parallel layers.

3:3.3. Metamorphic rocks

They are rocks that have undergone change or metamorphism. They are usually formed from Igneous or sedimentary rocks by changes in their texture and/or chemical composition by the action of intense heat and/or pressure. They are usually characterized by a banded structure. Common netamorphic rocks and their parent rocks are given below:

Metamorphic rocks	*Parent rocks*
Marble	Lime stone
Quartzite	Sand stone
Gneiss	Granite
Schist	Granite
Slate	Clays

3:4. Weathering of rocks

Weathering is the process responsible for soil formation. Rocks, which are the starting point in weathering, are first broken down into smaller rocks, and finally to minerals. The minerals once formed may also be attacked by weathering forces and are changed to new minerals. All these changes bring about a continued decrease in particle size. Weathering of rocks and minerals consists of physical, chemical, and biological process of disintegration and decomposition.

3:4.1. Physical weathering

Physical weathering is also known as disintegration. The factors responsible for this bring about a decrease in size of rocks and minerals, but usually, may not affect their chemical composition. The factors involved in physical weathering are temperature, water, and wind.

Temperature: Rocks are composed of different minerals and their coefficients of linear or volume expansion vary when heated. Alternate heating and cooling of rocks during day and night bring about a differential expansion of the minerals contained in the rocks. This imparts differential stresses on the rocks leading to cracks and peeling of surface layers.

Water: The cracks and crevices seen on the rocks get filled up with water when the rains come down. In cold regions, during winter nights, this water gets transformed into solid ice. This leads to an increase in volume. The force, thus created due to the increased volume, is irresistable and help in the disintegration of rocks. The rock and mineral particles carried by flowing water also bring about weathering due to abrasive action.

Glaciers or ice bergs are also responsible for weathering. The ice bergs possess considerable transporting power and act as major weathering force in temperate countries. The ice bergs of huge size can carry bigger fragments of rocks and crush them into powder. The soils of North America and Europe were first formed by glacial action. Glaciars are usually seen in the Himalayan areas.

Wind: Wind acts as a transporting agent and cause considerable weathering. Weathering is more intense, when it carries particles of dust, sand and gravel. The wind along with the carried particles hits on rocks and bring about exfoliation of surface layers of rocks due to the abrasive action.

3:4.2. Chemical weathering

The smaller particles of rocks and minerals, formed as a result of physical forces, are acted upon, later, by various chemical agents. Chemical weathering or decomposition brings about definite chemical changes. Thus, soluble materials are released, new minerals are synthesized, or left as resistant products.

The various decomposition processes are described below:

Hydrolysis: This is an important way in which chemical break down of minerals occur. In hydrolysis, a mineral combine with water to form an acid and a base. The decomposition of orthoclase feldspar is an example for this double decomposition.

$$KAlSi_3O_8 + HOH \longrightarrow HAlSi_3O_8 + KOH$$

Orthoclase feldspar (less soluble)	water	Acid silicate (fairly soluble)	Potassium hydroxide (highly soluble)

The released potassium may be used by plants or adsorbed on clays; while the acid silicate undergoes further changes and colloidal clay minerals are formed.

Oxidation: Oxygen is an active element and it combines freely with other elements. The action of oxygen is more profound in the case of compounds of iron, as a definite colour change results.

$$\underset{\text{(Black)}}{Fe\,S} \xrightarrow{\text{Oxidation}} \underset{\text{(Greenish)}}{Fe\,SO_4}$$

The oxidation of elements results in the formation of more bulky or more soluble compounds.

$$\underset{\text{(Slowly soluble)}}{Zn+O_2} \longrightarrow \underset{\text{(readily soluble)}}{ZnO_2}$$

Reduction: Reduction is the chemical process in which oxygen is removed from a mineral. Reduction of ferric ($Fe^{3}+$) ion to ferrous ion ($Fe^{2}+$) and subsequent leaching of ferrous ion due to its mobility is an example of this type of weathering.

Hydration: Hydration implies the attachment of H and OH ions to the compounds that are subjected to weathering which results in a change of the mineral. For example, haematite on hydration gives yellow limonite.

$$\underset{\text{(haematite-red,firm)}}{2Fe_2O_3+3H_2O} \longrightarrow \underset{\text{(limonite-yellow, soft)}}{2Fe_2O_3.3H_2O}$$

Carbonation: Carbonation is a common process in nature, where CO_2 combines with water to from carbonic acid; which reacts with carbonates to form more soluble bicarbonates.

$$CO_2+H\,OH \longrightarrow H_2\,CO_3$$

$$H_2\,CO_3 + Ca\,CO_3 \longrightarrow Ca\,(H\ CO_3)_2$$

Carbonic acid	Calcium carbonate (insoluble)	Calcium bi carbonate (highly soluble)

Solution: Water acts as a solvent for many solid materials, especially for salts, and it helps in the processes of weathering. The solution effects of CO_2 in water have been already mentioned. It helps in the conversion of a solid mineral to one of a liquid state. See the following example.

$$NaCl+H\,OH \rightarrow Na^{+}+Cl^{-}+H\,OH$$

Solution facilitates a continued removal of constituents from rocks, either in dissolved or in dispersed state. Forming solution in water is also very essential to bring about various other chemical changes such as hydration, hydrolysis, carbonation etc.

3:4.3 Biological weathering

The action of the living organisms on the parent materials, which results in their disintegration and decomposition, is termed biological weathering. The important living agents which help in weathering are plants, human beings, burrowing animals, earth-worms, micro organisms like alage, fungi, bacteria etc.

Animals like rats dig burrows which result in the formation of smaller minerals due to abrasive action. Similarly, roots of higher plants exert considerable pressure on rocks by way of growing into cracks seen on rocks. The micro-organisms help in the decomposition of organic residues which release considerable quantities of carbonic acid, and this acts as a weathering agent by the carbonation reaction. Likewise, many chemosynthetic bacteria bring about a series of oxidation reactions which are helpful in weathering.

3:4.4. The regolith

The weathering processes of disintegration and decomposition will give rise to *regolith*, the unconsolidated mantle of weathered rocks and soil materials on the earths surface, or the loose earth materials above solid rock

The upper portion of the regolith differs from the material below. The weathering actions of wind, water, and heat are more intense on this upper portion, since it is nearer to the atmosphere. Plant residues are also found disintegrated and partially decomposed in the zone. The upper portion of the regolith is the soil and is distinguishable from the material below, as it is having a relatively high organic matter content. Presence of plant roots and micro-organisms and presence of characteristic horizontal layers are other features.

3:5 Soil formation and development

Soil formation, in simple terms, is the formation of soil from the parent material. The weathering processes combined with the associated physical and chemical phenomena, constitute the processes of soil formation. The weathering of rocks provides the parent material from which the soil is formed. Simple forms of life followed by higher forms, start to live on that soil. Their activities, along with the various decomposition products formed, hasten soil formation. Some of the materials formed may be translocated from one point to another within the soil column. Eventually, a vertical differentiation of soil column takes place. The vertical differentiation of weathered materials (soil) into various layers or horizons may be called soil development. These horizons or layers are formed very slowly, and takes a very long time.

3.5.1 Factors involved in soil formation and development

The processes of soil formation and development, basically, includes the addition of organic and inorganic materials, the translocation of these materials from one point to another within the soil column, and the transformation of these materials within the soil. Several *active* and *passive* factors are involved in these processes. The major factors recognised are climate, organisms, parent material, topography, and time. Among these, the climate and organisms are the active factors; and the parent material, topography, and time constitute the passive factors.

Climate: Climate is the most influential factor determining the soil formation and development. The temperature and precipitation exert profound influence on the rate of chemical and physical weathering. Not only the total rainfall, but also its distribution are important in soil formation and development. They also determine the erosion and percolation characteristics of the soil. It is observed that, for every 10°C rise in temperature, the chemical reactions are doubled. Hence, soils of tropics are highly weathered. Other climatic factors like evaporation, wind etc. have also got their role in soil formation.

Organisms: Both animals and plants, which interact with rocks, mineral matter, water and air, play an important part in the soil development. The plants influence the soil forming processes by supplying organic matter, the decomposition of which produces CO_2 and humus. Micro-organisms, too, play an important role in soil building and soil development. Animals interfere in soil formation by mechanical ways; while human beings become a soil forming agent, when they start cultivation by tilling, bunding, fertilizing etc.

Parent material: The parent materials from which the soil is produced, play an important role in determining its development. The nature of parent materials controls the speed of weathering processes. It also determines the soil texture, erosivity, nature of clay content, nutrient status and colour. Usually, a soil formed from a basic parent material would be more fertile than that formed from an acidic parent material.

Topography: Topography or relief of an area, determines the speed of action of climatic forces. It can delay or speed up their action. Usually, a levelled area develop more deep and matured soils, compared to a slopy area. Thus, the topography not only modifies the climatic factors, but also act as a controlling factor in determining tha nature of profile formed.

Time: The formation of soil is a very slow process, and takes a very long time to develop a fully matured soil. It is a function of time. However, no fixed time period can be laid down to say when a parent material would be fully transformed into soil. It generally takes about 6000 years to form one foot of top soil. In tropics, the soils would be formed more faster than in the temperate regions.

There are no distinct stages in the development of soils, Only a few points can be identified as the rocks or recently deposited soil materials are transformed into a well developed soil profile. The major processes identified in the soil formation and development are decomposition, synthesis, illuviation, eluviation, accumulation, and homogenization.

3:5.2 Soil profile

Soil profile, in simple terms, is a vertical section through the soil mass. Due to the action of various soil forming process for a very long time, the soil mass is differentiated into a number of horizontal layers or *horizons*. The soil profile is a representation of various horizons, and the profile features are unique for a particular type of soil. The plants initiate this profile development by supplying organic matter. Water plays an important role in the transportation and deposition of soluble materials. These processes create a lead to layering or horizon development. A vertical section of the soil, from tha surface to the bed rock showing the various layers or horizons, is termed a soil profile.

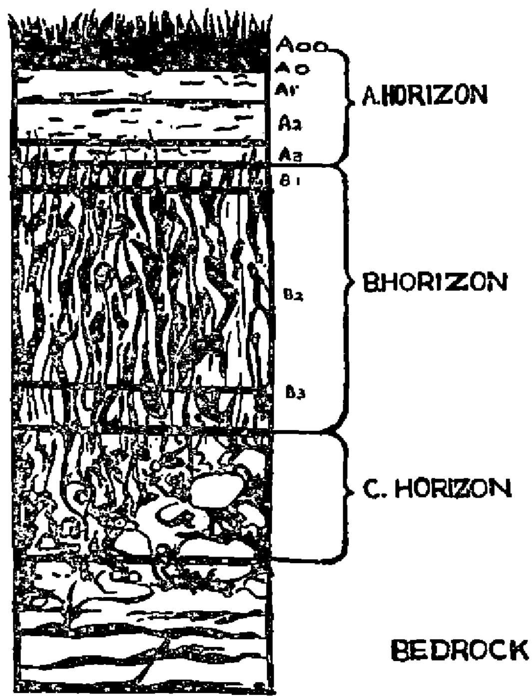


Fig. 3.2 A typical soil profile showing the horizons

The various horizons are formed as a result of the removal and deposition of weathered materials from upper to lower parts of soil. The different horizons can be distinguished from one another due to their difference in colour, chemical nature texture, depth etc. Generally, there are three horizons in a representative soil. They are called A, B and C horizons. In each horizon, there may be sub-horizons also. A typical soil profile is diagramatically represented in the Fig. 3.2.

Brief description of horizons and sub divisions

Aoo or O_1 — Top most horizon, composed of undecomposed organic matter (litter)

Ao or O_2 — Partially decomposed organic matter.

A_1 — Fully decomposed organic matter (humus), which imparts a darker colour.

A_2 — The region of heavy leaching, (eluvial zone)-light coloured layer.

A_3 | B_1 | Transitional layers.

B_2 — The zone of deposition, (illuvial zone), where materials leached from surface layers are deposited.

B_3 — Transitional layer.

C — The unconsolidated materials underlying the solum (A and B horizons), which supplies the parent materials from which the upper layers are formed.

Generally speaking, A horizon is the surface soil and contains more organic matter which provides a black colour to the top soil.

The B horizon mainly contains minerals which may not have weathered. It can be considered as the subsoil, and it contains many accumulated materials like iron oxide, aluminium oxide, clay etc.

The A and B horizons, the upper and most weathered part of the soil profile above the parent materials, are collectively referred to as *solum*. The word solum (plural: sola) is from Latin, meaning soil, land or ground.

The C horizon is also an unconsolidated layer where the parent materials are present. It may be produced from the bed rock, or may be deposited over the bed rock from other materials.

Below the parent materials or the C horizon, the bed rocks are seen. The parent materials are formed from the bed rocks.

The above described profile features may not be seen in all the soils, and each soil has its own profile features. The profile studies are very important in a crop production point of view, as it reveals the surface and sub surface characteristics of a soil which directly affects plant growth. The profile features also help in the classification of soils. It acts as a basis for soil science studies, too.

3:6. Soil surveys

Soil surveys are primarily aimed at gathering comprehensive information about soil and land resources of an area. Studying and recording major characteristics of the soils, classifying them into well defined units, and locating their extent and boundaries on a map are the main tasks associated with soil surveys. Though the basic objective of soil survey is to expand our knowledge and understanding of soils in relation to their genesis, development, classification, and nomenclature, the information obtained is also useful in planning and development programmes of the country. Soil survey reports are useful in *Land use planning* (planning for irrigation, drainage, rural zoning, planning for large dams for water storage etc.), *Farm planning* (determining the major land uses, cropping systems, tillage methods, fertilization, soil and water management etc.), *Forest management* (more or less similar to farm management) and in *Engineering works* (planning high ways, air ports, dams, canals etc.).

There are two main types of soil surveys—reconnaissance surveys and detailed surveys. In the case of reconnaissance surveys, the scale used for mapping is usually, 1 to 50,000. Soil profiles are located at intervals of 3 to 6km, depending upon soil heterogenity, and are examined as per standard procedures. Photographs of profiles and landscapes are also taken. Reconnaissance surveys and resultant maps provide information for identifying bench mark soils and delineating problem and potential areas. They are also helpful for a broad land use planning and agricultural development at the Taluk level and upwards.

Detailed surveys are mainly aimed at bringing out differences in respect of soil and terrain features, and maps with a scale large enough to delineate the phases of soil types, slopes, erosion etc. within a series are used. Base maps used are in the scale of 1to8,000 or aerial photographs in the scale of 1 to 20,000, or even longer. Auger samples of soils are examined at closer intervals,usually 250-500m intervals, depending upon soil heterogenity. Detailed surveys are helpful in the interpretation and classification of soils into land use classes, sub classes and capability units.

In Kerala State, the task of conducting soil surveys is entrusted with the State soil survey organisation attached to the Directorate of Agriculture (S. C. Unit), Trivandrum. The co-ordination and carrying out of soil survey works at the national level is done by the National Bureau of Soil Survey and Land use Planning, Nagpur.

4. Physical properties of soil

4:1. Introduction

The physical properties of a soil determine its practical adaptability. It determines such important characteristics of soil as water holding capacity, aeration, nutrient holding capacity etc. The important physical properties of soil are soil texture, soil structure, pore space or void, soil colour, soil temperature, soil consistency etc. The physical properties of a soil is primarily influenced by its mechanical composition.

4:2. Mechanical composition of soil

Mechanical composition of a soil is nothing but its solid phase composed of mineral matter. As we have already seen, the mineral particles are the chief components of most soils, except in organic soil such as peat. They consist of rock particles developed *in situ* by weathering, or deposited in bulk by wind or water. The mineral matter, thus formed, consists of soil particles or soil separates of different sizes. The soil particles are, usually, classified according to their size. The soil particles having a diameter of more than 2 mm is classified as *gravel*; while the material smaller than 2 mm in diameter is the *fine earth*. Only the fine earth is considered in the chemical and particle size analysis of soils. The componants of fine earth are *sand*, *silt*, and *clay*. All the soils on earth are the result of combinations of these fundamental particles in varying proportions.

The size limits of the fundamental soil particles have been prescribed by various national and international organisations. The most commonly used systems of classification of soil particles, based on size limits, are those proposed by the United States Department of Agriculture (USDA) and by the International Soil Science Society (ISSS). The most important classification is that of ISSS, and it is commonly followed.

The ISSS system is given below:

Fraction	*Particle diameter*
Gravel	> 2 mm
Coarse sand	0.2 —2 mm
Fine sand	0.02 —0.2 mm
Silt	0.002—0.02 mm
Clay	<0.002 mm

Sand and silt particles are almost spherical or cubical in shape. Soil that has been formed *in situ* and not been transported, may contain sand and silt particles of sharp edges. The edges of the soil particles deposited by wind or water are smoothened off in transportation. Clay particles are, however, plate or lath shaped, unlike sand and silt particles. The bigger sized soil separates like gravel and sand, and to an extent silt, are composed of primary minerals; and smaller sized particles like silt and clay consist of secondary minerals.

4:3 Soil texture

The term soil texture is used to indicate the relative proportion of soil particles or soil separates in a soil sample. Soil texture gives the degree of coarseness or fineness of the soil. There are several techniques for determining the percentage of coarse sand, fine sand, silt, and clay in a soil sample. The determination of soil separates is by means of particle size analysis (formerly mechanical analysis). This is conducted by sedimentation, sieving and or by micrometry.

According to the proportions, in which the fundamental soil particles are present in a soil sample, there could be several textural classes. There are 12 textural classes, according to the USDA soil textural classification chart (Fig. 4.1). For determining the textural class, USDA system employs a textural triangle; and by plotting the percentage of sand, silt, and clay obtained by mechanical analysis on this, we could determine the textural class of the soil in question. The principal soil textural classes recognised, ranked according to increasing amounts of fine particles are sand, loamy sand, sandy loam, loam, silt, silt loam, sandy clay loam, clay loam, silty clay loam, sandy clay, silty clay, and clay.

While designating the different textural classes, the names of predominant

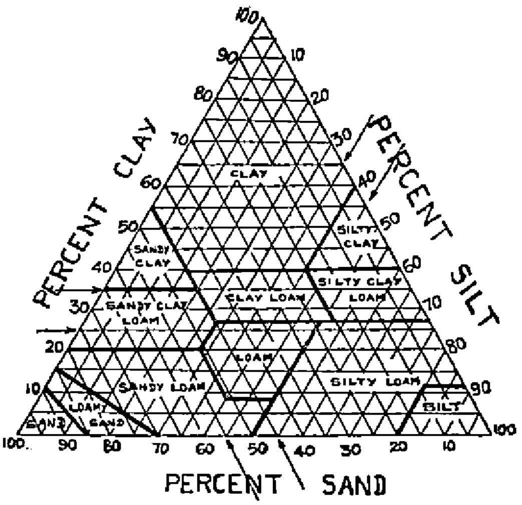


Fig. 4.1 USDA soil textural classification chart

size fractions are used. The word 'loam' is used whenever all the three major size fractions occur in sizable proportions. A textural class, when it is designated by the names of two size fractions such as silty clay, denotes that the clay characteristics are outstanding. It also contains a substantial quantity of silt. A silty clay loam is similar to silty clay, except that it contains sand in a sizable proportion. Sandy soils are coarse textured; loam soils are medium textured; and clay soils are fine textured. A few of the important textural classes are described below:

Sandy soils: In sandy soils, 85 percent or more of sand particles are present. They are of low fertility and have low specific surfaces. They are coarse textured, loose, and well aerated. They have low water holding and ion exchange capacities.

Clayey soils. They contain more than 40 per cent clay particles and below 45 per cent sand or silt. They are composed of secondary minerals, and possess high specific surface and ion exchange capacity. They have good water and nutrient holding capacities.

Loamy soils: A soil that contains about 40 percent sand, 40 percent silt, and 15 percent clay may be called a loamy soil. They are intermediate in properties to light and heavy textured soils. They are the ideal soils in crop production.

The coarseness or fineness of soil could be noted in the field by a sense of feel. The soil is rubbed between the thumb and finger in a wet condition, and the farmer interprets the feel as whether the soil a coarse textured, medium textured or fine textured one. Where laboratory facilities are there, the proportion of particles are found out by mechanical analysis or particle size analysis. After finding out the percentage of sand, silt, and clay, they are projected on the textural triangle and the exact class of soil is found out.

4:4 Soil structure

Soil structure refers to the arrangement of soil particles with respect to each other into certain patterns. The soil particles like sand, silt, and clay are not found separated in the soil, but aggregate themselves to form various structurals units. The soil structure determines the properties of soil like aeration, permeability, tilth, erosivity, and water holding capacity Soil structure is usually described in terms of type, class, or grade.

Types of soil structure

Type refers to the shape and arrangement of aggregates. The principal types are as follows (Fig 4.2).

Platy structure: In this type, particles are arranged as thin horizontal plates.

Prismatic: Here, the vertical axes of aggregates are longer than the horizontal axes.

Columnar: When the prismatic structure is with dome shaped tops, it is columnar.

Blocky: The structure is blocky, when the particles are arranged around a point and bounded by flat or rounded surfaces. *Angular blocky*-when the blocks have sharp edges and corners; and *sub angular blocky*-when the blocks have sharp edges, but rounded corners.

Spheroidal: When the particles are arranged around a point and when both the corners and edges are round, it is spheroidal structure. All rounded aggregates may be grouped under this. This

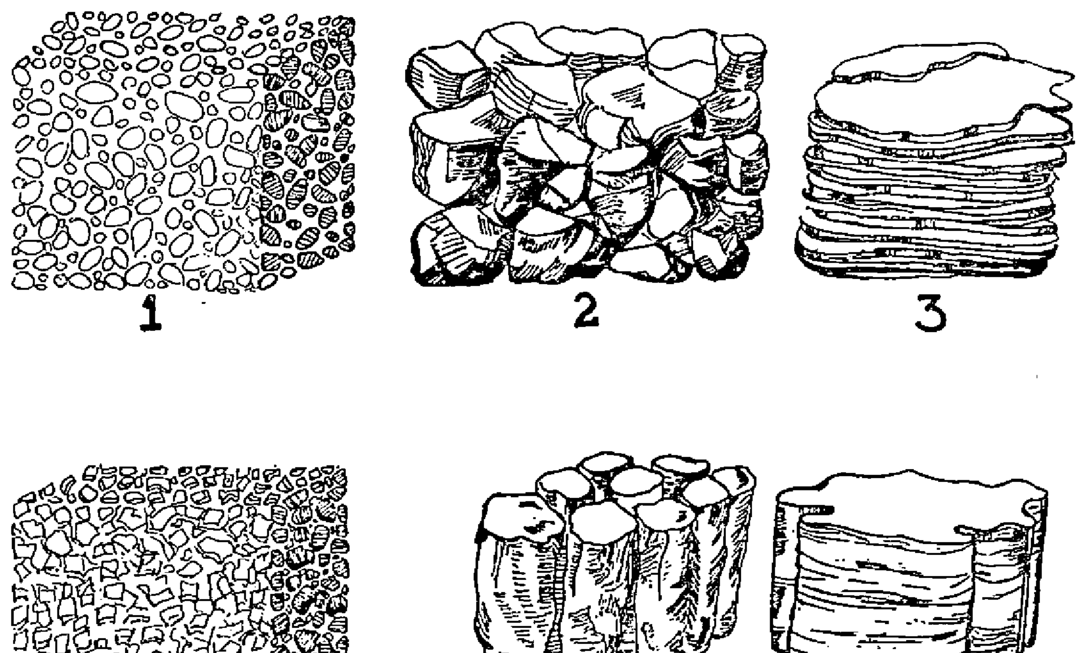


Fig. 4.2 Principal types and grades of soil structure
1. Single grain 2. Blocky 3. Platy 4. Granular 5. Prismatic 6. Massive

nclude *granular* and *crumb* structure. Granular or crumbs are the ideal soil structure for plant growth.

Classes

Class refers to the size range of the aggregates. There are five classes recognised in each of the types. They are *very fine, fine, medium, coarse*, and *very coarse*.

Grades

Grade of soil structure denotes the degree of aggregation. Grades are termed *structureless,* when there is no observable aggregation. It may be *massive*, if the structureless soil is coherent as in dense soil crusts and plough pans; and *single grained,* if noncoherent as in sands or silts. Other grades are *weak, moderate, strong,* and *very strong.*

Structure is a varying physical property, and it is affected by the use of tillage implements, organic matter application, microbial activity, soil moisture content, type of cations present on the clay particles, lime content, kind of crops grown etc.

4:5 Soil colour

Soil colour may be inherited from the colour of the parent material, or may have resulted from the soil forming processes. The colour may be imparted by the organic matter content or mineral content of the soil. Red, yellow, or brown colours are imparted mostly by iron compounds; and dark colour is due to the presence of organic matter, magnetite etc. Soil colour largely influences the properties of soil like temperature. A black soil absorbs more heat and warms up quickly than light coloured soils. Generally, black soils are found to be more fertile.

Usually, soil colours are compared by using standard colour charts like Munsell colour charts. It was developed by A. M. Munsell in 1905. The colour is expressed in terms of three variables—the hue, the value, and the chroma. For example, a soil having a bright reddish brown colour can be noted as 5 YR 5/6 according to Munsell charts, where 5 YR represents hue, 5 represents value, and 6 represents chroma.

4:6. Soil temperature

It regulates the important physiological functions of soil as seed germination, microbial activity, root and shoot growth, and nutrient availability. According to the type of crop grown, optimum soil temperature varies. As in the case of atmospheric temperature, very low and very high temperatures are unfavourable to plant growth. Soil temperature is influenced by various factors like soil colour, slope, water content, vegetative cover etc. For example, a dark soil will absorb more heat than light soils, and soils with more water retain more heat for a long time. Soil temperature is also an important criterion in the classification of soils.

4:7. Particle density and Bulk density

Particle density is the mass of unit volume of soil particles. Particle density is also called soil density or true specific gravity. Bulk density refers to the mass of unit volume of dry soil which include the pore spaces also. The term apparent specific gravity is also used to denote bulk density.

$$\text{Particle density} = \frac{\text{Mass of soil solids}}{\text{Volume of soil solids.}}$$

$$\text{Bulk density} = \frac{\text{Mass of soil}}{\text{Volume of soil}}$$

Bulk density depends upon the soil pore spaces as well as the soil solids. However, particle density is concerned with the soil solids only.

4:8. Pore space

The portion of soil occupied by water and air is termed as pore space or void. Sandy soils are having low pore spaces of about 30 percent, and clays may have about 50-60 percent. Well managed loamy soils may have a pore space of about 40-50 percent. Though clayey soils possess more pore spaces than sandy soils, being individually larger, the pore spaces in the latter is more conducive to aeration and drainage.

4:9. Plasticity and cohesion

The property of a moist soil to change its shape when a force is applied, and to retain this shape even when the force is with drawn, is called plasticity. Cohesion refers to the property of soil particles to attract or stick to one another. These two properties largely influence the workability and consistancy of soils.

4:10. Soil air

The soils may have a pore space of 30–60 percent depending on the texture. The pore spaces are occupied by soil water and soil air. The macro (bigger)pores are filled with air and micro (smaller) pores or capillary pores are occupied by water. However, this is a changing phenomena, depending upon the relative proportion of water and air. For example, in a flooded soil, practically all pore spaces would be occupied by water; and in a dry soil, there may be more air than usually present. Normally, all the pore spaces ,not filled with water are occupied by the air. The condition in which nearly one-third of the pore spaces occupied by air and two–third by water is the optimum for the successful growth of plants.

The composition of soil air is somewhat similar to that of the atmospheric air. However, the soil air contains a slightly more moisture, more carbondioxide, and a little less oxygen. The carbondioxide is mainly derived from the plants and the organic matter present in the soil, and its quantity is highly affected by crop growth and biological activities of soil. The composition of a typical soil air and atmospheric air are given below for comparison.

	Soil air	*Atmospheric air*
Oxygen (%)	20.65	20 97
Carbon dioxide(%)	3.25	0.03
Nitrogen (%)	79.20	79.00

5. Soil water

5:1. Introduction

A typical soil contains about 25 percent of the total volume occupied by water. Soil water exerts the maximum influence on the growth of plants than any other soil characteristics. Plants require large quantities of water to sustain their life. Nearly 90 percent of the plant tissues are composed of water, and it is performing several functions both directly and indirectly. Water serves as a medium for making the nutrients available to plants. It is also used to absorb and transport the nutrients from the soil to the plant tissues. Water is also an essential raw material for the most complex and vital biochemical activity happening on earth, the photosynthesis. The products of photosynthesis are also conveyed in water solution to various parts of the plant. The maintenance of turgidity—rigidity and shape-is another function attributed to water in plants. This is especially important in herbaceous plants. Soil water also aids in the maintenance of soil temperature.

We have seen that soil contains both macro and micro pores and the pores occupy about 50 percent of the total volume in a typical soil. In normal cases, soil water will be occupying only the micro-pores. If the soil water began to occupy macro pores also, it means that drainage is impeded and soil air content reduced. Excess quantity of water in soil retards or inhibits plant growth. Drainage is extremely necessary in such cases. Similarly, when there is drought, soil moisture content will . be very less, which may even lead to the death of plants. Therefore, it is essential that we should take necessary precautions to maintain the soil water at an optimum level. For this, we should have an idea of the nature of soil water and its energetics.

5:2. Soil water terminology

Soil water is dynamic in nature, moving from one place to another under the influence of water moving forces caused by rainfall, infiltration, percolation, irrigation, evapo-transpiration, temperature etc. Large differences are also there in the amount and energy condition of water in adjacent areas of soil. A number of terms and units are used to describe the soil moisture content. A beginner in soil water study may get confused with this terms and units. Hence, an introduction to the most commonly used terminologies are relevant here.

5:2.1. Soil moisture tension

It has been found that moisture is held in the soil by the forces of adhesion, cohesion and solution, and such other forces; and since it is under a tension due to these forces, work must be done to remove soil moisture. It is also observed that the tension with which water is held in the soil depends upon the amount present–the smaller the amount the greater the tension. We have to quantify this tension and the term soil moisture tension is used.

Soil moisture tension is thus a measure of the tenacity or force with which water is held in the soil. It is measured in terms of force per unit area or pressure that must be exerted to remove water from an area. Soil moisture tension is usually expressed in pressure units. The units pascal (SI system), bar (Metric system) and atmosphere (Imperial system) are the usually applied units. Other units like newton per m^2, dynes per cm^2, and height of water column in cm are also sometimes used. The pF scale (Schofield, 1935) was also used earlier, which is the logarithm to the base of 10 of the numerical value of the soil moisture tension expressed in cm of water column. However, the units pascal (kilopascal-kpa or Megapascal-MPa) and bar are the most commonly accepted units of soil moisture tension nowadays. The relationship between these units are given below.

1 bar = 100 kPa (10^5 Pa)
= 100 kN m^{-2} (10^5 N m^{-2})
= 10^6 dynes cm^{-2}
= 1017 cm of water column
= 0.987 atmosphere

5:2.2. *Soil water potential*

As we have seen, soil moisture tension is the measure of the force with which water is retained in the soil. However, water potential is the measure of energy status of water present in the soil. In other words, it is the capability of a unit mass of water to do work, as compared to the work that an equal mass of pure free water at the same location could do. Since water is held in the soil by forces of adsorption, cohesion, solution etc., the soil water is not capable of doing as much work as pure free water, and hence, soil water potential is generally negative. The total soil water potential is contributed by various component potentials like gravitational potential, pressure potential, capillary or metric potential, and osmotic or solute potential. Soil water potential is generally measured in pressure units or energy units. Pressure units, especially pascal and bar are preferred.

According to this concept, the energy status of a pure free water is taken as zero. When the forces of retention in the soil is increased, the energy status of water is lowered. In other words, when the soil moisture tension is increasing, its energy status is reduced and assumes a negative sign. That is, soil water potential is the negative soil moisture teneion. For example, if we say a particular soil is having a moisture tension of 0.3 bar (30 KPa), we should understand that its soil water potential is—0.3 bar or—30 kPa. The concept of soil water potential is nowadays more accepted rather than soil moisture tension.

5:2.3 *Moisture content*

It is a general term used to express the amount of water present in a given quantity of soil. Moisture content is expressed, either as percentage moisture content by weight of dry soil, or as percentage moisture content by volume of soil.

5:3 Classification of soil water

The physical characteristics and the biological characteristics of the soil water are used to classify the soil water. The tension characteristics of the soil water is used to classify the soil, and this form the basis of physical classification of soil water. It is a known fact that all the moisture present in soil is not available to plants. So, based on the nature of availability of water for biological purposes, we can have a classification—the biological classification of water. The biological classification of water is more important on a crop production point of view.

5:3.1 *Physical classification of soil water*

Based on the relative degree of retention of water in the soil, there are three kinds of soil water—the free water, the capillary water and the hygroscopic water.

Free water: The free water, or the gravitational water, or the drainage water is the water that behaves according to the laws of gravity. It is the free water held in the soil at a pressure below 0.3 bars. The free water is mainly present in the macropores. It is not available to plants and percolates down under the influence of gravity.

Capillary water: The capillary water is the water held in the capillary pores (micro pores) of soil which behaves according to the laws of capillarity. It is present as a thin film around the soil particles and held at a pressure between 0.3 to 31 bars. A part of this capillary water is available to plants.

Hygroscopic water: The water that is held at a pressure above 31 bars is called hygroscopic water. It is seen as a very thin film around the soil particles and not available to plants. Actually it is seen as a solid film and moves only in vapour form.

5:3.2 *Biological classification of water*

Based on the nature of availability of water to plants, we may have the superfluous water, the available water and the unavailable water in the soil.

Superfluous water: The superfluous water is not available to plants. It simply moves down into deeper layers due to the force of gravity. This is the water held above the field capacity.

Available water: The available water is held between field capacity and permanent wilting point. It is held at a pressure between 0.3 bar and 15 bar. For successful plant growth, water should be supplied when 50-75 percentage of available moisture has been depleted. This 50-75 percentage of the available moisture is known as readily available water.

Unavailable water: The water held at a pressure above 15 bar is practically not available to plants. This portion of soil water is seen as a very thin film around the soil particles, and held at very high forces of retention. It includes the hygroscopic water and a part of capillary water.

5:4. Soil moisture constants

The soil moisture content in a particular soil is not constant at any given pressure since it is subjected to vapour pressure differences and pressure gradients. However, certain moisture levels are important in the scientific water management of crops and in the study of soil moisture characteristics. These are generally refered as soil moisture constants.

5:4.1. *Maximum water holding capacity*

The soil is said to be at maximum water holding capacity, when all the pore spaces of the soil—both macro and micro pores—are filled with water. This constant is also called saturation capacity or maximum retentive capacity. The tension of water at this point is almost zero, and it is equal to free water surface.

5:4.2. *Field capacity*

The water received in the soil through rainfall or irrigation infiltrates into the soil, and continues to move in the soil mass to deeper layers, because of the gravitational force. The downward movement of water practically ceases after about 48 to 72 hours. The water retained in the soil under this situation is called field capacity which forms the upper limit of available water for plants. Thus, the field capacity can be defined as the maximum amount of water that is retained by the soil after the drainage of gravitational water, and it forms the upper limit of available moisture for plants.

The soil moisture tension of many freely drained soils at field capacity has been found to be about 0.33 bar. However, the soil moisture tension at field capacity vary from soil to soil and it generally ranges from 0.1 bar to 0.33 bar.

Field capacity is determined in the field by flooding water in an area of 2-5 m^2, and allowing it to drain for one to three days after preventing surface evaporation by means of polythene sheets or thick straw mulches. After this time, soil samples are collected from the wetted zone, and the moisture is determined by the gravimetric method.

5:4.3. Permanent wilting point

The permanent wilting point (or percentage) is also known as the lower limit of available water or wilting coefficient. The permanent wilting percentage is the soil moisture content at which plants can no longer obtain moisture to meet its physiological requirements and permanently wilt. For many soils, permanent wilting occurs at about 15 bars, though it ranges depending on soil texture, kind and condition of plants, the amount of soluble salts in the soil solution, and climatic factors. However, there is not much difference in the moisture percentages regardless of the tension at this point. So, the moisture content of soil at 15 bar pressure is commonly taken for this point.

Usually, plants show symptoms of wilting, when the soil moisture level surpasses readily available moisture range. This is temporary wilting, and it occurs when 50-75% of the total available water is depleted. The temporary wilting can be cured by adding water. However, if the moisture content approached the permanent wilting point, the recovery of the plant is not possible, and it would permanently wilt. Even if we irrigate the plant, it would not recover at this point.

Under field conditions, indicator plants in containers are used to determine the permanent wilting point. Usually, sunflower plant is used as an indicator plant. The plants are allowed to wilt in the field, and are then put in a moisture chamber to test whether it regain turgidity. This process is repeated until the plant permanently wilts. At that point, the residual soil moisture in the container is calculated as the permanent wilting percentage. Permanent wilting percentage at 15 bar can also be determined by means of pressure membrane apparatus in the laboratory.

5.4.4. Hygroscopic coefficient

This is also an assumed constant of soil moisture content, at which all the capillary water is removed from the soil. The soil moisture tension which corresponds to hygroscopic co-efficient is about 31 bars. This constant is not of much significance in agriculture.

5:5. Determination of soil moisture

5:5.1: Gravimetric method

Gravimetric method of soil moisture determination is the most commonly employed method. Soil moisture measurement is done on soil samples of known weight or volume. The soil samples are collected with a soil auger or sampling tube in air tight aluminium containers. Then, the samples are weighed and are dried in an oven at 105°C for about 24 hours until all the moisture is driven off. After removing from the oven, they are cooled slowly to room temperature and weighed again. The difference in weight gives the weight of soil moisture in the sample and expressed as percentage.

Percentage of soil moisture by weight
= (weight of moist sample-weight of oven dry sample)x100/weight of oven dry sample.
Percentage of soil moisture by volume=
= Percentage of moisture content by weight x Bulk density

5:5.2. Tensiometer:

Tensiometer provides a measure of the soil moisture tension or the potential, and from this the soil moisture content can also be computed. A tensiometer consists of a porous porcelain cup, connected with a tube to a mercury manometer or vacuum guage. After filling the tube with water, the cup of the tensiometer is installed at desired depths. As the soil moisture is depleted, water from the porous cup moves out, and it will create a vacuum in the system. This is recorded in the manometer and gives a measure of the soil moisture tension, and from this the moisture status of the soil can be found out. Tension measuremants by tensiometers are generally limited to one bar but practically the useful limit is 0.85bar.

5:5.3. Resistance blocks:

Resistance blocks are made up of electrodes embedded in moisture sensitive materials like gypsum, nylon, or fibre glass. These blocks are installed at desired depth in the soil, and the electrical resistance developed at the electrodes are measured by using a potentiometer. The electrical resistance of the blocks will vary with the moisture content of the soil, ie., in a wet soil, the resistance will be low, and in a dry soil it will be more. This resistance is interpreted in terms of gravimetric soil moisture by using calibration charts or special devices. It is mainly used in dry soils ie., soils with moisture tensions of 1-10 bars.

5:5.4. Neutron moisture meter:

In this device, fast moving neutrons from a radio active source are allowed to hit on the H+atoms present in the soil, and the number of slowed down neutrons as a result of the collision are found out. The major source of H+ atoms in the soil is water molecules, and so, the number of neutrons slowed as a result of collision is directly proportional to the moisture content of the soil.

In addition to the four methods described above, other famous methods like Pressure membrane and Pressure plate technique are also there to estimate the soil moisture.

6. Soil colloids

6:1. Introduction:

The soil colloids are the most active portion of a soil. In a colloidal system, there will be a dispersed phase and a dispersal medium. In the soil colloid, the clay and humus forms the former, and water acts as a medium of dispersal. Usually, particles having a size below one micron show the colloidal properties. They will not settle and seen only through an electron microscope. They are highly stable.

Both organic and inorganic colloidal particles are present in the soil. The inorganic colloidal particles are the clay minerals of various types, and the organic colloids are the humus. Both of these are seen in an intimate admixture in the soil. We may see the characteristics and nature of soil colloids in this chapter.

6:2. Clay minerals:

The important clay minerals of the world are kaolinite, montmorillonite, illite, chlorite, vermiculite, halloysite, and amorphous clays. These are described below:

Kaolinite: The crystals of these minerals are made up of one sheet of silica and one sheet of alumina, and so, called a 1:1 type mineral. The two sheets are held by shared oxygen atoms, and the different units are held together by tight oxygen-hydroxyl linkages. Water, therefore, can not penetrate between the sheets, and due to this, the clay does not expand on wetting. Low surface charges, low cation exchange capacity and limited colloidal properties are other characteristics.

Montmorillonite: Here, the crystal units are made up of two sheets of silica and one sheet of alumina held together by shared oxygen atoms (2:1).The different crystal units are connected by weak oxygen-oxygen linkages, and so, water penetrate on wetting and expand. High surface charges and high cation exchange capacity are other features. It is more plastic and cohesive than kaolinite.

Illite: Illite has the same crystalline structure as that of montmorillonite. The difference is that the crystal units are connected by additional linkages of potassium atoms. They show characteristics which are intermediate to that of montmorillonite and kaolinite.

Sesquioxide clays: These are mixtures of iron oxides and aluminium hydroxides found in certain soils of the tropics. They are amorphous or crystalline and do not expand on wetting. Low fertility status, low exchange capacity and high toxic aluminium content are other notable characteristics.

Chlorite, vermiculite, halloysite etc: Chlorite, vermiculite, halloysite etc. are the other important clay colloids present in the soil. Chlorite is a 2:2 type clay mineral, vermiculite a 2:1 type, and halloysite a 1:1 type clay mineral.

Amorphous clays: are also there which originated from volcanic ash and not developed fully into crystals.

6:3. Soil organic matter:

Soil usually contains 4-6 percent organic matter by volume, and seen in combination with mineral particles. Though it comes only a very small portion, it plays a significant role in the productivity of soil. The organic matter serves as a food for soil micro organisms which are responsible for decomposing complex materials into simple substances readily used dy the plants. The addition of organic matter improves the working quality or friability of soil. Organic matter also helps to form the crumb structure in farming. The intermediate products of decompositien of organic matter have also got their share in improving the physical condition of the soil. The humus produced as a result of decomposition of organic matter is present in the soil in a colloidal form. Humus has got high cation exchange capacity which ultimately increases the fertility status of the soil.

6:3.1 Nature of soil organic matter

The soil organic matter consists of a series of products which range from undecayed remnants of plants and animals to fairly amorphous brown to black materials, which have no trace of the anatomical structure of the material from which it is formed. In addition to the organic constituents present in undecayed plant and animal tissues, soil organic matter contains living and dead microbial cells, microbially synthesized compounds, and derivatives of these compounds produced during the decay. The kind and content of organic matter present in a soil is highly influenced by climatic factors like rainfall, temperature; soil factors like soil reaction, drainage; and biotic factors like vegetation and soil micro organisms. The organic matter content in most of the Indian soils is generally low because of the high rate of decomposition under tropical and subtropical climate.

6:3.2 Humic and non-humic substances

Soil organic matter may be divided into two groups based on the above discussion—non-humic substances and humic substances. Non-humic substances include all those substances occuring in plants and micro-organisms that are not attacked or being attacked by the soil micro-organisms. Carbohydrates, proteins, fats, waxes, resins, pigments, and certain low-molecular weight compounds can be included in this group. Most of these compounds are easily attacked by soil organisms, and have a rapid turn over in the soil. Humic substances, however, are those materials produced in the soil as a result of microbial decomposition and are either yellow or brown to black, acidic, polydisperse substances of high molecular weight.

Humic substances or the humus is the highly reactive portion of the soil and is entirely different from the oiganic substances from which it is formed. Humus is the major organic colloid present in the soil. The humus particles are amorphous in nature and posses high cation exchange capacity. Humus is sparingly soluble in water and have very large surface area. It possesses good nutrient holding capacity and is less plastic and cohesive in nature. The average composition of humus is as follows.

Carbon	50%
Oxygen	35%
Nitrogen	5%
Hydrogen	5%
Ash (other elements)	5%

6:3.3 *Organic matter and soil productivity*

Organic matter present in the soil influences most of the physical and chemical properties of soil. The important roles of organic matter in the soil are discussed below:

Nutrient supply: Organic matter acts as a reservoir for plant nutrients. Major portions of the soil nitrogen, soil phosphorus, and sulphur exist in an organic form. As the organic matter decomposes, these elements become available to plants. They also supply a large amount of micro-nutrients needed for the crop.

Vitamins, auxins and antibiotics: Auxins and vitamins are added to the soil through the crop residues and the organic manures, and also produced by the living population of the soil. It is reported that plants can take up vitamins from the external medium through the root system Auxins produced in the soil have a positive action on the seed germination, growth of roots, and aerial organs; and on the yield and quality of the crops. Some amount of antibiotic substances are also produced in the soil which may minimize the incidence of diseases.

Effect on mineral compounds: Organic acids and carbondioxide produced during the process of decomposition can increase the availability of insoluble phosphates and some metallic trace elements.

Retention of cations: Soil organic matter accounts for an appreciable part of the total cation exchange capacity which helps to retain cations in the soil. Retention of cations will guard against the possible losses by means of leaching and other means.

Buffering effect: Organic matter has also got a buffering action, by which it reduces the likelihood of damage to plant roots from excessive acids, alkalies, or salts—whether naturally present in the soil or added to it, and thus, helps to stabilise the soil pH.

Soil structure: It is a known fact that application of organic matter such as crop residues and manures increases the bonding of soil mineral particles into water stable aggregates. The decomposition products of organic matter are the agents which help to bind the soil particles. These aggregates, in turn, helps in the formation of a crumb structure which is friable and loose. The crumb structure is considered as the most appropriate for crop produetion.

Soil moisture retention: Organic matter increases the capacity of soil to absorb and retain water to the extent of several times its dry weight. Beneficial effects on water holding capacity is more pronounced in sandy soils. Increase in the available water holding capacity to the extent of even 33 pereent was noticed in sandy loam soils by the addition of organic matter.

Soil temperature: Organic matter acts as a protective covering on the soil surface, which in turn, helps to maintain the soil temperature.

Soil tilth: The addition of organic matter improves the workability or friability of soil. Its addition to clay make it more porous and workable.

Soil erosion: As already seen, organic matter addition helps to improve the water holding capacity of soil. Its addition, thus, improves the infiltration of rain water, reduces the run off losses and ultimately lessens the soil erosion hazards.

Drainage: The addition of organic matter improves the drainage characteristics of soils, especially in heavy soils. It has been shown that organic matter improves the porosity of soils. The increase in porosity defenitely improves the drainage characteristics.

6.4 Ion exchange

Now, we shall see the ion exchange phenomena occurring in the soil due to the soil colloids. Clay minerals and humus, in general, have a permanent net negative charge. Due to the unsatisfied negative charges on the clay minerals' positive ions (cations) are attracted and adsorbed on it. Normally, this attraction is strong enough to hold the adsorbed cations against any possible leaching by rain water or irrigation water. However, when a concentrated solution of any cation is added, the added cations replace some of the adsorbed cations on the clay minerals, and instead, they get adsorbed on it. This phenomenon is known as *cation cxchange.* In soils the most common exchangeable cations are Ca^{2+}, Mg^{2+}, H^+, K^+, Na^+, and NH_4^+.

Similarly, when clay minerals like sesquioxide clays have a net positive charge, they are capable of adsorbing and exchanging anions such as sulphates, phosphates, and nitrates. This phenomenon is known as *anion exchange.* Common anions found in soils are SO_4^{2-}, Cl^-, NO_3^-, $H_2PO_4^{2-}$, HCO_3^-, and anions of humic acids.

The capacity of soils to adsorb and exchange cations and anions, varies greatly with the content of clay and organic matter and the minerological composition. The *cation exchange capacity* (CEC) of a soil may be defined as the amount of a cation species bound at pH 7 and expressed as milli equivalents per 100 g. (me/100 g). The CEC values of certain soil colloids are given below:

Kaolinite	—	3-10 me/100 g
Illite	—	10-30 me/100 g
Montmorillonite	—	80-150 me/100 g
Humus	—	200 me/100 g

Anion exchange capacity is also there. It is the capacity of a soil to adsorb and exchange anions, and usually defined as the amount of phosphate bound at pH 4 (Piper, 1950) or pH 5.7 (Deas and Rubins, 1947).

The term ion exchange is given to denote both cation exchange and anion exchange collectively. Ion exchange is the most important of all the processes occuring in a soil, and propably the most important phenomenon which support life on earth next only to photosynthesis. The plants which are the primary producers of food are dependant on ion exchange for a steady nutrient supply.

7. Soil reaction

7:1. Introduction

The response of a soil to an acid or alkali may be termed as its reaction. A soil may be acidic, alkaline, or neutral in reaction. Usually, the reaction is denoted by pH. The term pH was originated from two French words *Pouvoir hydrogene* meaning hydrogen power. The pH of a solution is a measure of the hydrogen ion concentration in that solution. The pH is defined as the negative logarithm of hydrogen ion concentration in moles per litre, or logarithm of the reciprocal of hydrogen ion concentration in moles per litre.

$$pH = \log [H+]$$

$$\text{or} = \log \frac{1}{[H+]}$$

pH of a solution depends upon the relative proportion of acidic or basic ions present in that solution. If a solution contains more H+ ions, it would be acidic in reaction; and more OH^- ions, then it would be basic. For instance, pure water contains an equal amount of H+ and OH^- ions, and so, it will be neutral in reaction. The pH of a solution is generally measured by using a pH meter, and it is intrepreted on a pH scale. The pH scale is not an arithmetic one but a logarithmic one. Each whole unit on it is ten times the adjacent whole unit. For example, at pH 5, it contains ten times more H+ ions than at pH6, and 100 times than that of at pH7.

The pH scale reading ranges from 0-14. The solutions having a pH below 7 are said to be acidic in reaction and those above 7 are alkaline. A solution having a pH of 7 is neutral in reaction.

A soil solution contains a large number of dissolved salts in it, and that may produce an acidic or basic recaction depending upon their chemical nature. If a solution contains more H+ ions, then that soil would be acidic in nature; and if more basic ions (Ca, Mg, Na etc.) are present, then that soil would be basic in nature. The adaptability of a soil for the cultivation of crops considerably depends upon soil acidity.

7:2 Soil Acidity

Among the various chemical properties of soil, soil reaction or pH is a very important factor, which affects the suitability of a soil to grow crops. The soils which are having a pH below 7 can be termed as acid soils. However, for all practical purposes, those soils which show a pH of below 5.5 and which respond to liming only are referred as acidic soils. The acid soils are generally formed in humid regions where rainfall is very high. In such a condition, the soluble bases formed as a result of weathering would be carried down by the percolating water, and that lead to acidity. Basic ions of Ca, Mg, K and Na are replaced by H+ ions in such a condition.

7:3. Active and Potential Acidity

The acidity contributed by the hydrogen ions present in the soil solution is termed as active acidity. This can be measured by using a pH meter. The acidity contributed by the release of H+ ions by the clay colloids can be termed potential acidity or reserve acidity. There exists an equilibrium between potential and active acidity. As more and more H+ ions from the soil solution are replaced, more and more H+ ions are released from the clay colloids. So, when the soil amelioration measures like liming are practised to neutralise the acidity, both active and potential acidity are to be taken into consideration. The bulk of the total acidity is contributed by the potential acidity. Certain adsorbed ions present on the clay colloids are also responsible for increasing the acidity. The most glaring example for this is the aluminium ions present in the clay complex. They may undergo hydrolysis, which leads to the supply of a large number of hydrogen ions. A single Al+++ ion could release 3 H+ ions.

$$Al^{+++} + H_2O \rightarrow Al(OH)_2 + 3H^+$$

In Kerala, most of the soils are acidic in reaction. Only the black soils of chittoor are alkaline in reaction.

7:4. Reasons for soil acidity

Several reasons are attributed to for the development of acidity in a soil. They are summarised below:

1. In humid areas, where rainfall is high, the soluble basic salts of Ca, Mg, K, Na etc. are highly leached, and this would reduce the base saturation in a soil. The acidic salts are somewhat resistant to leaching, and their proportion in comparison to bases increase in the soil. This would lead to the development of an acid soil.

2. Most of the basic nutrients such as K, Mg, etc. present in the soil are absorbed by plants for their metabolic activities. This may lead to a relative high concentration of acidic salts in the soil, which lead to acidity.

3. The soils formed from acidic parent materials usually show acidity. For example, a soil formed from a parent meterial containing high amount of silica may show acidity.

4. The continued application of acid forming fertilizers like ammonium sulphate, urea etc. may contribute to acidity. The ammonium ions present in these fertilizers replace the basic ions present on the clay complex, which in turn are lost by leaching.

5. The organic matter on microbial decomposition produces many organic acids. These organic acids act as agents for dissolution of basic salts, leading to their leaching; or they themselves produce acidity.

6. Presence of alumino silicate clay minerals (sesquioxide clay minerals) in large proportions also enhance the acidity.

7:5. Effect of soil acidity on plant growth

The soil acidity has several deleterious effects on plant growth. The important effects of soil acidity on plant growth are mentioned below:

1. The acid soils are chiefly formed due to the leaching of bases. As a result, they are generally deficient in basic elements like Ca, Mg, Mo etc.

2. As the pH decreases, solubility of micronutrients like Al, B, Fe, Cu etc. increase and their amounts may reach to toxic level in the soil.

3. The availability of phosphorus to plants decreases, as available phosphorus is converted into insoluble compounds with Fe, Al, Mn etc. in an acid medium.

4. Microbial activities leading to the decomposition of organic matter is decreased, as acidity is detrimental to their activities and growth.

5. Nitrogen fixation by the nitrogen fixing bacteria are also found to be reduced in an acidic condition.

6. Root growth of many cultivated plants are adversely affected.

7. The increased absorption of acid salts may lead to salt imbalance in plant cells, which lead to denaturation and destruction of enzymes.

It has been found that most of the crop plants prefer a neutral or slightly acidic soil for optimum growth.

7:6. Correcting soil acidity

The best method to correct soil acidity is to supply the soil with bases like Ca and Mg, which are lost by leaching. For this, liming is practised. The amount of lime to be applied is mainly based on the extent of soil acidity. The soil test results can be used as a guideline in this regard. Liming materials are to be applied and worked into the soil before one month of sowing. When more lime is to be applied, it is better to apply in split doses. Ammoniacal and water soluble phosphatic fertilizers should not be applied along with liming materials, as it may lead to loss of ammonia and fixation of phosphorus.

7:7 Liming materials

The various substances added to soil to correct acidity are termed liming materials. The common liming materials are discussed here.

Calcium carbonate (also known as limestone or calcite): Finely powdered calcium carbonate (Ca CO_3) is used as a liming material. Calcium carbonate is usually taken as a standard to find out the neutralising value of other liming materials. The neutralising value of Ca CO_3 is taken as 100.

Calcium oxide (Quick lime/Burntlime/Unslaked lime): Calcium oxide (CaO) is one of the most commonly used and effective liming material, and produced by heating limestone. The neutralising value of CaO is 179.

Calcium hydroxide: Calcium hydroxide (Ca)(OH_2) is also known as slaked lime, hydrated lime or builder's lime. When calcium oxide is treated with water, slaked lime is produced. The neutralizing value is 136.

Calcium – Magnesium carbonates: The carbonates of calcium and magnesium occur in different forms. When Ca CO_3 and Mg CO_3 occur in equimolar proportions, it is known as *dolomite* [(Ca Mg $(CO_3)_2$]. In other proportions, they are said to be *dolomitic limestones* The neutralising value of dolomite is 109; and that of dolomitic limestone differs, according to the proportion of Ca CO_3 or Mg CO_3 present.

Basic slag: This is a bye-product of steel industry, and contain mainly calcium silicate with phosphorus and many micro nutrients. Neutralising value is 86.

Several other miscellaneous materials like pressmud—a bye-product from sugar industry, certain bye products of paper industry, ground coral shells etc. can also be used as liming materials.

The basic reaction of a liming material when added to the soil can be shown taking calcium carbonate as an example. When Ca CO_3 is added to soil solution, it behaves as follows:

$$Ca\,CO_3 + H_2O \rightarrow Ca^{++} + H\,CO_3^- + OH^-$$

$$H^+ \text{ (Soil solution)} + OH^- \rightarrow H_2O$$

The OH−ions produced as a result of reaction with water is utilised to remove hydrogen ions from the soil solution. The reaction of any liming material is similar to the above reaction.

7:8 Neutralising value

Neutralising value of a liming material is given as *calcium carbonate equivalent* (CCE). Liming materials usually differ in their ability to neutralize acids. So, to compare these materials, pure calcium carbonate is taken as a standard, and its neutralizing value is considered to be 100 percent. Calcium carbonate equivalent is defined as the acid neutralizing capacity of an agricultural liming material expressed as a percentage of calcium carbonate on weight basis.

7:9 Effects of liming

The beneficial effects of liming in agricultural lands is summarised below:

1. Liming reduces soil acidity.
2. It increases the availability of nutrients like calcium, magnesium and molybdenum.
3. It reduces the concentration of Al, Fe, Mn, Cu, Zn etc. in the soil, which may have present in toxic levels.
4. It increases the activity of micro organisms which bring about decomposition of organic matter and nitrification.
5. Liming improves the soil structure.
6. It enhances the activity of nitrogen fixing bacteria.
7. Availability of phosphorus is increased, when lime is applied to an acidic soil.

As we have seen through the foregoing discussion, soil acidity and its correction by means of liming are very important in any farming system. Liming particularly assumes importance in Kerala, where most of the soils are acidic.

8. Plant nutrients and Soil testing

8:1. Introduction:

We know that our universe is composed basically of elements and their combinations. There are 92 naturally occuring elements, and if we include the artificially made elements too, the total go upto 108. All the living beings are also composed of these elements, and more than 60 elements have been detected in plant tissues. Some may be present in the plant body in abundant quantities and some others in traces. However, a regular supply of all these 60 elements may not be needed for the proper growth and development of plants. By the supply of some 18 elements, higher plants can function normally and produce food. This food when consumed by the animals get a share of the elements for their body build up. These 18 elements are generally referred to as essential elements. A regular supply of these 18 elements are highly indispensable for the proper functioning of the plant.

Plants depend upon soil, water, and air for the regular supply of essential elements. In the presence of sunlight, the energy giving source, plants manufacture food, utilising these elements for their own use and for posterity.

8:2. Criteria of essentiality:

As we have already seen, plants take up more than 60 elements. All these are, however, not essential. In order to distinguish elements which are required essential from those which may be taken up by the plants but are not essential, Arnon (1954) laid down certain criteria. According to him, an element can be called essential when the plant must be unable to grow normally or complete its life cycle in the absence of the element; the element is specific and cannot be replaced by the other; and the element plays a direct role in metabolism. However, only the first part is unequivocally accepted, and since the requirements for essentiality imposed by this definition is too rigid from a practical point of view, the definition suggested by Nicholas (1963) is more acceptable.

Nicholas suggested the term *functional* or *metabolism nutrient* to include any mineral element that functions in plant metabolism, whether or not its action is specific. We adopt this definition to avoid the confusion that may arise when more rigid criteria as that of Arnon's are imposed. For example, if Arnon's criteria are followed, chlorine would not be classed as essential for higher plants, since bromine may substitute chlorine at higher concentrations. Similar is the case with molybdenum, which can substitute vanadium in certain species of plants. The case of sodium is yet different. It has been found to increase the yield of several crops; however, its essentiality has not been conclusively proved! To avoid such difficulties and confusions, nowadays, Nicholas' functional nutrient approach is accepted to study the essentiality of plant nutrients.

8:3. Essential elements so far recognised:

There are 18 elements so far recognised as essential for higher groups of plants. The names of these elements and the chemical forms in which the plant takes up them are given in the table. 8.1. Out of these, three nutrients, viz. carbon, hydrogen and oxygen are supplied by air and water, and therefore, are never in short supply. The remaining elements are supplied by soil. If the soil is deficient in meeting the requirement, they are supplied through fertilizers.

Carbon, hydrogen, oxygen, nitrogen, phosphorus and sulphur are the elements which constitute the proteins—the building components of protoplasm. Others are potassium, calcium, magnesium, iron, manganese, molybdenum, copper, boron, zinc, chlorine, sodium, and cobalt. Sodium and cobalt were the latest to the list of essential elements (Sodium-1957, cobalt-1959). However, all these 18 elements are not needed for all groups of plants. Only 15 among them barring Ca, Bo and Cl, are required by all groups of plants. These three elements, viz. calcium, boron and chlorine are, however, essential for higher groups of plants; ie., for all the crop plants, the number of essential elements is 18.

Table 8:1. Essential elements.

Element	Symbol	Chemical forms available to plants
1	2	3
Macronutrients		
Carbon	C	CO_2
Hydrogen	H	H_2O
Oxygen	O	CO_2, H_2O, O_2
Nitrogen	N	NH_4^+, NO_3^-, NH_3
Phosphorus	P	H_3PO_4, $H_2PO_4^-$, HPO_4^{2-}
Potassium	K	K^+
Calcium	Ca	Ca^{2+}
Magnesium	Mg	Mg^{2+}
Sulphur	S	SO_4^{2-}
Micronutrients		
Iron	Fe	Fe^{2+}
Manganese	Mn	Mn^{2+}, Mn^{3+}
Copper	Cu	Cu^+, Cu^{2+}
Zinc	Zn	Zn^{2+}
Molybdenum	Mo	MoO_4^{2-}
Boron	B	$B_4O_7^{2-}$, $H_2BO_3^-$, HBO_3^{2-}, BO_3^{3-}
Chlorine	Cl	Cl^-
Sodium	Na	Na^+
Cobalt	Co	Co^{2+}

In addition to the 18 mentioned, there are 6 more, which are found to be essential for certain groups or species of plants. Their details are given below:

Element	*Group or plant species*
Vanadium	*Scenedesmus oblyques*
Silicon	Diatoms
Iodine	*Polysiphonia*
Selenium	*Astragalus* sp
Gallium	*Aspergillus niger*
Aluminium	Ferns.

8:4. Macro and micronutrients

The essential elements are grouped under two categories, based on the quantitative requirement. Elements which are required by plants in large quanties are termed as macronutrients, and those required in small quantities as micro-nutrients. Macronutrients are often those which are required by plants in concentrations exceeding one part per million, and include C, H, O, N, P, K, Ca, Mg and S. Micronutrients are needed in less than one part ber million, and include Mn, Cu, Zn, Mo, B, Cl and Co. Iron, though behaves as a macronutrient, is also regarded as a micronutrient due to some historical reasons. There is still another term—ultra micronutrient—for elements like molybdenum and cobalt, which may be required by certain plants at a very a low concentration as one part per billion.

Several other terms have also been used for both macro and micro nutrients. For example, macro nutrients are often referred to as major nutrients, and micro nutrients as trace elements, oligo elements or spurene elements. Macro elements may some times be divided and called primary and secondary elements. Primary elements are those macro nutrients which are required by the plant in large quantities and include C, H, O, N, P and K., and secondary elemente are required in relatively smaller but in appreciable quantities and include Ca, Mg and S. However, the terms macro nutrients and micro nutrients are the most frequently used and commonly accepted ones.

8:5 The role of essential elements

8:5.1. Carbon, oxygen and hydrogen

Carbon, oxygen, and hydrogen are obtained by plants mainly from air and water unlike other elements derived from the soil minerals. Carbon and hydrogen are taken up by plants in a combined form as CO_2 and H_2O. However, oxygen is partly taken up in the molecular form. They are converted to simple carbohydrates by photosynthesis and ultimately transformed into amino acids, proteins and protoplasm These three elements which are essential for all life forms constitute about 94 percent of the dry weight of plants. Apart from having a major structural role, they play a key role in providing energy required for the growth and metabolism of plants. The primary sources of supply of these elements, excepting perhaps water, are not under the control of man and so there is not much scope to alter the supply. Since carbon, hydrogen, and oxygen are not derived from soil, they are not mineral nutrients. Only the remaining 15 are considered as mineral nutrients.

8:5.2. The mineral nutrients

Nitrogen

Nitrogen is a vitally important element for plant growth and development. Unlike carbon, hydrogen, and oxygen, its supply can be controlled by man. He is doing it by means of organic manures and chemical fertilizers. Though air is the primary source of nitrogen, most plants are unable to utilise the atmospheric nitrogen directly.

They get it from soil. However, leguminous plants (in certain cases, some non-leguminous plants too) directly utilize the atmospheric nitrogen with the help of symbiotic nitrogen fixing bacteria like *Rhizobium* living on them. Several non-symbiotic micro-organisms like *Azotobacter* can also fix atmospheric nitrogen into available forms.

Nitrogen is absorbed by plants mainly in the form of nitrates, though smaller amounts of other forms like ammonia and amide can also be absorbed. In moist, warm, aerated soils, most of the nitrogen compounds would be converted to the nitrate forms.

Niirogen is a major structural constituent of the cell, and it plays an important role in plant metabolism by virtue of being an essential constituent of several metabolically active compounds like amino acids, proteins, nucleic acids, enzymes, alkaloids etc. Nitrogen is an integral part of the chlorophyll molecule. It is essential for healthy vegetative growth, and imparts a deep green colour to the foliage. Nitrogen is also related to carbohydrate utilization. For the proper utilization of phosphorus and potassium also, an adequate supply of nitrogen is a must.

When the nitrogen supply is a limiting factor, it create several ill effects. Both the rate and extent of protein synthesis is affected. Nitrogen deficiency makes the plants stunted and yellow in appearance. The yellowing usually starts from older leaves and then proceeds upwards. In the case of severe nitrogen shortage, the leaves become brownish and subsequently die. The flowering and fruit setting are adversely affected. Flower buds usually turn pale and shed prematurely. The maturation of the fruit may be early but the size and the quality of fruits are affected. In cereals, nitrogen deficiency causes shrivelling of leaves and hastens maturity.

An over supply of nitrogen is also harmful. Excess amounts of nitrogen can prolong the growing period and delay the crop maturity. High nitrogen supply also produces succulance in plants, and enhances their sensitivity to moisture and temperature stresses. This would make the plants more susceptible to lodging, diseases and other pests. Excess amounts of nitrogen can also impair the quality of crops like tobacco, potato, sugarcane, and sugarbeet.

Phosphorus

Similar to nitrogen, phosphorus is also a major nutrient element and plays an important role in plant metabolism. Plants absorb most of their phosphorus requirement as $H_2PO_4^-$ ion and a smaller quantity as HPO_4^{2-} ion. Plants can absorb some soluble organic phosphates too.

Phosphorus is required by the plant for several physiological functions. It is a constituent of nucleic acids, phytins, and phospholipids. Its role in the energy transfer processes, so vital to life, need no emphasiz. The element is required by the plant for the proper initiation and development of reproductive primordia. For the maturity of crops in the right stage, this element is a must. Phosphorus also influences the quality of crops, and plays a significant role in fruit and seed development. An adequate supply of phosphorus impart good strength to cell wall, and makes the cereals resistant to lodging

When the phosphorus is deficient in the soil it would affect the root development, fruit and seed formation, and delay maturity of crops. The plant may be stunted, and the leaves of the plants may turn to a reddish or purplish colour due to an abnormal increase in the sugar and anthocyanin content. However, phosphorus deficiency is not so marked as that of nitrogen. Phosphorus deficiency affects nitrogen metabolism too, which eventually results in the decrease of total nitrogen content of the plants. It has also been observed that animals, feeding on crop residues of phosphorus deficient soils, develop stiff joints and lose glossiness of skin.

Though an over supply of phosphorus does not produce any ill effects in normal course, it is reported to be associated with reduced yield in certain crops, and reduced availability of micronutrients like iron, zinc etc. to plants.

Potassium

Potassium is the third major mineral nutrient required by the plants, and is absorbed in the form of K^+ ions. Potassium is found in soils in varying amounts. Though it is not an essential component of proteins, fats, or carbohydrates as that of many other essential elements; it is an important element required by plants for many physiological functions. It is required for the carbohydrate metabolism and translocation of sugars and starches. Potassium is known to increase the resistance of plants to the stress of moisture. It imparts considerable resistance to plants against pests, diseases, and lodging. In cereals, potassium improves the proper development of mechanical tissues in the straw, making them less susceptible to lodging. Potassium salts have a great buffering action and stabilize various enzyme systems. Potassium also plays a catalytic role by activating a number of enzymes.

The deficiency of potassium often leads to marginal drying of leaves and browning of tips. Growth is reduced; quality of crops like tobacco, citrus etc. are adversely affected. Potassium shortage in cereals is accompanied by weakening of straw, which makes them liable to lodging.

An over supply of the element may lead to delayed maturity of crops. It may also reduces the availability of many other cations, besides leading to *luxury consumption* of potassium. The absorption of potassium in excess of the plant's requirement for optimum growth is known as luxury consumption.

Calcium

Calcium is required by all higher plants. It is an essential constituent of plant cell wall and is required for the maintenance of cellular organization. Calcium is also suggested to play a role in cell elongation both in stem and root. It is an activator of a number of enzymes concerned with hydrolysis. Activity of nitrogen fixing symbiotic bacteria are highly influenced by calcium supply. It plays an important role in making other cations available to plants by the base exchange action. Calcium also plays an important role in neutralising the charges on the acidic molecules of phosphoric acid and organic acids which may become injurious to plants.

The deficiency of calcium is associated with reduced root growth, and root tips may die. The deficiency of calcium makes soil devoid of adequate base saturation, and it would cause acidity. In this condition, elements like iron, manganese etc. become highly soluble and may reach to toxic level.

Magnesium

It is an important constituent of chlorophyll, and so, is a highly essential element for all green plants. Magnesium is a constituent part of the chromosomes which are the bearers of the hereditary characters. It plays a significant role in protein synthesis, being a part of polyribosoms. Magnesium is an activator of a number of enzymes—most of which are concerned with carbohydrate metabolism, phosphate transfer, and decarboxylations. It is also concerned with carbon assimilation and organic acid metabolism.

The deficiency of magnesium is often associated with chlorosis of leaves. The chlorosis is an intervenal one, in which, only the veins remains green. In advanced cases, the leaf tissues become uniformly yellow and may cause premature defoliation.

Sulphur

Plants absorb sulphur as So_4^{--} ion. Sulphur is required for the synthesis of the sulphur containing amino acids—cystine, cysteine, and methionine—and thus, for protein synthesis. It activate many proteolytic enzymes such as papainases. It is a constituent of certain vitamins and co-enzyme A. Sulphur is a major constituent of straw and plant stalks It also take part in the carbohydrate metabolism.

Deficiency of sulphur results in the yellowing of new leaves, abnormal elongation of roots, stems etc. The protein synthesis and break down may also be affected.

Iron

Iron is an important element required for the synthesis of chlorophyll. It is an activator of many enzymes, which take part in the plant metabolism. In some micro organisms, iron is a structural component of their pigments. Iron is also a structural constituent of many enzymes.

Iron deficiency is characterized by intervenal chlorosis, which progresses rapidly over the entire leaf. Severe deficiency makes the leaf completely white. When the deficiency is not severe, the parallel veined leaves show chlorotic striping; and the reticulate veined leaves show chlorotic mottling or marbling. Severe iron deficiency also results in the disintegration of chloroplasts, and decreases their size. In fruit trees, leaves are reduced in size and are thin and papery, and may develop reddish brown necrotic areas. Under severe conditions, young shoots may also die back.

Manganese

Manganese functions in the carbohydrate metabolism, phosphorelation reactions, and in citric acid cycle by way of activating many enzymes connected with these reactions. It plays a significant role in the Hill's reaction of photosynthesis and nitrogen metabolism. It is also associated with chloroplast development.

The deficiency of manganese results in the appearance of small chlorotic patches on leaves in the area between veins (intervenal chlorosis) in middle or older leaves. The chlorotic leaf areas soon become necrotic and turn red, brown, or reddish brown. Chlorosis of leaves considerably reduces photosynthesis. Since symptoms of Mn deficiency are so characteristic, specific names are ofton given, eg, *Pahala* blight of sugarcane, frenching of tung tree, grey speck of oats, marsh spot of peas etc.

Excessive supply of manganese is toxic to plants. Common symptoms of toxicity is the chlorosis of young leaves. in cereals, the chlorotic leaves, leaf sheaths, and the lower part of the stem often develop minute brown spots.

Zinc

Zinc is absorbed by the plants as Zn^{2+} ions, and sometimes as a molecular complex of chelating agents as EDTA. Zinc functions in plant metabolism as an activator of many enzymes. Zinc has been found to play an important role in regulating the auxin concentration in plants. It also plays a significant role in the formation of chlorophyll along with iron and manganese.

The results of the deficiency of zinc differ widely between plant species. Common symptoms are intervenal chlorosis, reduction in the size of young leaves, bronzing, and discoloration of the foliage. A reduction in shoot growth and shortening of internodes may also be noticed. In fruit crops, the deficiency may cause little leaf symptoms. Zinc defeciency symptoms are given descriptive names in several crops such as mottle leaf of citrus, white bud of maize, sickle leaf of cocoa, *khaira* disease of rice etc.

The toxicity of zinc usually results in mild chlorosis of young leaves, especially between the veins, which later become dry and papery. The affected leaves show rolling of the leaf margins. Roots may also turn brown and necrotic.

Copper

Copper is absorbed by the plants as Cu^{+} and Cu^{2+} ions. Copper is an activator of several enzymes and believed to take part in the light reactions of photosynthesis. Some of the copper containing compounds are involved in the photosynthesis; and the deficiency may cause decreased rates of photosynthesis. The copper deficiency symptoms varies with crops. The common symptoms are multiple bud formation, dieback, staining fruits, malformation of leaves etc. The amount of copper present in plants in relation to other heavy metals like iron and manganese etc. are more important than the total copper content. It is quite common that copper deficient plants show an accumulation of iron in cells.

When the copper content reaches toxic levels, the young leaves show chlorosis between the veins; and old leaves often develop brilliant reddish orange or pink colouration. Severe rolling of the leaf margins due to the loss of turgor also result, and ultimately the leaves become dried and withered.

Molybdenum

Molybdenum is required by plants only in minute quantities. Nevertheless, it is an important functional element in plants. It is part of an enzyme called nitrate reductase concerned with the reduction of nitrate to nitrite. Molybdenum is required by all the nitrogen fixing agents—bacteria, blue green algae, and others. It also plays an important role in the nitrogen metabolism of plants. Molybdenum is believed to be involved in photosynthesis too.

The deficiency of molybdenum causes an accumulation of nitrate in plants. Nitrogen fixation, assimilation, and reduction are adversely affected, when molybdenum content is inadequate. Photosynthesis is also reduced in molybdenum deficient plants. In citrus, molybdenum deficiency is described as 'yellow spot of citrus'. In citrus, the leaves during the early summer flush develop water soaked areas, which eventually enlarge and coalesce. Severely affected leaves are shed, and the branches would be leafless.

Toxicity of molybdenum imparts chlorosis to the plants, though not pronounced. The plants often develop brilliant tints– golden yellow or blue. In potato, tomato, and flax, the toxicity results reddish or golden yellow colour of the shoots.

Boron

Boron is believed to play an important role in the development and differentiation of tissues, particularly that of vascular tissues. It also functions in the maturation of cells by regulating the formation and lignification of cell walls. Boron is involved in the carbohydrate metabolism of plants too, especially in the translocation of sugars.

The deficiency of boron may be first noticed as cessation of growth of terminal buds, followed by death of young leaves. Root crops are easily affected by boron deficiency. The internal tissues of roots show black heart symptoms. As boron is involved in the reproductive phase of plants, deficiency of this element results in sterility and malformation of reproductive organs. Boron deficiency symptoms have descriptive names in several crops, eg. 'heart-rot' of sugarbeet, 'browning' or 'hollow stem' of cauliflower, 'top sickness' of tobacco, 'brown heart' of turnip etc.

Because of boron toxicity, young leaves develop chlorosis between the veins, which usually starts from the base of a leaf and spreads towards the apex. In certain cereals, for example, barley and maize, the emerging leaves may be severely chlorotic or bleached, and may fail to unroll. Blossoms are depressed and flower buds may also show chlorotic sepals and petals.

Chlorine

Chlorine is taken up by the plants as the chloride ion, Cl^-. Bromine can substitute chlorine at higher concentrations. Chlorine is believed to be associated with oxygen evolution in primary photosynthetic reactions. It is claimed to be involved in the cyclic photophosphorelation.

The exact role of chlorine in plan nutrition is yet to be found out..

Chlorine deficiency symptoms are difficult to identify and differentiate. However, the leaves of chlorine deficient plants display symptoms of wilt, chlorosis, necrosis, and bronze discolouration. In some cases, reduced root growth is also noticed.

The symptoms of chloride toxicity vary with plant species. Reduction in the number and size of leaves, bronzing or yellowing of the foliage and browning and scorching of the leaf margins are the common symptoms.

Cobalt

Cobalt is an essential element required by the nitrogen fixing bacteria, *Rhizobia*, for the fixation of elemental nitrogen. Cobalt is a structural component of Vitamin B_{12} (Cyanocobalamine), which in turn is needed for the production of heamoglobin concerned with nitrogen fixation. Besides legumes, responses to cobalt have also been reported in cotton, and mustard. It is said that cobalt improved growth, transpiration, and photosynthesis. Cobalt may also play a catalytic role as an activator of many enzymes concerned with plant metabolism.

Sodium

Though it is known that the growth of several crops is stimulated by the application of sodium, it is reported to be essential for only a few higher plants. In sugarbeets, the essentiality of sodium has been reported, and that its functions are more than simply a substitute for potassium. It has been generally believed that sodium may substitute potassium, especially when the latter is deficient in the soil. Beneficial effects of sodium is also observed, even when potassium is supplied in plenty, in crops like celery, sugarbeet, swiss chard, table beet, mangel and turnip. Recently, a report from Australia claims that sodium is an essential element for a group of C_4 plants.

The important role of this element reported is in the maintenance of osmotic relations of the cell. Sodium helps the plant to withstand desiccation, and thereby resist drought by providing a high internal osmotic concentration. Water uptake by the plants is also influenced by sodium.

8.6 Soil testing

The main purpose of soil testing is to evaluate the fertility status of the soil. It provides a basis for fertilizer, lime, and gypsum recommendations. Soil test information is then used, along with an evaluation of specific crop requirements, cropping history, and physical characteristics of soil, in determining the exact amounts of fertilizers and soil amendments needed for a crop. Soil tests have got another added advantage. As the soil reaction and deficiency of nutrient elements in a soil could be found out before the crops are planted, it could be corrected before the actual sowing of crops.

8:6.1 Soil sampling

Soil tests and their interpretation are based on the soil samples sent for analysis. For testing purpose, only a small quantity of soil is required in the laboratory. Only 1–10g of the soil is subjected to testing purposes and their results are interpolated to represent the whole area from which the sample is drawn. Therefore, it is important that the sample must be true representative of the area from which it is taken.

Principles to be followed in soil sampling

1) Sample each field separately

   When the areas within the field distinctly differ in crop growth, in soil, elevation, or cropping history or past treatment, divide the field suitably and sample each area separately.

2) Avoid drawing samples from spots which do not represent the field.

   eg: Old bunds, marshy spots, hedges etc.

3) Do not sample a field within three months of the application of lime or fertilizers.

4) Take samples from 15 cm depth in ordinary farming situation. If perennial crops are to be grown, take from 25cm depth; and from 5cm depth for pastures and lawns.

5) Where crops have been planted in lines, samples must be taken between the lines.

6) Use proper sampling tools

A soil tube, an auger or a *Mammatty* (Fig. 8.1) can be conveniently used according to situations. In wet lands, soil auger is the best tool. In dry lands both soil tube and *Mammatty* can be used conveniently.

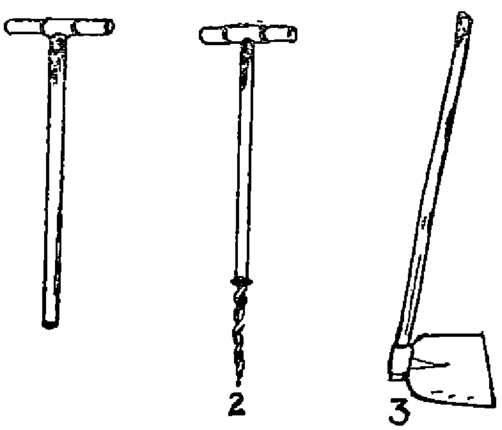


Fig. 8.1 Common soil sampling tools
1. Soil tube 2. Soil auger 3. Mammatty

Procedure of soil sample collection and method of despatch of the sample

Scrape the litter (organic debris and undecomposed leaves) from the surface and expose the soil. Then, dig a 'V' shaped hole to the required depth (15 or 25cm) and cut a thin slice from a side of the hole. Collect at least 10 samples from each area and put them in a clean bucket. Break all the lumps, and mix well in the container. Reduce the size of the sample by successive quartering to about 500g.

Dry the samples thus got in shade for an hour or two by spreading over a paper or polythene sheet. Use polythene bags for bagging the samples. These are then put in cloth bags. Identify each sample by name or number and also by the cultivator's name. Paper tags can be used for this purpose. Fill up completely the information sheet furnished by the soil testing laboratories, and send the sheet along with the sample container to the soil testing laboratory.

The information sheet should ordinarily contain the following details. If standard information sheets are not available, give information on these points in ordinary sheets of paper.

1. Name of the cultivator
2. Full address
3. Village; Taluk
4. District
5. Survey number
6. Proposed crop and variety of the existing crop and variety
7. History of the field for the past three years (Crops grown, fertilizers used etc.)
8. Wet/dry/garden land
9. Extent of sampling area
10. Depth of sampling
11. Signature of farmer

8:6.2 Procedure at the Soil Testing Laboratory

Though we are sending 500 g of the soil to the laboratory, only a small quantity of the soil is subjected to testing. Usually, 1-10g of the soil sample is used depending on the nature of the test. According to the results obtained, the soil is first rated and classes assigned. There are 10 classes (0-9) for each parameter. Based on the status of the soil, ie., whether low, medium, or high and also on the assigned class, organic manures, fertilizer and lime recommendations are given.

Soils with averege fertility values are given 100 percent of the general fertilizer recommendations. A soil with 10 kg ha^{-1} of available phosphorus is considered to be average in terms of phosphorus content, and require 100 percent of the general fertilizer recommendation. For rating the potassium status as average, the soil should contain 115 kg ha^{-1} of available potassium. The average fertility values for total nitrogen, however, differ between soils. For sandy soils, the average total nitrogen value is 0.03 percent (organic carbon 0.3%), and for loamy and clayey soils, the average value is 0.05 percent (organic carbon 0.5%). The details of the various soil fertility classes and the recommendations of the major nutrients for each class as percentage to general recommendation are given in Table 8.2.

Usually, the test results furnished by the laboratory contain three parts. First part indicates results of analyses of the soil sample. Actual analytical data and ratings are usually given.

This part may contain the following details.

1. pH or soil reaction which indicate whether the soil is acidic, alkaline or normal.

Table 8.2. Soil fertility classes and fertilizer recommendations

Soil fertility class	General rating of fertility status	Percentage of organic carbon: Sandy soil	Percentage of organic carbon: Clayey/loamy soil	Nitrogen recommendation as % to general recommendation	Available phosphorus kg ha $^{-1}$	Available potassium kg ha $^{-1}$	Phosphorus and potassium recommended as % to general recommendation
1	2	3	4	5	6	7	8
0	Low	0.00—0 10	0.00—0.16	128	0.0— 3.0	0— 35	128
1	Low	0.11—0.20	0.17—0.33	117	3.1— 6.5	36— 75	117
2	Low	0.21—0.30	0.34—0.50	106	6.6—10.0	76—115	106
3	Medium	0.31—0.45	0.51—0.75	97	10.1—13.5	116—155	94
4	Medium	0.46—0.60	0.76—1.00	91	13.6—17.0	156—195	83
5	Medium	0.61—0.75	1.01—1.25	84	17.1—20.5	196—235	71
6	Medium	0.76—0.90	1.26—1.50	78	20.6—24.0	236—275	60
7	High	0.91—1.10	1.51—1.83	71	24.1—27.5	276—315	48
8	High	1.11—1.30	1.84—2.16	63	27.6—31.0	316—355	37
9	High	1.31—1.50	2.17—2.50	54	31.1—34.5	356—395	25

2. Organic carbon (as a measure of available nitrogen).
3. Total soluble salts (as a measure of salinity).
4. Available phosphorus.
5. Available potassium
6. Any other pertinant informations

The second part is fertilizer recommendations for the crop based on soil analysis, history of the field, and recent research work. This part indicates quantities of nitrogen (N), phosphate (P_2O_5), potash (K_2O), and also of lime or gypsum to be applied. The recommendation on organic manures will also be given.

The third part of the soil test and fertilizer recommendation report indicates methods and time of application of fertilizers and other practices required to make the fertilizer use more efficient and effective.

8:6.3. Soil testing facilities in Kerala

Soil testing laboratories are functioning in each district of Kerala excepting Pathanamthitta and Kasaragod. Besides these 12 laboratories, there are two more mobile soil testing laboratories-one at Alleppey, for the southern districts and another at Pattambi, for the northern districts. Five more mobile soil testing laboratories are expected to be commissioned shortly. Farmers can send the soil samples to the laboratories directly or through the Agricultural Offices functioning in the state. The soil testing service is rendered free of cost in Kerala.

A central soil testing laboratory is also working at Trivandrum under the control of a Chief Soil Chemist who co-ordinate the working of the soil testing laboratories and ensures quality control in the soil testing service.

In addition to the laboratories mentioned which are run by the Agricultural Department, institutions like Coffee Board, Rubber Board, UPASI, FACT etc. are also rendering soil testing service.

9. Organic manures

9:1 Introduction

Organic manures are derived from plant, animal and human residues—usually bulky in nature, and are added to soil to maintain soil conditions and soil fertility. Organic manures may be classified as bulky and concentrated. Green manures and several plant and animal residues form the bulky organic manures. Concentrated organic manures include oil cakes and animal origin manures such as fish meal and bone meal. The addition of organic manures in sufficient quantities is is essential for successful crop production.

9:2 Bulky organic manures

These usually, contain a very low percentage of plant nutrients, and applied in very large quantities. The main aim of adding them is to build up the organic matter content of soil.

Farm yard manure: This is the most commonly used organic manure in India. Farm yard manure is a decomposed mixture of dung and urine of cattle, along with straw and litter used as bedding, and remnants of straw, fodder etc. fed to the cattle. In India, a major portion of these are used as fuel, and are lost. The traditional method of preservation of the farm yard manure in the farms is highly inefficient as it leads to considerable loss of nutrients in it. The loss of urine is an important factor in reducing the effectiveness of manure. The average composition of farm yard manure is given below:

N — 0.4%
P — 0.3%
K — 0.2%

For obtaining quality farm yard manure in the farm, some important precautions are to be observed. Most important among them is the conservation of urine. For this purpose, sufficient bedding must be spread on the floor of the cattle shed in the evening, and they have to be collected in the morning. Then, these are spread in pits of sufficient dimensions. (The pit can be of 4–6 m in length, 1.5 m in width. and 1 m in depth). Each day, the collected dung and urine mixed litter is added to the pit, and when it reaches about 0.5 m height above ground level, the top portion is plastered with a slurry of cowdung and mud. The plastering ensures the conservation of moisture in the manure and prevent the proliferation of houseflies. It is better to make a second pit when the first one got filled. By the time the second pit is also filled, the manure from the first pit would be in a readily usable form.

The quality of farm yard manure can be improved by feeding the cattle with protein rich foods. The loss of ammonia from the manure can be prevented by adding gypsum and superphosphate to the manure. Biogas generation from the farm yard manure and using the spent manure from biogas plant is a right step for conserving the farm yard manure. Biogas plants are attracting the attention of farmers and research workers, as it fulfil two purposes-one to provide fuel and the other to give quality manure. It is also reported that biogas generation from farm yard manure increases its manurial value.

Compost: Composting is the process of conversion of plant and animal residues to quickly utilizable form to improve and maintain soil fertility. Waste materials of various kinds like cereal straw, crop stubbles, groundnut husk, farm weeds, house refuse, wood ash, litter from cattle sheds etc. can be converted into a quickly utilizable manure by composting. Two methods are generally followed in composting—one is anaerobic and the other is aerobic. Aerobic process is followed in rainy season, and here, the compost materials are heaped on a well drained site before the advent of rainy season. Occasionally, the heap is turned using rakes and when it sinks, it is made into a fresh heap, and can be used in about four months time.

The anaerobic method is mainly followed in rural areas, where the farm refuses are put into pits of size 5 x 1.5 x 1m in dimension. Each day's refuse is spread on the floor, and when it reaches 30 cm, some water and cowdung slurry are sprinkled over it. This heaping process is repeated till the heap rises to about 0.5 m above ground level. Then, it is plastered with a 2-5 cm layer of mud and cowdung. In such situations, the decomposition is anaerobic and high temperature does not develop. Here, loss of ammonia is very low, and within four to five months, good quality compost is produced. *Bangalore method of composting*, is an example for this. In *Indore method of composting* the decomposition is mainly brought about by aerobic organisms, as no plastering is resorted to. In the *Coimbatore method of composting*, the materials taken from the pit is again spread on the ground in heaps and plastered. It is kept as such till it is used in the field.

Reinforced compost: Compost generally contains less phosphorus and so it can be made up by adding some phosphorus fertilizer to the compost. Then, it is called *reinforced compost*. When superphosphate is added to compost, it is known as *super compost*

Town compost: The refuses available from towns like night soil, town refuses, and earth are added one by one in pits taken in uninhabited areas. These would be converted into compost within 3 months.

Sewage and sludge: The sewage and sludge available in cities are allowed to ferment and settle. Then, air is forced through it, and activated sludge is produced. It contains about 3-6%N, 2% P_2O_5 and 1% K_2O. The effluent, free of toxic elements, can be used for irrigation.

Night soil: The dehydrated night soil along with the absorbing material produces a poudrette which can be used as a manure.

Plant residues: The plant residues left after the harvest of the crops, threshing, and cleaning operations are good for use as bulky organic manures. The household ash is also a good manure. Its potash content may sometimes raise its status to the level of a concentrated organic manure. Certain important materials coming under this category are given in the Table 9.1.

9:3 Concentrated organic manures

They contain higher amounts of major nutrient elements compared to bulky organic manures. These are concentrated sources of organic manures obtained from plants or animals. The important concentrated organic manures are described below:

Table. 9.1. Analysis of common plant residues

Items	N (%)	P_2O_5 (%)	K_2O (%)
Paddy straw	0.36	0.08	0.71
Sugarcane trash	0.35	0.10	0.60
Rice hulls	0.30 to 0.50	0.20 to 0.50	0.30 to 0.50
Groundnut husk	1.60 to 1.80	0.33 to 0.50	1.10 to 1.70
Household ash	0.50 to 1.90	1.60 to 4.20	2.30 to 12.0

Source:— Hand book of Agriculture, 1980; ICAR, New Delhi.

Oil cakes: Many edible and non-edible oil cakes are used as organic manures. Usually, edible oil cakes like coconut oil cake, groundnut oil cakes etc. are fed to cattle. However, to a lesser extent, these are also used as manures. Others like castor cakes, neem cakes etc. are excellent manures. They are of high nutrient values, and should be well powdered before use to get the maximum benefit.

Bone meal: This contain high percentage of phosphorus (20-25%) and suitable for acidic soils. It is slow acting, and therefore, more effective in long duration crops.

Blood meal: The dried blood obtained from slaughter house are powdered well and used as a manure. It contains about 10-12% of quickly available nitrogen.

Fish meal: The non-edible fishes and the waste obtained from fish processing factories are dried and powdered to produce the fishmeal. It contains fairly good amount of phosphorus, in addition to nitrogen.

Guvano: It is a powdered product obtained from the excreta of birds. It contains both nitrogen and phosphorus.

The nutrient composition of certain important bulky and concentrated organic manures are given in the Table 9.2.

Table 9.2: Analysis of important organic manures

Items	N (%)	P_2O_5(%)	K_2O(%)
Groundnut cake	7.0	1.5	1.3
Castor cake	4.3	2.0	1.3
Mustard cake	4.5	1.5	—
Neem cake	5.2	1.0	1.4
Mahua cake	2.5	0.8	1.8
Gingelly cake	6.2	2.0	1.2
Coconut cake	3.0	1.9	1.8
Farm yard manure	0.4	0.3	0.2
Cowdung (fresh)	1.57	0.25	0.18
Compost	0.5	0.26	0.5
Poultry manure	1.2 to 1.5	—	—
Deep litter poultry-manure	3.0	2.78	2.0
Sheep manure	0.8 to 1.6	—	—
Horse manure	0.6 to 1.6	—	—
Bone meal	3.5	21.0	—
Blood (dried)	11.5	—	0.6
Fishmeal	4.1	3.9	0.3

Source: Farm Guide, 1987.

9:4 Green manures

Green manures are bulky organic manures used to enrich the organic matter content of soil. In connection with green manures, two terms—green manuring and green leaf manuring—are inportant. Green manuring consists of raising a quick growing crop, often a legume,and ploughing it *in situ*. Here, the green manure crops are grown as a pure crop or as an intercrop and then incorporated into the soil, when they attain required maturity. The crops that are suitable for green manuring includes sunnhemp, daincha, cowpea, cluster beans, sesbania etc.

In green leaf manuring, the leaves and young branches of shrubs or trees grown elsewhere are collected and transported to the field, where it is incorporated by ploughing. Plants like *Gliricidia, Sesbania, Calotropis* etc. are suitable for this purpose. These plants can be grown on the bunds of paddy fields or in other vacant spaces, and cuttings can be taken at least two times a year.

9:4.1. Importance of green manuring:

The importance of green manuring and its role in the maintenance of soil fertility and productivity can be discerned from the following facts.

1 Green manuring increases the organic matter content of the soil.

2 The practice improves, the soil structure, water holding capacity, drainage, aeration etc. of the soil.

3 Green manure supplies a substantial quantity of nutrients, especially nitrogen to the crops. Leguminous green manures are important in this aspect.

4 The microbial activity of the soil is increased, which in turn, increases the availability of nutrients such as Ca, P, Mg etc.

5 The deep rooted green manure crops absorb nutrients from deep layers of soil and make them available in surface soils, which is of much benefit to shallow rooted crops.

6 The leaching losses of many nutrient elements are reduced as the green manure crops utilize them.

In addition to the above purposes, greeen manure crops are also grown for certain other objectives.

As a cover crop: As a cover crop, they reduce the weed growth, control soil erosion, and prevent escape of moisture from the soil. For example, cover crops like *Calapagonium* are very famous in rubber gardens.

As a shade plant: Shade plants are usually grown to protect newly planted seedlings and in nurseries. They provide shade and help to maintain the soil temperature.

As a forage: Certain green manure crops form excellent forage for cattle. eg., sunnhemp, subabul etc.

9:4.2 Desirable properties of green manure crops

A good green manure crop should have the following properties.

1) It should be suitable for different soils and climatic conditions.

2) It should be quick growing and produce succulant and easily decomposable twigs and leaves.

3) Leguminous crops are preferable as green manures, as they provide additional amount of nitrogen to the soil through nitrogen fixation.

4) It should be drought tolerant.

5) It should resist the incidence of pests and diseases.

9:4.3 Important green manure crops

Sunnhemp (Crotalaria juncea): Sunn hemp is a fast growing green manure crop. About 20-30 kg seeds are required for sowing one hectare which produces about 10-20 tonnes/ha of green manures. The plant flowers in about 45 days after planting, and at that stage it can be incorporated to the soil.

Dhaincha (Sesbania aculeata): This crop is suited for marginal lands and flood affected areas. It grows easily in almost all soil and climatic conditions. It can withstand drought also. Seed rate followed is 20-40 kg/ha and provide 10-15 tonnes/ha of green manure in about 4-5 months.

Sesbania (Sesbania speciosa): This is very similar to *Dhaincha*. Best suited for planting on bunds of rice fields. Usual seed rate ranges from 25-50 kg/ha. It is a heavy yielder of green manure, and may produce even upto 25 t/ha of green manure within 5 months.

Kolingi or wild indigo (*Tephrosia purpurea*): *Kolingi* is suitable for drought prone areas and it is usually grown in areas of Palghat and Trichur districts after the *Mundakan* crop in paddy fields. Normally, 20-30 kg/ha of seeds are required and yield about 4-8 tonnes/ha of green manure. Since the seed coat is very hard, germination may be delayed. So, some means to induce germination may be taken up. A usual practice is to add equal quantity of sand to the seed, and pounding the mixture lightly in a mortar to loosen the seed coats. Alternatively, the seeds can be dipped in hot water for 3-4 minutes Soaking of seeds for 24 hrs · in ordinary water is also good.

9:4.4 Green leaf manure crops

Subabul (Leucaena leucocephala:) Subabul or Ipil-Ipil is a multi purpose tree which is becoming popular in Kerala. Almost all the parts of this tree is useful and is better known as a living fertilizer tree. It provides 4F's viz., food, feed, fuel and fertilizer. The importance of subabul can be observed from the following facts:

1. Subabul leaves contain fairly good amount of nutrients, and so used as a greenmanure. The nitrogen content of the leaves is almost double as that of *'Giiricidia'*.

2. It can be used as a forage crop. The leaves are usually fed to cattle. But, it contains a toxic principle which, if present in large quantities in the animal body, result in the shedding of hairs. However, the toxicity has practically no effect in the case of ruminants like cows, goats and buffaloes, since the chewing of the cud results in the detoxification of the toxic content—an amino acid called *mimosine*. But, to be on the safer side, the content of subabul leaves in the total green fodder may not exceed 40-50 percent. When the leaves are fed to non-ruminants like fowls and pigs, the content of leaves should be restricted to 5-10 per cent of the total feed.

3. The wood obtained from the tree is used as a fuel and in paper industry.

4. The plant can be used as a standard for growing crops like pepper and vanilla.

5. The tender fruits are used as vegetable.

6. Subabul, when grown along the contours–suitably spaced (as alley crops) on slopy lands—is effective against soil erosion.

Subabul can be grown as a pure crop or as an alley crop. Usually, a spacing of about 60-90 cm is given. The crop is raised usually by sowing seeds. From one hectare of subabul, about 100–125 tonnes of green manure is obtained per year.

Gliricidia (Gliricidia maculata): This plant is an important green manure crop as far as Kerala is concerned. It can be grown in waste-lands and as a living fence. As an alley crop also, it is desirable. Planting is done both by seeds and stem cuttings. From the third year of planting onwards, green leaves can be cut. Usually, two cuttings are taken in a year. About 11-16 kg of green leaves are obtained from a plant in a year.

In addition to the crops meintoned above, the leaves of many other shrubs and trees like *Calotropis (Erukku)*, *Thespesia (Poovarasu)*, *Lagerstroemia (Maruthu) Vatta, Pezhu, Venga* etc. are also used for green leaf manures in Kerala.

9:4.5 *Important cover crops*

Calapagonium (Calapagonium mucanoides): It is a good leguminous cover crop suitable for coconut gardens and plantation crops like rubber. For sowing in one hectare, 3-4.5 kg seeds are required. Once the crop is established, further sowing would not be needed, since the seeds produced by the crop fall on the ground and germinate *in situ* which would give a permanent soil cover to the crop.

Pueraria (Pueraria phaseoloides): This is also a very popular cover crop. It is a vigorus twiner and creeper that can be propagated by seeds and cuttings. It can stand strong sun and smothers even weeds like *Eupatorium*. Seed rate is about 3.0–4.5 kg/ha.

Other cover crops of interest in Kerala conditions are *Centrosema pubescens* and *Mucuna bracteata*. *Mucuna* is important in certain situations, since it is not eaten by cattle.

For obtaining maximum results from the green manure crops, some important points are to be borne in mind. For the proper decomposition and rotting of green manure, the soil should contain adequate moisture at the time of incorporation. The manure plants are to be incorporated in to the soil when they start flowering. After flowering, the plant parts may get hardened. Green manure crops, especially over aged ones and those having a wide CN ratio (carbon : nitrogen ratio) should be applied sufficiently in advance to the sowing of crops. Otherwise, the germination and early growth of the crop may be affected.

10. Soils of Kerala

10:1. Introduction

The soils of Kerala differ widely in their characteristics and properties. Climate and physiographical features are playing a major role in the soil forming processes here. For studying different soils in a meaningful manner, it is customary to classify them into certain groups. Based on their genesis, morphological features, and physico-chemical properties, ten major soil groups are identified in Kerala. They are laterites, red loams, riverine alluvium, coastal alluvium, brown hydromorphic, saline hydromorphic, Kuttanad alluvium, Onattukara alluvium, black soil, and forest loam. A brief description of these soil groups are given in this chapter.

10:2. Laterites

The laterite soils (*Chenkalmannu, Vettukalmannu)* are the prominent soil group of Kerala. They are usually loams of some kind. The midlands and the mid-upland regions of Kerala largely comprise of these type of soils. Heavy rainfall and high temperature prevalent in the state are quite favourable for the formation of these soils. Laterites are formed by the leaching of bases and silica from the original parent rock with the resultant accumulation of iron and aluminium oxides. The surface is reddish brown to yellowish red in colour, and is mostly gravelly loam to gravelly clay loam in texture. The profiles have well developed B horizon with ferruginous and quartz gravels. The soil mass below the B horizon is usually compact and vesicular. It includes both quarriable type which can be cut into blocks, and non-quarriable type which breaks into irregular lumps. Extensive stretches of indurated laterites with hard surface crusts are a common sight in Cannanore, Calicut and Malappuram districts.

Water holding capacity of laterite soils is very poor. They are generally deficient in nitrogen, phosphorus, potassium, and bases including calcium. The organic matter content is also low. The pH varies from 5.0-6.2. Application of lime, organic matter, fertilizers, and such other management practices can restore the fertility of these soils. Coconut, tapioca, banana, vegetables etc. are grown in the lower elevations and plantation crops such as rubber and cashewnut at higher elevations.

10:3. Red loams

These soils are of localised occurance and are mainly seen in Trivandrum district. They are yellow, red, or deep red in colour. Red loams are deep soils without much expression of horizons. Red loams or *Chuvannamannu* contain high amount of haematite (iron oxide ore) which impart the red colour. They are low in organic matter, nitrogen, and almost all essential plant nutrients. The soils are acidic in reaction (pH 4.0-5.5). Coconut is the major crop grown in these soils.

10:4. Riverine alluvium

These are mainly found along the banks of rivers and their tributaries. Alluvial soils or *Ekkalmannu* are formed by the deposition of soil particles carried by water. The horizon differentiation is not well expressed. They are very deep soils with surface texture ranging from sandy loam to clay loam. They contain fairly good amount of nitrogen, potassium and organic matter, but are deficient in calcium and phosphorus. These soils are poorly drained and are strongly acidic in reaction. (pH 4.5 to 5.5). Crops such as rice, sugarcane, vegetables, coconut, arecanut, and banana are usually grown in these soils.

10:5. Coastal alluvium *(Chorimanal)*

These soils are mainly found in the coastal areas of Kerala upto about 10 km from the sea coast. They vary in texture from sandy loam to pure sand. Water holding capacity of these soils are very low as they contain large number of macro-pores. They are highly deficient in nitrogen, phosphorus, potassium, calcium, and organic matter. They are slightly acidic and the pH ranges from 5.0 to 6.0. By following good management practices, these soils can be made productive. Large quantities of organic matter should be applied to restore the water holding capacity and other physical properties of soil.

Coconut is the major crop grown in this tract. Crops like rice, tobacco, tapioca, and sesame can also be grown in these soils by following suitable scientific practices.

10:6. Brown hydromorphic

Brown hydromorphic soils are mostly confined to valley bottoms of undulating topography in the midlands and in low lying areas of coastal belt. These soils have been formed as a result of transportation and sedimentation of material from adjoining hill slopes and also through deposition by rivers. Wide variations in morphological features and physico-chemical properties are seen. In most cases, soil profile development has occured under impeded drainage conditions, and therefore, exhibit hydromorphic features such as grey horizons, mottling streaks, hard pans, organic matter depositions, iron and manganese concretions etc. They are moderately rich in organic matter, nitrogen, and potassium; but deficient in lime and phosphate. Rice, coconut, banana, and vegetables are grown in these soils.

10:7. Saline hydromorphic

This kind of saline soils are usually seen in the coastal tracts of the districts of Ernakulam, Alleppey, Trichur and Cannanore. The famous *'Pokkali'* lands of Ernakulam, the *'Kaipad'* lands of Cannanore, and the *'Kole'* lands of Trichur are covered with these soils. Wide fluctuations in the intensity of salinity have been observed. The wide net work of back waters and estuaries bordering the coastal line of Kerala serve as inlet of tidal waters to flow into these areas causing salinity. Most of the salts are leached out upon flooding, especially during rainy season. Maximum accumulation of toxic salts are observed during summer months. They are in general brownish in colour, deep, ill drained, and of heavy texture. In most cases, the soils are acidic due to the presence of undecomposed organic matter in the lower layers. The main crops grown are rice, coconut, and vegetables.

10:8 Kuttanad alluvium

The entire Kuttanad region of Ambalapuzha and Shertalai taluks of Alleppey district and Vaikom taluk of Kottayam district, are covered by these type of soils. A part of Ernakulam district is also covered The area occupied by this region is about 875 km^2, and the major part of the region lies below the sea level. The area is susceptible to seasonal ingress of saline water by way of tidal inflow from the sea. During rainy season, fresh water reaches the area through rivers and streams. It may again become saline by way of sea water intrusion. Kuttanad soils are typically water logged soils, and rice cultivation is taken up by way of dewatering after the monsoons ie., by obout September–October. Coconut is also grown on raised bunds.

The Kuttanad soils can be grouped into three categories viz. *Kayal* soils, *Karappadam* soils and *Kari* soils.

Kayal soils: Kayal soils are found in the low lying parts of this region in the reclaimed lake beds. They are deep, ill drained, and dark brown. Kayal soils are also alluvial soils having silty loam to silty clay loam surface texture. The soils are slightly acidic, medium in organic matter, and poor in nutrients. However, they are rich in calcium due to the presence of lime shells. Salinity is a major problem. A whitish colour may be observed on the surface due to accumulation of salts. In this kind of soils, the outer bunds should have a height of atleast 2.5 meters to contain the flood water from inundating the fields.

Karappadam soils: These cover the major portion of Kuttanad and occur along the Inland water ways and rivers. Karappadam soils are river borne alluvial soils lying 1–2 meters below the sea level. Soils are deep, ill drained, and dark grey in colour with clay loam texture. High acidity and high salt content are other features. They are poor in lime and available nutrients, especially phosphate. However, they contain fairly good amount of decaying organic matter.

Kari soils: The Kari soils are like the peaty soils. They occur in isolated patches on the South West and North East margins of Kuttanad. These soils are formed from the dead remains of plants, and usually contain a large quantity of undecomposed organic matter in a partially carbonised form, which do not decompose easily due to excess water and lack of air. They are characterised by a deep black colour, heavy texture, poor drainage, and very strong acidity. The pH may approach as low as 3.0 during summer months. The soils are rich in total nitrogen, but often deficient in phosphorus and calcium. Soluble salts of iron and manganese are observed in toxic concentrations in some places.

10:9 Onattukara alluvium

Onattukara region comprises of Karunagappally, Karthikappally and Mavelikkara taluks of Quilon and Alleppey districts. The soils found in these region are peculiar and classed separately as Onattukara alluvium. They mainly occur as marine deposits. The soils are coarse textured with immature profiles. Water table is high in low lying areas and drainage is a problem. The soils are acidic and poor in all the major plant nutrients. The main crops grown in this tract are coconut, rice, and sesame.

10:10 Black soils.

Black soils are seen in Chittur areas of Palghat district as an extension of the black soils of Deccan plateau. These soils contain high percentage of clay and possess high cation exchange capacity. Due to this, they become highly sticking on wetting and develop cracks on drying. They contain high amount of sodium and magnesium but usually deficient in organic matter, nitrogen, and phosphorus. Dispersion of organic matter may also takes place at the soil surface. Inadequate aeration and high amount of sodium make these soils unsuitable for most of the crops. The soils are alkaline in reaction, and pH varies from 7.0–8.5. Cotton is the major crop in this region. Sugarcane and rice are also grown.

10:11 Forest loams

The forest soils *Vanamannu* of Kerala constitute about 25 per cent of the total land of state. They contain a thick layer of organic matter which may be at different stages of decomposition. These soils are generally acidic with the pH ranging from 5.0–6.5. The soils are dark; reddish brown to black in colour with loam to silty loam texture. Due to deforestation and denudation, high erosion and leaching take place, and with the result, the soils are loosing their fertility. They are in general rich in nitrogen, but show deficiencies of potassium, calcium, and such other bases. Forest soils are suitable for the cultivation of crops such as coffee, tea, pepper, rubber and cardamom.

11. Soil erosion and its control

11.1 Introduction

Soil erosion and its control is a serious problem facing world agriculture. The term *soil erosion* is applied to the process of detachment and displacement of soil particles from land surfaces. The soil ero-sion is taking place in nature with the active involvement of agencies such as water wind, sea waves, and ice bergs. The soil erosion taking place in the nature can be grouped into two broad categories. The *natural erosion* or the *geologic erosion* or the *normal erosion* is taking place in nature from time immemorial, and there exists an equilibrium between the replaced soil and the soil formed as a result of weathering processes. This takes place so slowly that ages are required for it to make any marked alteration in land surface. That means, it is not a soil detereorating process. However, when the soil loss exceeds the addition, which is accelerated by human interferance, it is *accelerated erosion* or simply *soil erosin*. It has a detrimental effect on soil and soil fertility. When we refer to soil erosion, usually we mean accelerated soil erosion only.

11:2 Why soil erosion?

The major reasons attributed to the accelerated erosion are the indiscriminate destruction of forests, unscientific cultivation practices followed in slopy areas, and heavy grazing in pasture and grass lands. Due to the massive destruction of forests, the natural vegetative cover on land surface is lost. This leads to exposure of surface soil to the free action of erosive factors like heavy rainfall, strong winds etc, and the fertile top soil is lost in no time. It is observed that for the formation of one inch of soil, nature takes about 1000 years. However, the entire surface layer (15 cm) could be lost in a very short time, if erosion take place.

The unscientific cultivation practices followed on the slopy lands may lead to large scale soil loss by erosion. This has resulted in severe denundation of natural soil cover by allowing direct action of erosive agents on the top soil which has been made loose for cultivation. Severe grazing followed in pasture lands also leads to continuous exposure of soil and severe destruction of soil structure, which ultimately results in soil loss.

Large scale erosion may convert the fertile lands to barren and unproductive in a very short span of time. The sand and silt particles carried down to the valleys by the running water is deposited in river basins, and this may lead to frequent floods and diversion of course of flow through fertile river banks. The silting of dams takes place due to deposition of sand and silt, which may considerably reduce their storage capacity. The multi-million dam projects may be thus made useless which can create flood havoc due to the severe erosion taking place in their catchment areas.

Wind erosion is also responsible for destroying the valuable top soil in many areas. The wind erosion taking place in desert regions ultimately results in the transformation of fertile cultivable lands to uncultivable waste lands due to large scale deposition of sand particles.

Soil erosion can be of different types based on the agents causing them and their action. The important among them are discussed elsewhere.

11:3 Rain water erosion

The falling rain drops and the excess water flowing through soil surface at high velocities possess very high erosive power. As a result of this action, the top soil would be lost in different stages, and if this goes unchecked, ultimately the land would be converted to deep gullies and ravines. The water erosion due to rainfall takes place in different stages as splash erosion, sheet erosion, rill erosion or gully erosion.

Splash erosion: Splash erosion or the rain drop erosion is by the direct action of the failing rain drops. As the rain drops are having high kinetic energy, they detach and displace some amount of top soil from the area where it falls.

Sheet erosion: The loss of fertile top soil as thin sheets or films can be called as sheet erosion. This is an advanced stage of splash erosion. Here, surface soil from very large areas are lost in very thin sheets or layers. It is often unnoticed by the farmer as the visual effect of sheet erosion is not so prominent. It is taking place very slowly, but the entire top soil would be lost as time goes on. The muddy water emanating from the fields after rainfall is a good example for this types of erosion.

Rill erosion: If the sheet erosion proceeds unchecked, it advances further. At this stage, minute finger shaped grooves would be seen throughout the field. They may disappear on ploughing but appears again. If kept uncontrolled, the width and depth of these rills increase.

Gully erosion: It is the most severe form of rain water erosion. This is an advanced stage of rill erosion, which when kept unchecked, transform to deeper and wider channels. With each heavy rainfall, these channels or gullies continue to go deeper and wider, and finally, the entire land is divided into numerous ravines. This is the most spectacular form of erosion, and the land become unfit for cultivation.

11:4 Land slides or slip erosion

This takes place in slopy and mountainous areas. The slope forming material is moved outward and downward all on a sudden along with rocks, massive trees, soil etc. Earthquakes, heavy rainfall etc. are the major factors causing landslides or slips. Heavy destruction of forests have paved the way for frequent land slides in the mountaionus regions of Kerala.

11:5. Stream bank erosion

The torrential rains in the hilly areas lead to sudden increase in the volume of water flowing through hill streams. Usually, the streams may be too small to carry the entire water, which causes flooding of rivers and large scale erosion throughout the stream banks.

11:6. Sea shore erosion

The waves in the sea are slowly, but steadily. eating up the sea shore areas. During heavy rains and winds, sea becomes turbulent. These would cause creation of fierce looking waves which carry away large stretches of coastal areas into sea. Likewise, vegetation on them are also lost in a very short time.

11:7. Wind erosion

Wind erosion is prominent in low rainfall areas where there is less vegetation and the land exposed to heavy winds. The high velocity winds carry large quantities of soils along with it. When the wind velocity subsides, these particles would be deposited in far off places which may be fertile cultivated areas. Thus, the deserts are slowly expanding to fertile adjacent areas. Wind causes the movement of soil particles in three ways— saltation, suspension, and surface creep.

Saltation: In this type of soil movement by wind, soil particles having a size of between 0.1 to 0.5 mm diameter are directly hit by wind which lead to a bouncing action of soil particles. This bouncing action of soil particles are called 'saltations'. A major part of the soil particles carried by wind are moving through saltation.

Suspension: In this type, very small soil particles of less than 0.1 mm in diameter are carried in suspension and these would be transported to very long distances according to the direction of wind. This leads to permanent loss of surface soil.

Surface creep: Soil particles larger than about 0.5 mm in diameter but smaller than 1.0 mm which may not be carried by the saltation movement, move on the ground surface as a soil creep.

11:8. Factors influencing erosion

The intensity of erosion is influenced by many factors. They are described in brief.

Rainfall: The *amount* and *distribution* of rainfall play a significant role in erosion. Rather than the total amount of rainfall, tha intensity of rainfall is more important. A light rain, which can be easily absorbed in the soil, causes no run off and soil loss. As the intensity of rain increases and more rainfalls that can enter the soil, there is more run off and soil loss.

Wind: Heavy winds can increase the intensity of erosion both by water and wind.

The type of soil: The nature of surface soil determines its resistance to run off losses. Usually, soils with good water holding capacity and infiltration are less subjected to erosion.

The slope of the land: As the slope of the land increases, the velocity of surface flow also increases. The speed of surface flow directly determines the quantity of soil that is carried by water.

The ground cover and land use pattern: The vegetation in an area exarts a profound influence in reducing the erosive action of wind and water. The vegetative cover intercepts the rainfall and reduces the direct impact of water drops on the ground. The plants also supply considerable quantities of organic matter which Improves the soil structure.

Human factor: The large scale deforestation for cultivation purposes, the indiscriminate grazing in pasture lands, the unscientific use of land in slopy areas etc. are the major erosion causing factors. All these are said to be done for the benefit of man. However, when we see the results in the right perspective, we would ba surprised to know how these are all detrimental to the very existance of human kind!

11:9. Soil and water conservation measures

The principle followed in any soil and water conservation practice is to soak the soil with the rainfall as much as possible by increasing infiltration and percolation characteristics, thereby reducing the run off of water. This objective can be achieved by following various agronomic, and engineering or mechanical measures.

11:9.1. Agronomic measures

These involve the interception of rainfall and reducing their splash effect. These enhance the intake of water by soil by improving the organic matter content and soil structure. They are more effective in low rainfall areas, permeable soils, and in less slopy areas. In heavy rainfall areas,erodablesoils, and in long, steepy slopes, agronomic measures have to be strengthened with mechanical measures. Compared to mechanical measures, agronomic measures are cheap. The important agronomic measures for soil and water conservation are briefly outlined.

Contour farming: Contour farming is the cultivation of crops across the slope, keeping the same level as far as possible ie., along the contour lines. All the subsequent cultural operations are also done across the slope of the land. It reduces the down flow of water, as the ridges and rows of plants placed across the slope form a series of barriers to the flowing water and thus reduces the run off. It is beneficial in the scanty rainfall areas too, since it conserves available rain water.

Strip cropping This may be more effective than contour farming. Here, the principle is to plant crops in different strips across the slope of land. The alternate strips are to be constituted by erosion permiting crops and erosion resisting or soil protecting crops. This practice reduces the length of slope and checks run off. Considerable re-silting occurs in the strip occupied by soil protecting crops. Crops like maize. rice, sorghum, tapioca, root crops etc. are soil exposing crops ie., erosion permitting crops; while most of the leguminous crops are soil protecting crops.

Stubble mulching: Surface mulching using different materials is found to be useful in controlling erosion by reducing the surface flow of water as well as bringing about various other favourable effects. They include reducing the evaporation of water from soil surface, increasing infiltration,suppression of weeds, improvement of soil structure etc.

Cover cropping: It involves the practice of growing crops which possess good land covering capacity. The vegetative cover provided by the cover crops act as a barrier to flow of water, and the binding action of roots reduces the nutrient loss due to leaching and similar means. Leguminous crops like *Calapagonium, Pueraria, Centrosema* etc. are the commonly grown cover crops.

Alley cropping: Alley cropping denotes the planting of certain erosion resisting crops in hedges, at intervals, across the slope of the land, keeping the same level, that is, along the contours. Plants like subabul (*Leucaena leucocephala*)are very suitable for raising alleys of hedges in coconut gardens and cassava (tapioca) fields of Western Ghats of Kerala to prevent soil erosion, and for getting a perennial supply of green manure and forage. This method of alley cropping of subabul for soil conservation has been put to wide use in Philippines and Indonesia. There, thousands of hectares of hill slopes are planted with subabul, along the contour lines, as a measure against soil erosion.

Crop rotation: This involves the practice of introducing erosion resisting crops in rotation with erosion permitting crops. Usually, leguminous crops are planted in rotation with crops like tapioca, cereals etc.

Conservation tillage: Any tillage system that reduces soil and water loss compared to clean tillage is termed conservation tillage. All the so called *minimum tillage* and *no-tillage* methods which reduces soil erosion and run off are covered by this.

Mixed cropping: Mixed cropping is practised mainly as an insurance against the possible loss of one or more crops due to some unforeseen calamities. This is also found to be very effective in covering the land continuously, and thus, protecting the soil from the beating action of rain drops and the resultant erosion of soil.

11:9.2 Mechanical measures

These are usually resorted in areas where agronomic measures alone are found to be ineffective in checking erosion. Mechanical measures or engineering measures are particularly suitable for heavy rainfall areas and in steep slopes. The principle behind these means is to reduce the run off velocity by dividing the lengthy slopes into many short compartments. The important methods under these include:

Basin listing: Basin listing is the process of making a large number of small basins across the slope along the contour by using a basin lister. These basins thus created act as a storage for the rain water and retain it for a fairly long time. This practice increases the infiltration and reduces the run off.

Sub soiling: The process of breaking the hard pans and impermeable sub soil layers by means of sub soilers is known as subsoiling. This makes the soil more permeable and helps in reducing the run off and erosion.

Contour bunding: Contour bunding consists of making narrow and broad based embankments or bunds along the contour lines, so that soil and water is conserved. Countour bunding is an important soil and water conservation measure followed in arid and semi-arid regions with high infiltration and is commonly adopted in agricultural lands. In Kerala, particularly in the Western Ghats, most commonly adopted mechanical measure of soil conservation is by means of contour bunding. Since the slope of land in most cases exceeds 33 per cent, we have to re-inforce the embankments or bunds by some means. Usually, we use rubbles for reinforcing the bunds and the method is known as *rubble pitched contour bunding* (Fig.11.1) and the bunds formed are called rubble pitched bunds or contour stone walls(*Kayyala*). The soil conservation department of Kerala is also advocating rubble pitched contour bunding, which is similar to Puertorican type of terracing, in their programmes.

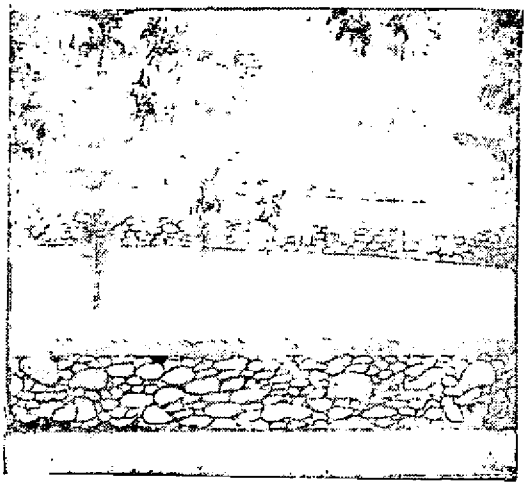


Fig. 11. 1. Rubble pitched contour bunds (diagramatic)

For fixing the contour lines dumpy levels or more conveniently an 'A' frame can be used. The 'A' frame is a simple device commonly used by masons for fixing the levels and the farmer can make one easily. He can fix the contour lines by noting points of equal levels in the field. After noting the contour lines and fixing the intervals of bunding, rubble pitched bunds are made.

Contour trenching: In this method, trenches are taken along the contour lines, which intercept run-off of water, and thereby preventing soil and water losses. Trenching is commonly followed in coffee gardens of Wynad.

Terracing: Terracing has to be followed for cultivation in areas having a slope more than 10 per cent. Terraces of various types like channel terraces, graded terraces, diversion type terraces, bench terraces etc. are followed according to severity of erosion and slope of the area. Bench terracing is followed in the steepest slopes of even more than 33 per cent and here, slopy areas are divided into a large number of platforms. They help to retain water, manure, fertilizer etc. Though the initial establishment costs are very high, this is the only effective practice that can be followed in steep slopes.

From the above discussions, it is obvious that in heavy rainfall areas conservation of soil and in low rainfall areas conservation of water are of extreme importance for successful crop production.

11:10 Control of Wind Erosion

The main principles involved in the control of wind erosion are reducing the wind velocity at ground level, reducing sediments from wind stream, and reducing erodability of top soil. These can be achieved by following practises like making bunds at right angles to the direction of wind, planting protective vegetation at right angles to direction of wind, and by providing shelter belts or wind-breaks on the windward side of the field *Wind strip cropping* is also an effective method. Here, erosion permissive and resistant crops are planted horizontal to each other. Providing suitable cover crops and mulches on the soil surface prevent soil erosion due to wind, to a large extent.

AGRONOMY

12. The scope and importance of agronomy

We have seen in the introductory chapter that the term 'agriculture' is broadly used to denote the sciences of raising both plants and animals. In the plant science group, there are three major divisions, viz., agronomy, horticulture and forestry. We may examine the importance and scope of agronomy in this chapter.

Agronomy defined

The term 'agronomy' is derived from two Greek words, *Agros* (field) and *Nemein* (manage), meaning field management. The term was first introduced in the Agricultural colleges and experiment stations of the United States around 1890's to designate the branch of agriculture dealing with climate, soils, fertilizers, and crops. Later, the term came to be used generally to indicate that branch of agriculture dealing with the science and the art of field crop culture and soil management. In the present context, instead of soil management, the usage land management is more appropriate, since in agronomy, besides soil, management of water, climate, space, vegetation etc. are also involved. Thus, we may define agronomy as *that branch of agriculture dealing with the science and the art of production of field crops, and management of land.*

The scope of agronomy

The definition suggests that agronomy comprises the study of two businesses; the production of crops and management of land. The crops included under agronomy are those which are grown under a relatively extensive system of culture. The crops which are called field crops are generally put under agronomy, in contrast to garden crops (fruits, vegetables and ornamental plants) grown under an intensive system of cultivation and included under horticulture. Production of food for man, fibre for his clothing, feed for his animals, and other farm products for his industries is the main task of agronomy. The crops such as cereals, pulses, oil seeds, root and tuber crops, fibre crops, sugar crops, narcotic crops, forage crops, beverage crops, spices and condiments, green manure crops, and several other miscellaneous crops, grown under an extensive system of culture are included under agronomy.

The management of land as a whole–in respect of soil, water, space, climate, and vegetation–is also the concern of agronomy. This is done regardless of whether the crops grown are field, garden, or forest crops. The term 'agronomy is also frequently used synonimous to management, while describing crops.

The development of agronomy through the ages

Agronomy had its origin largely in the sciences of botany, chemistry, physics, mathematics, and economics. Though the term agronomy came to be known in 1890's only, the knowledge which form the science had been developed form time immemorial, and it is being refined through years of experience and expertise. This is a continuous process. The Old Testament of The Bible and the Greek epic poem *The Odyssy*-written by Homer (who is believed to have lived between 900-700 B. C.)-mention several agricultural practices followed during ancient times. Ancient Greeks, Romans and the Chineese. contributed a lot to the development of agronomy. The Chineese invented the plough by around 2700 B. C. Hesiod, a Greek poet who died in 776 B. C., formulated rules of husbandry, which were followed and quoted for about 1000 years. Writings of Romans-especially those of Cato, Varro, Virgil, and Columella-were the sources of information of agricultural practices followed by Romans.

After the decline of Roman empire, agriculture fell into a long period of decay. The 'Dark Ages' of Europe (5th to 12th Centuary) was a sad period for agronomy, too, like other sciences. However, the book *Opus ruralium commodorum* which is a collection of agricultural practices followed from the time of Homer, written by Pietro de Crescenzi (1230-1307), is a commendable one. De Crescenzi is referred to as the father of modern agronomy by many.

The first experiment in agronomy may be those of Jan Baptiste Van Helmont, (1577-1644). Van Helmont reported the results of an experiment with a willow shoot, which in his view, proved that water was the only nutrient of plant. Though his conclusions were wrong in the present level of knowledge, it stimulated further investigations at that period. Another notable agronomist of that period was Jethro Tull (1674-1741), who developed a drill and a horse-drawn cultivator. His book 'Horse Hoeing Husbandry' was long considered as an authoritative book on English Agriculture. The contributions of Arthur Young (1741-1820), who published 'Annals of Agriculture' in 46 volumes, is also noteworthy.

Scientific research in agronomy, based on the field-plot method of experimentation, may be said to have begun with the establishment of the first experiment station by J. B. Boussingault in Alsace in 1834. Further impetus was given to experimentation by J. H. Gilbert and J. B. Lawes by establishing the famous Agricultural Experiment Station at Rothamsted, England in 1843. As we have seen earlier, agronomy has been approved as a distinct and recognised branch of agricultural science since about 1890. The American Society of Agronomy was established in 1908. In the initial stages, when agriculture began to be studied on a formal style, many of the now independant supporting disciplines such as agricultural economics, agricultural extension, agricultural statistics etc. were all taught as parts of agronomy. As these disciplines developed and a wealth of information were added, they emerged as independant supporting sciences. Similarly, the sciences such as agro-meteorology, weed science and seed technology were so far recognised as distinct branches of agronomy. Now, they have been approved as independant supporting sciences in many circles. As more and more informations are added, it is imperative that new independant disciplines would emerge.

Agronomy today

In the present concept, agronomy includes a vast area of study. The important areas of study identified under agronomy are given below.

Agro-meteorology: The study of meteorological parameters in relation to crop production.

Seed technology: The study of seeds and connected technologies for produ-ation, processing, preservation and other related aspects.

Weed Science: The study of weeds and their management in crop production.

Soil management: Soil management denotes the sum total of all tillage operations, cropping practices, fertilizers, lime, and other treatments conducted on, or applied to a soil for the production of crops. Soil fertility and its management, tillage, and soil and water conservation are the major areas covered under soil management.

Water management: Water management is that part of agronomy which deals with all those aspects connected with water in crop production including irrigation and drainage.

Farming systems: The study of the entire complex of resource preparations, allocations, decisions, and activities within an operational farm unit and related crop production problems.

Dry land farming: The study of the specialised techniques and principles involved in the crop production in low rainfall areas.

Crop husbandry: The science and the art of production of field crops.

Agrostology: It is a specialised field of agronomy which deals with study of grasses for animal consumption.

Agro-forestry: Agro-forestry denotes an integration of farming with forestry practices for the benefit of agriculture.

13. Seed and its importance

13.1 Introduction

Plants begin their life from seeds, and in most cases, end their life with the production of seeds. Seeds are the principal way of survival of a plant species. However, seeds are many other things for man. For him, seed is the basic input in agricultural production and without good seed investment on fertilizers, water etc. will not pay the divident which he expects Of the various inputs needed for agricultural production, seed is the cheapest also. Man recognised the importance of improved seed since long and he knows, much about seed and the maintenance of its quality now

13:2 Seed defined

Botanically, seed is a fertile and ripened ovule which contains an embryonic plant supplied with food-storage tissues and surrounded by a seed coat. In other words seed is a ripened ovule containing an embryo. A fruit, however, is a ripened ovary containing the seeds ie., the ripened ovules. The ovary and the ovules which develop into fruit and seed are present in the pistill of a flower. The ovary which contains the ovules is the most important part of a flower. It may not always be possible to distinguish the fruit and seed, as they are sometimes joined in a single unit. In such cases, the fruit itself is treated as the seed as in rice or wheat.

In a broader sense, the word 'seed' is used to denote not only true seeds but also other propagating materials which include seedlings, tubers, bulbs, bulbils, rhizomes, suckers, cuttings, grafts, buddings, and other vegetative structures used for propagation or multiplication of plants. Thus, we may come across with such terms as seed potato, seed ginger etc. which means nothing but potato tubers and ginger rhizomes used for planting purposes.

13.3 Importance of seeds

Seeds have myriad functions to perform and have numerous uses. In the first place, seeds are a way to insure continuing life. They are also the means for the spread of new life from place to place by the involvement of agencies such as wind, animals, and human beings. The plant breeder uses seed as a beginning, when he has effected some major changes in the plant.

Seeds form food for man, animals, and other living things. As mentioned earlier, a seed in the strict sense, is an embryo—a living organism—embedded in the supporting or the food storage tissues such as endosperm and cotyledons. These endosperm and cotyledons with their food reserves, serve as a staple food for man and animals. Food prepared from the seeds, especially that of the cereals, form the major food of the world. As a feed also, seeds are very important. The plant family Poaceae (Graminae), which includes the cereals and millets, contribute more food (seeds) than any other plant families put together. The Fabaceae

(Leguminosae), the second most important plant family, provides pulses which are rich in proteins and are essential in a balanced diet.

Seeds are the raw materials for making a diversity of products such as pharmaceuticals, cosmetics, alcoholic beverages etc. It finds a place in arts too. Most seeds are objects of beauty in form, proportion, surface and colour.

Above all, seeds are a symbol. They colour our language and habits of thought. Our language and culture contain many words and concepts based on seeds. Our *Puranas* and the Bible contains several such examples. The famous parable of the sower in the Bible is a classic example. Ancient philosopher and law maker, Manu wrote in the famous book 'Manusmrithi', *'Subeejam sushethre Jayathe sambathyathe'* (Good seed in good fields yields abundant produce). The famous Malayalam proverb *'Vithugunam pathugunam'* is another example. Our old civilizations were aware of the importance of quality seeds!

From the foregoing discussion, we may be under the impression that all seeds are beneficial to man. Certainly not! Weed seeds create enormous problems to man. They affect his crop by way of competition for soil, water, nutrients, and space. The result is reduction in yield. Weeds affect human life in several other ways too. All of them need not be listed here since they are described elsewhere. The seeds of certain plants are responsible for some of our serious social problems too. For example, opium, cannabis etc. yield narcotic drugs, the addiction to which is a serious problem facing many nations.

Thus, it could be seen that seeds are unique things. However, everything about seeds-their number, forms and peculiarities-have a bearing on their main purpose-to insure continuing life. We must not forget this fundamental fact while studying seeds.

The importance of seed is such that its production, processing, preservation etc. need special attention. Scientific principles and techniques in the production and handling of seeds are also to be standardised. The science of Seed Technology thus emerged as a separate discipline to deal with seed production, processing, marketing and such other related aspects. Nowadays, Seed Technology has been approved as a separate discipline by many taking into consideration its importance.

13:4 Seed dormancy

When viable seeds are set to germinate, some may fail to do so, even if environmental conditions are favourable. They will not germinate until they undergo some kind of changes or a resting period. This condition is known as seed dormancy. It can be defined as the condition of a viable seed which prevents germination, when it is supplied with the conditions normally considered to be suitable for germination, viz. adequate moisture, suitable temperature, and adequate aeration.

The failure of seeds to sprout does not always mean that they are dormant or non-viable. Environmental conditions may be unfavourable for germination. The term seed dormancy is generally restricted to those cases which fail to germinate because of some internal factors alone. In contrast, if the seed can germinate immediately upon the absorption of water without a barrier to germination, the seed is said to be *quiescent* and the condition is called *quiescence*. There is another term-*vivipary*—worth mentioning in this connection. Under some conditions, the seeds of certain plants may germinate while still attached to the mother plant. This phenomenon is called vivipary eg., Chow-chow (a vegetable) jackfruit etc.

Seed dormancy is often divided into two categories-*primary dormancy* and *secondary dormancy*. When conditions that [prevent germination exist within the seed at the time it matures on the plant, the state of the seed is called primary dormancy (also known as natural dormancy, inherent dormancy and endogenous dormancy). Such dormancy prevents the seed from germinating viviparіously. After a seed has lost its primary dormancy, chances are that it may again become dormant, if the seed is subjected to particular unfavourable conditions. This is referred to as secondary dormancy or induced dormancy.

There are yet some other kinds of dormancies too. For example, in certain wild flowers, the germination of the seed may occur but growth is restricted to the establishment of the root system and the epicotyl fails to grow. This kind of situation can be referred to as *epicotyl dormancy*, and in most cases, can be broken by exposure to low temperatures.

13:4.1 *Importance of seed dormancy*

Seed dormancy provides a delay mechanism for the higher plants which enables dispersal from the mother plant before germination. It could also enable the seed to germinate at more opportune time or positions. From the crop production point of view also, it is important. If the crop seeds are showing vivipary, the farmer will be in difficulty, since he cannot time his operations. Prolonged dormancy also alter his plans. In such cases, he has to overcome this with certin methods or prodedures. An understanding of the possible reasons for seed dormancy may become important in such situations.

13:4.2 *Reasons for seed dormancy*

Impermeability of seed coats to water: Impermeability of the seed coats to water is a major factor in maintaining seed dormancy in several plants. The embryo may be non-dormant (quiescent), but is sealed inside a water impermeable covering. Such effects of seed coat is seen in several members of the plant families as *Fabaceae (Leguminosae)*, *Malvaceae*, *Cannaceae*, *Geraniaceae*, *Chenopodiace*, *Convolvualace*, *Rosaceae*, and *Solanaceae*. Green manure crops like peuraria and calapagonium of the family *Fabaceae* are classic examples to show this type of seed dormancy. In nature, seed coverings are softened by various agents of the environment including mechanical abrasion alternate freezing and thawing, attack by soil micro organisms, passage through the digestive traits of birds, fire etc.

Physically resistant seed coats to embryo expansion: In general, once water is absorbed by the seed, and the embryo is not dormant, the expanding force of germination will rupture the seed coats and break apart any outer covering. However, in certain plants, especially weeds like wild mustard (*Brassica* sp.); the seed coats are so strong enough to prevent any expansion of the embryo and impose restrictions on seed germination.

Impermeability of seed coats to oxygen: In certain seeds, there is some physical restriction in the movement of oxygen to the imbibed embryo, either due to the inner membraneous seed coat or to the enclosing nucellus or endosperm.

Presence of chemical inhibitors: Specific chemical substances that prevent germination are produced by many plants. Inhibitors may occur in the juices of fleshy fruit as in tomato, citrus, and cucurbits; dry covering of seed as in wheat; or in seed coats, endosperm or even in the embryo itself.

Presence of rudimentary embryo: In some plants, the embryos are not completely developed morphologically at the time of seed ripening, and normally undergo further growth within the seed after its removal from the plant. eg: certain orchids.

Internal or endogenous dormancy: Many freshly harvested seeds, though the embryos are completely developed, fail to germinate even when environmental conditions are favourable. Dormancy of such seeds is a result of the physiological condition of the embryo. The embryos of such seeds will not grow, even if seed coats are removed. This dormancy tends to disappear with time. Apple and peach are examples for showing this type of dormancy. Germination of this kind of seeds occur only after a period of *'after ripening'*. All the physiological changes that occur within a seed so that germination can take place are referred to as after ripening. In many wild plants, after-ripening occurs during the winter, while the seeds lie on the ground or just under the soil surface. Such seeds will not germinate as soon as they fall from the parent plant, but will germinate in the following spring, if environmental conditions are favourable.

13:4.3 Methods of breaking dormancy

The seed dormancy presents problems in may cases. Farmers are interested in getting seeds that germinate soon after it is harvested. This is normally possible only with seeds that have a short dormant period or none at all. Several methods have been devised to break the dormancy to suite our requirements. The methods may vary depending on its causes. A brief account of the important methods are given below.

Scarification (scratching): Hard seededness can be removed by way of scarification. Scarification may be any process of breaking, scratching, or mechanically altering the seed covering to make it permeable to water and gases. Scarification may be mechanical or by dipping in acid or by dipping in a solvent. It has been observed that machine threshed legume seeds had a higher percentage of germination than those that have been threshed by hand. *Impaction* or *percussion* treatments aresome times employed. cover crop seed *Peuraria*, to break the dormancy mix the seeds with sand about 1–2 times the quantity of seed, and then gently grind in a mortar.

Acid scarification is also commonly employed eg: *Peuraria*. Soaking the seed in concentrated sulphuric acid for 10 minutes will soften the hard seed coat. Then the seeds are thoroughly washed in water before sowing.

Hot water treatment is another method of scarification. In crops like *Calapagonium* and *Peuraria*, this method is applicable. Take the seeds in a bucket and pour the hot water of about 60–80°C into it till the seeds are submerged. Keep it as such for 4 to 5 hours.

Pre washing or pre-soaking of seeds: Pre-washing, where the seeds are continuously rinsed in running water and pre-soaking, where the seeds are soaked in static water can result in a fairly rapid uptake of moisture by seeds and may overcome some of the causes of dormancy. Inhibitors present in some seeds can be leached out by washing or soaking.

Alternating temperatures: The germination of certain seeds like Kentucky blue grass (*Poa pratensis*) is found to be greatly improved when it is subjected to temperatures of 20°C for 16-18 hours and 30°C for 6-8 hours. Similarly, the percentage germination of Johnson grass (*Sorghum halepense*) seeds is increased by alternate treatments at 30°C for 18-22 hours and 45°C for 2-8 hours. However, this method of breaking dormancy is effective only in a few species. In general, these are effective in seeds in which the dormancy is inherent in the embryo (endogenous dormancy).

Stratification: Stratification or moist chilling is subjecting the seeds to very low temperatures in moist medium. Temperatures between 5° and 10°C for 2-3 months are effective with conifer seeds in breaking this dormancy and improving the percentage of germination. For temperate plants like apple, peach etc. stratification at 0-5°C for a few weeks is effective. After-ripening of this kind of seeds occur more rapidly, when they are stratified in moist medium.

Light: In certain seeds, light improves germination at low temperatures, eg: seeds of *Veronica longifolia*. In kentuckey blue grass, exposure to light is effective in improving germination at alternating and constant temperatures. Thus, light could be considered as a method of breaking dormancy in certain species.

Application of growth regulators: Treating the seeds with some of the plant growth regulators, especially Gibberelic Acid (GA_3) is effective to break dormancy and to induce early germination. The chilling requirement or stratification can be replaced by treating the seeds with GA_3. eg: temperate fruits.

13:4.4. Secondary dormancy:

We have earlier seen that secondary dormancy is the condition in which a seed after losing its primary dormancy becomes dormant again due to certain unfavourable conditions. Usually, secondary dormancy can develop only when at least one of the conditions essential for germination is unfavourable. For instance, the seeds of white mustard fail to germinate, when they are exposed to higher concentrations of carbondioxide. It will not germinate even under favourable conditions for a long period after the removal of the carbon dioxide. Similarly, light sensitive seeds may pass into secondary dormancy, if kept in the dark; and seeds that germinate only in the dark may become dormant, if exposed to light. Likewise, exposure to low temperatures and high temperatures may also induce secondary dormancy.

The reasons for secondary dormancy can be attributed to changes in seed coat, since in some species, the embryos are able to grow immediately, if the seed coats are removed. The dormancy may also be produced by physiological changes that occur within the embryo itself. Like the primary dormancy, secondary dormancy may also be broken by various treatments.

13:5. Seeds of local and hybrid varieties:

13:5.1. Terminology:

Before going in detail on this section, we may first familiarise with certain important terms.

Cultivar: A cultivar may be defined as an assemblage of cultivated plants, which is designated by any character, either morphological, physiological chemical or others, significant for the purpose of agronomy, horticulture and forestry, and which, when reproduced sexually or asexually, retains its distinguishing characters. The term cultivar (written cv-singular, and cvs–plural) is a contraction of the phrase 'cultivated variety' which can be used in any language to prevent confusion with the botanical taxonomic term 'variety', an intraspecific unit which represents a morphological variant of the species. The use of the term is as recommended by the *International Code of Nomenclature for cultivated plants*, 1969.

Thus, the complete scientific name of any plant developed or maintained under cultivation includes the genus, the species and the cultivar name. The generic and specific names are in Latin forms and the cultivar name in words of a common language. It can be written in either of the forms written below.

Oryza sativa cv. Jaya

Oryza sativa 'Jaya'

The cuitivar name can be attached to the common name of the crop also eg: Rice 'Jaya'.

Variety: Variety is a distinct morphological subgrouping within a species, usually, resulting from geographical separation. The varietal name is also to be written in Latin form.

For example, cabbage, cauliflower, kale, brussels sprouts, knol-kohl, sprouting broccoli etc. are varieties of a species *Brassica oleraceae.*

Cabbage	*B. oleraceae* var. *capitata*
Cauliflower	*B. oleraceae* var. *botrytis*
Kale	*B. oleraceae* var. *acephala*
Brussels-sprouts	*B. oleraceae* var. *gemmifera*
Knol-kohl	*B. oleraceae* var. *gongylodes*
Sprouting brocooli	*B. oleraceae* var. *tolica*

However, there is a tendancy to use the term 'variety' synonimous to 'cultivar' in many circles. This practice should be discouraged, since this may create confusion with the actual variety. Therefore, it is better to use the term 'variety' for botanical varieties alone and 'cuitivar' for cultivated varieties.

Local cultivars (variety): Local cultivars are a group of cultivated plants in existance from long and is being cultivated by the local farming community. eg: Rice— *'Thavalakannan'*, *'Thekkan cheera'*.They are, in general, low yielders and respond less to fertilizers and other improved cultivation practices.

High yielding cultivars (varieties): These are a group of cultivars which are inherently capable of producing high yield. These are produced, as a result of the advancement in plant breeding. For instance, IR-8, Jaya, Thriveni etc. are high yielding cultivars of rice.

Improved cultivars: These include both high yielding cultivars and those that are bred for specific objectives like straw yield, disease resistance, insect resistance, cold resistance etc. Tha preent trend is to use the term 'improved' rather than 'high yielding'.

Hybrid vigour

Hybrid vigour or heterosis is tha increased vigour, growth, size, yield or function of a hybrid progeny (F_1) over the parents that results from crossing two genetically unlike individuals. It may also be the extra vigour or growth of a hybrid progeny in relation to the average of the parents.

F_1—generation: The first generation progeny after a cross between two parents.

Hybrid cultivars (varieties): Hybrid cultivars are also improved cultivars, but is a first generation (F_1) hybrid, reconstituted on each occasion by crossing two or more parents maintained either by inbreeding or as clones. For example, in coconut, T x D is a F_1 hybrid between Tall and Dwarf palms.

Clone: Clone is a group of homogeneous plants originating from a single individual and propagated by vegetative methods.

13:5.2 Differences between local and hybrid cultivars

As we have seen, local cultivars are in cultivation for centuries. They are, in general, low in yielding ability, susceptible to lodging, and less responsive to fertilizers. The seeds, if maintained properly, will be true to type and produce the same kind of plants on cultivation. However, hybrid cultivars are generally obtained by crossing two genetically dissimilar parents. Scientists observed that in many crops, the F_1 progeny produced immediately after crossing two dissimilar parents shows some extra vigour unlike their parents. In most cases, they are heavy yielders also. This led to the possibility of exploiting hybrid vigour in crops. The first instance of exploiting hybrid vigour occurred in maize, and hybrid maize was the result, which actually revolutionized maize industry.

However, one problem with sexually propagated plants is that we have to produce hybrid seeds each time before sowing. If we use the seeds of hybrid cultivars (F_1) for further cultivation, the progeny will be heterozygous and lose the hybrid vigour. That means, we have to produce hybrid seeds each time for cultivation, by crossing selected parents. Since this is quite cumbersome, this method is recommended for crops which produce seeds in large numbers in an inflorescence or flower and also in plants where male sterile lines are possible. In maize, the hybridization programmes are carried out usually with male sterile lines. Vegetatively propagated plants are in an advantage over the exploitation of hybrid vigour. Once we are able to detect desirable vigour in its progenies we can convey this to successive generations by means of vegetative propagation.

13:5.3 Impact of hybrid seeds in important crops

Rice: Heterosis or hybrid vigour has been noted by many workers in such characters as height, tillering ability, earliness and yield as early as 1953 in India. However, utilization of heterosis for the commercial production of hybrid rice* is dependent upon the availability of male sterile lines and restoring lines, or other means of controlled pollination on a mass scale. Chinese scientists have succeeded in the production of hybrid rice on commercial basis. They obtain hybrid paddy seeds by crossing three rice lines—the 'male sterile', the 'maintaining' and the 'restoring' lines. Using one fifteenth of the normally required amount of seeds they get 25 percent more yield than the conventional varieties .

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* The cultivars such as IR-8, Jaya, Jyothi, Annapurna etc. are not hybrid rice in the strict sense. These cultivars were developed as a result of the breeding technique, hybridisation and selection or combination breeding. Hybridization is first done to combine desirable characters into a single genotype. The characters are then stabilized by way of selection. Several techniques are there in combination breeding. In these cases, the cultivars produced are true to type and will not segregate in the successive generations unlike hybrid cultivars.

Recently, Chinese agronomists devised methods to grow rice without seeds. Tillers or young shoots from rice stocks are planted instead of seeds. If the vegetative propagation of rice plants is made easy, then the exploitation of hybrid vigour would be more economical.

Coconut. Coconut is a cross pollinated crop. Most successful and important breeding method applicable here is heterosis breeding ie., productian of hybrid cultivars. Coconut palms are generally grouped into two viz., *tall palms* and *dwarf palms*. Scientists have found that by crossing these two, and planting the progeny (F_1), hybrid vigour can be utilized. Two types of hybrid cultivars can be achieved by this type of crossing namely,

T x D (tall is the mother palm)

D x T (dwarf is the mother palm)

Other important hybrids recommended for cultivation are

Tall x Gangabondum

Laccadive Ordinary x Gangabondum

Andaman Ordinary x Gangabondum

Yellow Dwarf x Tall

The hybrid palms have desirable characteristics like precocity in bearing, vigorous growth, higher productivity, and better nut and copra characteristics.

Tapioca. Production of hybrid cultivars have good scope in tapioca by heterosis breeding. A hybrid evolved can be used for establishing a clone, which means there is no necessity for breeding every year. In other words, we can maintain the traits of F_1 progeny through vegetative propagation. Since crossing is done only once and further multiplication is by vegetative method, hybrid vigour is maintained throughout the successive generations.

There are 5 important hybrids evolved in Kerala and recommended for cultivation.

Name	*Cross*
H-97	*Manjavella* x S-300
H-165	*Chadayamangalamvella* x *Kalikalan*
H-226	*Aethakkarappan* x M 4
H-1687 (Sreevisakh)	Complex hybrid derivative
H-2304 (Sreesahya)	Complex hybrid derivative

M4 is the famous local cultivar and and is of excellant cooking quality. But its yield level is poor. It yields on an average 12–14 tonnes/ha. However, hybrid cultivars can yield upto 40-50 tonnes/ha under recommended management practices.

Pepper: Pepper is also a vegetatively propagated plant. So naturally, the hybrid vigour shown by the F1 generation can be passed over to successive progenies propagated by cuttings. The famous hybrid cultivar Panniyur-1 is an example. This cultivar was obtained from a cross between two local cultivars, *Uthirankotta* and *Cheriyakaniakadan*.

Banana: In banana also, utilization of hybrid vigour is easy, as the method of propagation is vegetative by means of suckers. However, hybrid cultivars are not popular in banana. Examples are Klue Teparod and Bodles Altafort. Hybridisation programmes in banana are being undertaken at the Tamil Nadu Agricultural University, Coimbatore.

Cardamom: Cardamom can be propagated vegetatively by rhizomes and also by seeds. However, seed propagation is more famous because of the dreadful disease of cardamom – the Katte – which is easily transmitted through rhizomes. The hazards are less when seeds are used.

Though there are no artificial hybrids in cardamom, there is one natural hybrid-'Vazhukka' obtained naturally from the cultivars, 'Mysore' and 'Malabar'.

Rubber: There is immense scope for exploiting hybrid vigour in rubber. All the famous rubber clones are obtained by means of hybridizarion. Rubber is propagated by seeds and by means of vegetative method-budding. Budding is the only possible method to exploit the traits of the mother plant-normally a hybrid.

The promising clones evolved at Rubber Research Institute of India, Kottayam, are given below.

Clones	*Parents*
RRII-105	Tjir 1 x GL 1
RRII-118	Mil 3/2 x Hil 28
RRII-203	PB 86 x Mil 3/2
RRII-208	Mil 3/2 x AVROS 255
RRII-116	Mil 3/2 x Hi. 28

Sugarcane: Sugarcane is a vegetatively propagated crop. It is propagated by means of stem cuttings-the setts, which means there is immense scope for exploitation of hybrid vigour in sugarcane. The vigour shown by the F1 generation can be carried over to subsequent generations. Hybridization between clones followed by clonal selection within the hybrid population is the procedure by which sugarcane cultivars are commonly developed. Yield, lodging resistance, resistance to frost, drought and water logging,disease resistance, insect resistance etc. are the objectives in breeding programmes.

Pulses: Hybrid vigour as expressed by high yield of the F1 over the best parent has been noted in several cases. However, no practical means of utilizing hybrid vigour is available, since pulses are self pollinated crops and propagated by seeds.

Mango: Mango is an important fruit crop of India. Several hybrid cultivars were developed in mango. Mallika (Neelum x Dasheri) and Amrapalli (Dasheri x Neelum) are popular hybrid cultivars of North India.

Hybridisation work in mango was carried out in the District Agricultural Farm, Talipparamba during the fiftees and sixtees. Four hybrids were selected. They are Hybrid No. 56 (Bennet Alphonso x Himayuddin), Hybrid No. 45 (Bennet Alphonso x Himayuddin), Hybrid No. 151 (Kalapady x Neelum) and Hybrid No. 87 (Kalapady x Alumpur Baneshan). They possess hybrid vigour and are high yielding and start bearing in 4-5 years as against 7-8 years in seedlings.

The hybrids are propagated by grafting.

Vegetables: A large number of hybrid cultivars were developed in many of the vegetables. Since in most of the vegetables, seed propagation is practiced, fresh F1 seeds are to be produced for their cultivation. The hybrid cultivars are early and high yielders. Some of the examples are-

Tomato	—	Karnataka hybrid, Mangala hybrid, Improved Meeruti x Pusa Ruby, Marglobe x Pusa Early Dwarf etc.
Brinjal	—	Pusa Anmol (Pusa Purple Long x Hyderpur), Suphal, Arka Navneet.
Capsicum	—	Bharath

14. Seed production and handling

14:1 Introduction

The use of good quality seed is of paramount importance in crop production. Seed quality is the sum total of many attributes or characteristics. Good seeds must have high germination percentage, proper size and development, high vigour, genetic purity (trueness to cultivar), uniformity or homogenity, freedom from weed seeds and other crop seeds, freedom from seed borne diseases, and freedom from inert and other extraneous materials. The highest quality seeds should possess all the above characteristics. This idea of high quality is seldom achieved in practice, and hence, only minimum quality standards are prescribed. However, in a seed production programme, the goal should be to achieve the highest quality rather than the minimum standards.

14:2 Conditions that affect quality

The conditions that affect the quality of seeds are *method of production, method of handling,* and *method of storage*. The conditions and events taking place in the seed during these stages determine the ultimate quality of seeds.

Method of production

The crops grown for seed production should receive extra care and attention. In order to produce good seeds, sound, well developed, disease free, unadulterated stocks should be used. Such seeds should be planted on good field and given good cultivation and maintenance. Proper *isolation distance* and *roguing* should be given to prevent contamination by genetic factors. The minimum distance to be given while two genetically different cultivars are grown side by is known as *isolation distance*. This is to avoid possible contamination by natural crossing with other cultivars grown along side. It also guards an extent against mechanical mixture at the time of sowing harvesting, threshing, processing, and handling of seeds. For cross pollinated crops, isolation distance will be more and for self pollinated crops, it will be less. The minimum isolation distance to be given for a few important crops are given in the Table 14.1.

The removal of off-type plants from the seed crop is known as *roguing*. Roguing is conducted to avoid possible genetic contamination by way of plants differing in their characteristics from those of the seed variety.

Weed control operations, pest and disease control etc. are the other operations to be taken up with great care to get quality seeds.

Method of handling

Crops harvested for seed purpose should be carefully handled at harvest time and during the period that intervenes between harvest and final storage. Care should be taken not to harvest the crop untill the seeds are mature. Every care has to be taken to avoid physical contamination by inert matter like broken seeds, soil praticles etc. This can be rectified by grading, screening, cleaning etc.

Table 14.1: Minimum isolation requirements for seed production of important crops

Type of pollination	Crops	Seed class	
		Foundation	Certified
Self pollinated	Rice, Wheat. Groundnut, Cowpea Soybean etc.	3 m.	3 m.
Self pollinated (but to a lesser degree than above)	Cotton	50 m.	30 m.
	Tomato	50 m.	25 m.
	Sesame	100 m.	50 m.
Often cross- pollinated	Brinjal	200 m.	100 m.
	Chillies	400 m.	200 m.
	Okra (bhindi)	400 m.	200 m.
	Amaranth	400 m.	200 m.
Cross-pollinated	Cucurbits (Bittergourd, cucumber etc.)	800 m.	400 m.
	Cabbage, cauli-flower etc.	1600 m.	1000 m.

Method of storage

Seeds should be dry before storage and efforts should be taken to keep them dry in storage. The objectives and methods of *seed drying* and *seed storage* are discussed in detail, as they are of much importance in determining the quality of seeds.

14:3 Seed drying

The presence of high moisture content in seeds during storage is one of the main reasons why they lose their ability to germinate. Seeds, are therefore, dried to safer moisture levels before storage to maintain seed viability and vigour. It involves basically the process of evaporation of moisture from seed.

The moisture content in seeds affects the respiration rate of seeds, and moisture levels above 20 per cent may produce heat enough to kill the seed. Some seeds may suffer mechnical damage in handling and processing, if they are moist. Micro-organisms may grow in moist lot of seeds, particularly, when the seeds are cracked or damaged. Insect damage is also related to moisture content of seeds. Most of the weevils and insects cannot breed properly at moisture levels below 8 per cent and tend to die. When fumigation is done to control insects, seed injury would be more, if the seeds contain high levels of moisture. Thus, it could be seen that seed drying is an important operation to be carried out scrupulously to get quality seeds.

Moisture is distributed in seeds in two forms, viz. the *surface moisture* which occurs on the outer surface and the *internal moisture* distributed throughout the inner parts of the seed. It is easy to expel this surface moisture while drying and the air readily absorb it. However, for removing the internal moisture, it has to be transferred to outer surface of the seed by way of diffusion where evaporation can take place.

14:3.1 Methods of seed drying

The methods of seed drying can be classified as natural or artificial. *Natural drying* takes place with atmospheric air moving naturally around damp seed spread on trays, canvas floor, or field. Sun drying comes under natural drying method. *Artificial drying* methods use heated or unheated air that is forced mechanically through a drier (forced air drying). We shall see the important methods of seed drying in detail.

Sun drying

Sun drying is the commonly employed seed drying method used by farmers, still now, even though several easy to dry artificial methods are available. Sun drying can be used to dry seeds as long as the relative humidity (RH) of the air is lower than the RH in equilibrium with the moisture content of the seeds. Sun drying involves spreading the threshed or winnowed produce in thin layers on cement floors or bamboo or pandanus mats and allowing it to dry in open sun light. The main advantage of sun drying is that, it requires no additional expenditure or special requisites. The disadvantages are delayed harvests, risks of weather damage, and increased chances of mechanical admixtures.

Certain precautions should be taken to ensure seed quality while sun drying. The threshing floor and the floor on which seeds are spread for drying should be dry and clean. To avoid mechnical admixing, as far as possible, only one crop cultivar may be handled on a threshing floor.

Forced air drying

In artificial drying methods, either heated or unheated air is forced into seeds. The air passing through the damp seeds absorb the moisture. The heat necessary for evaporating the water is contributed by the temperature drop of the air. This is the very basic principle of forced air drying.

Seeds behave like hygroscopic materials and their moisture content depends upon the temperature and humidity of the surrounding air. As we have seen earlier, the decisive factor here is the water vapour pressure in the seed and in the air surrounding it. As long as the vapour pressure in the seed is greater than that of surrounding air, vapour would move out of the seeds, which means the seed is losing moisture. When the vapour pressure gradient is reversed, the movement of water is also reversed, ie., the seeds would gain moisture. When the vapour pressures are equal, there is no movement of vapour. In this condition, the moisture content of the seed is in a state of equilibrium with the surrounding atmosphere and it is called *equilibrium moisture content* at that atmospheric condition.

There are three major drying methods with forced air.

Unheated or natural air drying: Here unheated, ie., natural air as such is forced to dry the seeds.

Dehumidified air drying: Air, after reducing the humid content chemically or by refrigeration, ie., after dehumidification, is used here.

Heated air drying: In this method, the drying air is heated considerably, usually, around 43°C, and forced for seed drying.

The first two methods may require more time from a few days to two weeks or more to reduce seed moisture to safer levels. The third method is the most common forced air drying method.

Advantages of forced air drying:

When compared to sun drying or ordinary drying methods, forced air drying has got certain advantages.

1) Earlier harvest of the crop is possible.

Early harvest of the crop provides higher yields of seeds, and losses from over ripening and shattering are less. The damage from insects and birds is also less, if harvested early. Early harvest means more moisture content in the seeds. Such seeds take longer time to get it dried in sun drying method. However, when forced drying is employed, total drying period is reduced.

2) Losses due to bad weather is reduced.

Sundrying is not dependable throughout the year, especially in the rainy season.

3) Early sale of the produce is possible.

If the crop is dried immediately after the harvest, the farmer could take them for sale.

4) Savings in labour.

Labour utilisation is comparatively less in forced air drying than sun drying.

Limitations of forced air drying:

1) There are chances of microbial growth in seeds.
2) The vigour of seeds may be reduced.
3) There are chances of hardening of seed-coat.
4) Seeds may be damaged while handling

14:3.2. Extent of drying required for seeds of major crops:

Seeds are to be dried until they attain a particular percentage of moisture. This moisture level differ from crops to crops. Maximum permissible moisture level of important crops are given below:

Crops	*Maximum percentage of moisture allowed*
Rice	12.0
Cowpea	9.0
Groundnut	9.0
Greengram	9.0
Blackgram	9.0
Sesame	9.0
Amaranth	8.0
Okra (bhindi)	10.0
Brinjal	8.0
Cucumber	7.0
Bittergourd	7.0
Tomato	8.0
Chillies	8.0

14 4. Seed storage

The average life span of seeds varies greatly with the kind and species of seeds. The maintenance of high seed germination capacity and viability until planting is of paramount importance in a seed production programme. If the seeds fail to give adequate healthy and vigorous plant stands, the seeds are practically, useless. Needless to say, good storage is a basic requirement in seed production.

The seeds are said to be in storage from the moment they reach physiological maturity, untill they germinate. The entire storage period can be divided into 6 stages.

1. Storage on plants (from physiological maturity to harvest).
2. Storage while processing (from harvest to storage in a warehouse)
3. Storage in ware houses.
4. Storage in transit.
5. Storage in retail stores.
6. Storage in the consumer's farm.

Unless appropriate principles of storage and handling are practiced, the germination capacity, health and vigour etc. would be considerably affected. So great care has to be taken during the above stages.

14:4.1. General principles of seed storage;

The general principles to be followed in storage to safeguard the viability and vigour of seeds are given below:

1 The storage conditions should be dry and cool.

2 Precautionary measures should be taken against storage pests and diseases.

3 There should be proper sanitation in the seed stores.

4 The moisture content of seeds under storage should be within the limits of safe moisture levels.

5 Store only high quality seeds, which are well cleaned, treated and are having good germination percentage.

14.4.2 Storage needs.

Storage needs of seeds depend upon the length of storage and prevailing climate of the area during the storage period. Long term storage demands more exacting conditions than short term storage. Similarly, the areas with favourable storage climate, for instance, an area where relative humidity is low, requires less efforts than areas of high relative humidity. It is important, to decide well in advance, how long it would be necessary to maintain the germination capacity of seed lots.

14:4.3. Seed longivity in storage:

Seed longivity in storage depends upon a number of factors. These have to be taken into consideration while assessing the *seed longivity* or how long the seed keeps its high germination and viability. They are briefly mentioned below:

Kind of seed: The seed longivity is considerably influenced by the kind of seed. Some kind of seeds are naturally short lived, eg, onion, soybean groundnut etc. Sometimes, different cultivars of the same species show differences in longivity.

Original seed quality: Good quality seeds, having high vigour and health, can be stored for a longer time than others. Even seed lots of good germination at the beginning of storage do decline rapidly with time, depending upon the severity of damage caused to it by means of mechanical injury or adverse weather.

Seed moisture: The moisture present in the seed is the most important factor influencing longivity. High moisture is probably the major cause of the loss of germination in seeeds. In general, there may not be fungal growth in seeds having a moisture content of 12 percent or below. Fungal attack starts at 13 percent moisture level and is much faster at 15 percent or above. At this level, respiration of fungi and seeds may induce generation of high temperature, thereby killing the seeds. Similar to fungi, insect attack would also be higher at higher moisture levels. Though insects can survive in seeds having 8 percent moisture content, they cannot reproduce. However, at 14 per cent, insect reproduction would be rapid and seed germination is lowered considerably. For ideal long term storage, where all deleterious factors are eliminated' a moisture content of 9 percent is indispensable.

Humidity: Seed longivity is affected by humidity of the atmosphere also. Seed attain a specific and characteristic moisture content when subjected to different levels of atmospheric humidities. This characteristic moisture content is referred to as equilibrium moisture content (EMC). At equilibrium moisture content, there is no net gain or loss in seed moisture content. The establishment of moisture equilibrium in seeds is a time dependant process. Under open storage conditions, seed moisture content fluctuates with changes in RH.

Storage temperature: Temperature also plays an important role in seed storage and its longivity. The higher the moisture content of seeds, the higher the adverses, effects of temperature. As the temperature increases insects and fungal activity also increases. Therefore decreasing both seed moisture and temperature is an effective way of maintaining seed quality in storage. A storage temperature below 21°C is desirable for seed storage. The ideal range of temperature for insect and fungal activity is between 21°C and 27°C. For safe storage of 1-9 months period, the following ranges will be fairly good for rice.

Moisture	*Temperature*	*RH*
12%	30°C	50%
13%	20°C	60%

Storage atmospheric gases: Oxygen and carbondioxide contents of the air around the seed also influence the storage life of seeds. Grains like rice having a moisture content below 10 per cent,survive longer at higher CO_2 and lower O_2 conditions around them. However, grains with 14 per cent moisture content or above will have only a shorter life at higher carbondioxide and lower oxygen conditions.

In addition to the longivity factors discussed in the foregoing, there are several other factors which may have an influence on storage and seed life. They are effects of sun light on seeds, fumigation effects, seed treatment effects etc.

14:5 Seed treatment

Seeds are usually subjected to certain treatments before storage or sowing in the fields. These trea'ments are mainly done with fungicides, insecticides or a combination of both with the objective of protecting them from seed borne or soil borne plant pathogens or storage insects. The treatments to induce germination or to break dormancy such as immersion in water, exposure to sunlight scarification etc. or other treatments to have variation (in plant breeding), vernalization come under the broad term seed treatment. The objectives and important methods of seed treatment are covered in this section.

14:5.1 Objectives of seed treatment

Seed treatment is done to achieve certain objectives. The following are the common objectives behind seed treatments.

To control and prevent the spread of plant diseases: Seed treatment for this objective is a reasonable guarantee against crop failure due to at least by externally seed borne pathogens. Even in the absence of seed born pathogens, it is a sound practice to use treated seeds. More details on these aspects are covered elsewhere.

To protect from storage insects: The incidence of storage insects is considerably reduced by seed treatment with insecticides.

To control soil insects: Soil insects are also controlled to a limited way by seed treatment with insecticides.

For convenience in sowing; In crops like cotton, seeds, on account of the fluff adhering to them cling together and cannot be easily sown, either through drills or by broadcasting. In such situations, seeds are so treated that the fluff became pasted on the seed and they cannot adhere to each other but roll apart just like tha grains or pulses.

To enhance the germination: Seeds, especially those with hard seed coats are dipped in water to get quick germination.

To break dormancy: There are several treatments such as hot water treatment, acid scarification, percussion, etc. to break the seed dormancy and to have early germination.

For better yields: Certain special treatments are claimed to produce increased yields in the treated crop. In *'Nendran'* banana suckers, certain treatments are preferred before the actual planting. Dipping in cowdung slurry and drying in shade is a usual practice folló-wed by many farmers which is said to increase yield.

For increased nitrogen fixation by legumes: The inoculation of legume seeds by organisms of the cross inoculation group also come under the purview of seed treatment.

Seed treatment for inducing variation: This is a useful tool in the hands of plant breeder. He subjects the seeds to X-rays or gamma-rays or some chemicals to induce mutation in experimenting seeds.

Seed treatment to induce earliness (Vernalization): Seeds, so treated, give rise to crops whose period of maturity become shorter than the normal period that takes when the seeds are sown without the treatment. The process of inducing earliness is called vernalization.

Likewise, seed treatment can be done for several objectives. However, in the present discussion our emphasis is mainly on seed treatment against diseases and other pests.

14:5.2 Conditions favouring seed treatment against diseases and other pests

Seed treatment against diseases and other pests may become essential in many situations. Seeds may suffer mechanical injury while harvesting and threshing operations. A breakage in the seed coat facilitate easy entry of the pathogen, and they, either damage the seed or weaken the resultant seedlings from the seed. Thus seed treatment is a guarantee to guard against infection to injured seeds.

Some times, chances are that saed. may be infested by disease organisms at the time of harvest. Seeds may also get infection while processing or storage. Seeds, thus carry disease causing organisms. To destroy them, seeds should be treated with disinfectants or disinfestants before storage or sowing.

If we have followed the post harvest handling of seeds scrupulously, we may get good quality, healthy seeds for sowing. However, chances are that seeds may be infected with disease pathogens while germination, especially from soil. Unfavorable soil conditions such as cold end damp soils greatly favour the development of diseases which damage the seeds. Seed treatment is rewarding In such situations too.

14:5.3 Types of seed treatment

Seed treatment with various materials are effected in a number of ways. It can be a dry or dust treatment, wet treatment, slurry treatment, pelleting or even seed coating. We shall see each of them briefly.

Dry or Dust treatment: In this method, the seed treatment material (chemical) would usually be a powder. The dry seed is thoroughly mixed with the powder usually in a seed dressing drum.

Wet treatment; Here, the treatment, materials are dissolved or made into a suspension with water and the seeds are immersed in this suspension orsolution for specified period of time.

Slurry treatment: In the slurry treatment, the treatment materials are made into a slurry with water and the seeds are treated with it.

Pelleting: Pelleting is usually done as a protection against soil micro-organisms. It also act, as a repellant against birds and rodents especially when seeds are broadcast.

Seed coating: In seed coating, certain materials are coated around the seeds. The coating may be for better growth or as a protectant against soil micro-organisms. Seed coating is mostly adopted in leguminous seeds with nitrogen fixing bacterial inoculum.

14:5.4 Chemicals used for seed treatment

Fungicides, insecticides, or a combination of the two are generally used for seed treatment. Fungicides are the most commonly used seed treatment chemicals.

Fungicides: Mercury compounds are most commonly used. Recently, due to the toxicity and ecological hazards involved, there is a growing tendency to discourage the use of mercurials and to promote the use of non-mercurials.

Mercury compounds come under two categories–organo mercurials and inorgano mercurials. Organo mercurials are recommended for the seed treatment of rice, cotton etc. Proper dosage is important. Over doses may result in seed injury and under doses may fail to control diseases. Examples for organo mercurials include Methoxy ethyl mercuric chloride (MEMC) and Phenyl mercury acetate (PMA).

Inorganic mercurials include mercuric chloride and mercurous chloride. They are toxic materials and extreme care should be taken while using them.

Numerous non-mercury compounds are also nowdays used in seed treatment. Examples of organo non-mercury compounds are captan, thiram, mancozeb, zineb etc. Inorganic non-mercury compounds include copper carbonate, cuprous oxide and copper sulphate. However, organic compounds are more famous and widely used for seed treatment.

Insecticides: insecticides are used for seed treatment to protect seeds from insects.These are used as such or combined with fungicides. Insecticicides used alone may damage the embryo of my the seed and when used in combination with a fungicide, damage is reduced. Most commonly used insecticides, are aldrin, lindane, dieldrin, heptachlor, chlordane, malathion etc.

Normally, insecticides are applied just before the seeds are planted, and that too after applying the fungicides or combining both. If the seeds are to be stored after the treatment moisture content and storage temperature should be kept low to help prevent damage.

14:5.5 Seed treatment for important crops

Certain common seed treatment methods employed for a few important crops are given in the Table 14.2).

Table 14.2. Seed treatment of important crops

Crop	Name of material	Dosage	Method of application
1	2	3	4
Rice	MEMC-3% (Agallol-3, Aretan-3 or MEMC-6% (Agallol-6, Emisan-6 etc.)	1g/litre of water 1g/2 litre of water	Soak the seeds for 30 minutes. Afterwards drain and resoak in plain water for 12 hours to induce germination.
	or Agrosan-GN	2.5g/kg of seed.	Dry treatment.
	or Ceresan-dry	2.5 g/kg of seed.	-do-
	or Hexasan	-do-	-do-
	or Captan	1.5g/kg of seed	-do-
Cowpea	Captan	1g/kg of seed.	Dry treatment.
	Groundnut oil or Coconut oil or Neem oil	10 ml/kg of seed.	Smear the seeds against storage pests.
Sesame	Agrosan-GN	2.5g/kg of seed.	Dry treatment.
Banana	Aldicarb	0.1% solution.	Dip the suckers against nematodes.
	HCH	0.2% ,,	Dip the suckers against rhizome weevil.
	Carbofuran-3%	20g/rhizome	Smear around rhizome at the time of planting.
Ginger	Mancozeb 0.3%	—	Soak the rhizome for 30 minutes
	Malathion 0.1%		
Sugarcane	MEMC—3% or MEMC—6%	5g/litre 2.5g/litre	Dip the cut ends of setts against red rot

5) *Pest control*: Control of weeds, insect pests and diseases etc., should be done scrupulously as any slackness in controlling them reduce the quality of seeds.

6) *Roguing*: Roguing should be done three times; first prior to flowering preferably at late vegetative phase, second at flowering, and third at maturity. The second and third rouging are extremely important to maintain the genetic purity of seeds.

Rogue out plants of other cultivars, wild rice plants, plants infested by stem borers, and diseased plants.

7) *Harvesting*: It is important to harvest the crop when the seed is ripe. Most improved rice cultivars show a variation in growing period by 5 to 15 days depending on the season. This variation is caused by variations in day-length, temperature, rainfall, sunlight, and cultural practices. In most cases, we may not be knowing the variations and we take the average growing period of a cultivar as a guide in deciding when to harvest. The time of harvest can be judged by a look on the panicle. The proper time of harvest will be when the grains on the upper portion of the panicles (80%) are straw coloured. Drain the fields 7 to 10 days before harvest to hasten maturity and to assure uniformity in field driage of grains.

8) *Threshing and winnowing*: The threshing floor should be neat and free from other paddy seeds. The threshed paddy seeds should be stacked in a cool and dry place away from walls and preferably on wooden stacks. Seeds are winnowed after threshing to remove chaff, dust, empty husks, and light grains.

9) *Drying*: The moisture content of paddy grains at harvest time varies with locations and seasons. During the *Virippu* harvest, the grains woule generally have a moisture content of 20 to 25 percent and during, the summer harvest this would be within 15 to 16 percent This has to be lowered to 14 percent or 13 percent moisture by drying before storage. Sun drying is the easy and cheapest method of seed drying and can be adopted as long as the RH of the air is lower than the RH in equilibrium with the moisture content of seeds.

If the RH of the hot air of the clear bright day goes down as low as 45 percent, the paddy takes only, two hours for sun-drying to reduce the moisture content to 14 percent level from an original content of 25 percent. However. the paddy seeds should be spread out as a thin layer. Sun drying can damage the seed, if the temperature rises above 44°C. Use clean dry tarpaulins or cemented floor for drying seeds.

10) *Seed storage*: Paddy seeds of high germination and vigour can be stored safely for six months at 11–13 percent, one year at 10-12 percent, two years at 9-11 percent and upto four years at 8-10 percent moisture contents.

Paddy seeds in storage at a low moisture content regain moisture under humid conditions. Seeds of 12 percent moisture regain moisture, whenever the RH of the air rises above 60 percent; and if they are dried to 9 percent, they regain moisture, whenever the RH is above 35 percent. Therefore, moisture proof packaging materials have to be used for storing seeds. Polythene bags of 700 guage are suitable for the packing and storage. When stored in this way, the viability can be maintained upto one year or more.

15. Quality control of seeds

1 Seed testing

15:1. Introduction

Production and maintenance of quality seeds are of prime importance in crop production, and there should be some ways to regulate the quality of seeds. The seed quality control system includes all aspects directed towards the production of quality seeds, and there are three important procedures to meet this end. They are seed testing, seed certification, and seed law enforcement. The various procedures under seed testing are covered in this chapter.

15:2. General aspects of seed testing:

Testing of seed quality is a very important procedure in seed production programmes. The main aim in testing seeds is to assess their quality and to determine whether seeds conform to the established quality standards or labelling specifications. That is to say, the suitability of a particular lot of seeds for planting depending upon its quality factors. The seed quality problems and the probable causes can be identified by means of seed testing. The need for drying and processing can also be determined by the results of seed tests. Seed testing also provides a basis for price and consumer preference in the markets.

It is very difficult to judge the quality of seeds, by visual inspection. A final say on seed quality can be possible only by testing for the quality attributes. Seed quality can be analysed into ten components; though all of them are not of equal value or importance. Practical laboratory methods are available to test all these attributes. We may have an idea of all these 10 attributes.

Analytical purity: Analytical purity indicates how much of the seed in the lot is pure crop seed. In other words, how much of the seed in the lot is of the correct botanical species. It is determined in the laboratory by examining a small sample. After removing seeds of other species and inert matter such as broken seeds, soil particles, chaff, and pieces of leaf or stem, the remaining pure seed is weighed and expressed as a percentage.

Species purity: Since the samples usually taken for analytical purity is too small, this method is not adequately precise to indicate the contamination by other crop seeds. For example, the working sample for analytical purity for rice is only 40g, and chances are that none of the seeds of other species might appear in the laboratory sample. A much larger sample is, therefore, taken and the number of foreign seeds in the quantity is determined and expressed as number of foreign seeds in the quantity examined.

Cultivar purity: Cultivar purity or trueness to variety indicates the genetic purity of the seed ie., how much of the seed belongs to the true cultivar in question. In general, it is very difficult to distinguish the seeds of different cultivars in a routine laboratory test. Therefore, the determination of cultivar purity is based on inspection of the plants from which the seed is to be harvested; supplemented by roguing operations and also by a laboratory test.

Freedom from weeds: Normally, this can be obtained from the laboratory report on analytical purity. However, for certain noxious weeds, this may not be enough. In such cases, a larger sample as in the case of species purity is examined and the number of weed seeds present are expressed as the number per unit weight.

Germination capacity: Germination capacity indicates the planting value of a particular lot of seed. It is usually expressed as the percentage by number of pure seeds which produce normal seedlings in a laboratory test. In general, germination capacity is the best indication of a seed lot's potential for establishing plants in the field.

Seed vigour; Seed vigour indicates a seed's ability to establish in poor field conditions. Good germination is usually associated with high vigour; however, it does not necessarily mean that seeds of high germination capacity always have the same vigour. In good field conditions, seeds of low vigour may also germinate; but it may not establish well. Low vigour may be due to mechanical damage, poor nutrition of the mother plant, immaturity at harvest, small size, senescence, or disease.

Seed size: Seed size, in general, is an indication of vigour. The size of a seed depends on its maturity at harvest and its position on the mother plant. Seeds from different plants in the same crop may also vary in size due to genetic or environmental factors. Small, shrivelled seeds and abnormal seeds have no planting value. Seed size can be measured in the laboratory and is usually expressed as the weight of 1000 seeds or volume of 1000 seeds. For instance, in rice, the seed size is assessed by determining 1000 grain weight and 1000 grain volume.

Seed moisture: Testing of moisture content is extremely important for safe storage, as high moisture content is the major cause of the loss of germination of seeds. This quality greatly affect the retention of germination capacity from harvest until sowing time.

Uniformity or homogenity: Testing for homogenity is also important. Every seed lot is a mixture of pure seeds, other crop seeds, weed seeds, and inert matter. The contents of every seed lot should be the same. For this, blending is usually resorted to. While sampling seeds, bigger seed lots have to be divided into smaller sub lots and sampled, and analysed indevidually to find the heterogenity.

Seed health: The testing for seed health is conducted to find out the associated micro-organisms causing seed born diseases.

The International Seed Testing Association (ISTA) founded in 1924 have done a lot to advance the quality of seed testing, and to have common methods of seed testing and evaluation of test results. They have published a set of International Rules for seed testing. The head office of ISTA is in Norway. The test proceedures discussed in this book are mainly based on ISTA rules.

15:3 Seed sampling

For determining the seed quality attributes like purity, germination capacity, moisture content etc., it is not expected to test the whole lot of seeds. It is neither physically possible nor practical. Hence, representative samples are taken from seed lots and tested. Usually, the quantity of seed sample subjected to testing is meagre, when compared to the seed lot which it is supposed to represent. Therefore, it is utmost important that a sample is drawn in such a way that it represents the whole lot of seed.

We may not expect that a seed lot is completely homogenous because of the natural variations in the field from which the seed is harvested. Even within the bag, it may not be homogenous because impurities may separate into layers in the process of filling the bags. It is imperative that a reasonable degree of homogenity must be assured for sampling purposes by some means.

There are certain terms in connection with the sampling procedures.

Primary sample: When we start the sampling procedure, first we draw a few samples at random from different portions in the lot. These first drawn samples are the primary sample.

Composite sample: When we combine or mix the primary samples, we get composite samples.

Submitted sample: From the composite sample, smaller samples of specified weights are taken through one or more stages. This is the sample which we send to laboratory for analysis and hence the name 'submitted sample'.

Working sample: In the laboratory, various tests are to be conducted. For this, it is not necessary to subject all the submitted samples for testing. For each quality traits, size of sample is specified. The sample that is subjected to actual testing is known as 'working sample'.

15:3.1 Drawal of primary samples

We may come across situations in which seed samples are to be taken from bags and from bulk storage. Though the sampling procedures for both these are essentially the same, there are certain differences in the drawal of primary samples. The steps in sampling procedure in these two cases are disscussed below:

Sampling seeds stored in bags (bag sampling)

The following steps shall be followed while sampling seeds from bags or bag sampling.

(1) Inspect the labels and bag markings and make sure which are all the bags constituting the total lot.

(2) Determine total number of bags in the lot.

(3) All portions of the lot should be accessible and sampled.

(4) Determine the number of bags of sample.

The following sampling intensity is prescribed for bag sampling.

Number of bags in the lot	*Number of bags to be sampled*
1—5	Sample each bag
6—30	Sample every third bag (but not less than 5)
31 or more	Sample every 5th bag (but not less than 10)

(5) Draw primary samples of almost equal quantity from each container or bag selected at random.

A stick or sleeve type trier or sampling probe, which consists of a hollow brass tube divided into a number of compartments inside a closed, fitting outer shell or sleeve, is used to draw the samples. The trier has a solid pointed end. The tube and sleeve have open slots in their walls. By turning the tube, the slots in the tube and sleeve can be made to come in a line, so that seeds can flow into the cavity of the tube. When the tube is given a half turn, the openings are closed.

Sampling loose seeds (Bulk sampling)

Seeds stored in bins, boxes, heaps, or other similar containers may be sampled by thrusting the hand or long bin samplers at an angle into the heap. The following sampling intensities may be adopted.

Size of seed lot	*Number of primary samples to be drawn*
Less than 50 kg;	at least 3 samples.
50—500 kg;	at least 5 samples.
501—3000 kg.	one primary sample for each 300 kg (but not less than 5)
3001—20000 kg	one primary sample for each 500 kg (but not less than 10).

The primary samples should be drawn from random positions and depths.

The sampling procedures after the drawal of primary samples are similar both for bag sampling and bulk sampling. When the primary samples taken are combined and mixed, they form the *composite sample*.

15:3.2 Preparation of submitted sample

The submitted sample is otherwise the minimum weight of seed sample to be sent for analysis to the Seed Testing Laboratory. The size of the submitted sample varies between crops. The minimum weight of submitted samples prescribed for important crops is given below:

Crop	*Maximum weight of seed lot (kg)*	*Size of submitted sample (g) (minimum)*
Rice	20,000	400
Wheat	20,000	1,000
Maize	20,000	1,000
Cowpea	20,000	1,000
Greengram	20,000	1,000
Black gram	20,000	1,000
Ground nut	20,000	1,000
Sesame	10,000	70
Cabbage	10,000	100
Cauliflower	10,000	100
Brinjal	10,000	150
Chillies	10,000	100
Okra (bhindi)	20,000	1,000
Tomato	10,000	150
Cucumber	10,000	150
Pumpkin	10,000	350

For obtaining the minimum weight of the sample as shown above, the composite sample should be mixed thoroughly first. Then by repeated quartering or by abstracting and subsequently combining small random portions, obtain submitted samples of required size.

15:3.3 Despatch of submitted sample

The sample may be packed in a cloth bag or double gunny bag and stitched nicely. If moisture test is to be conducted, a polythene bag holding a minor sample (100 g for those species that have to be ground and 50 g for all other species) should be included with the major sample. The following information should be placed inside the bag and submitted with the sample.

1. Date sampled.
2. Sampled by
3. Name and address of sender
4. Kind and variety
5. Origin or class of seed
6. Sample designation or lot No.
7. Quantity of seed in lot.
8. Kind of test required. Germination/ purity/moisture etc.
9. Remarks (Date of harvest)

As far as possible, after packing the sample and writing the full address of the Seed Testing Laboratory on the pack, it should be mailed immediately by parcel post. Avoid sending samples by rail, as it takes too long time to reach the Laboratory.

In Kerala State, there are two notified Seed Testing Laboratories, one attached to the Regional Agricultural Research Station, Pattambi (under the Kerala Agricultural University) and the other at Alleppey (run by the Department of Agriculture).

15:4 Purity analyses

We have already seen that out of the 10 seed quality attributes listed, four relate to the purity of the seed lot, viz, analytical purity, species purity, cultivar purity and freedom from weeds. Excepting cultivar purity, all the other purity attributes can be determined in a laboratory test. However, the primary emphasis of the seed purity analyses is given for the analytical purity.

Analytical purity is a measure of the amount of impurities in a seed sample and is expressed in terms of the percentage by weight of pure seed of the species under test. To indicate contamination by seeds of weeds or other crop seeds, analytical purity is not sufficiently precise, because the sample is too small. For example, the working sample prescribed for analytical purity for rice is only 40 g and chances are that none of the seeds of other species might appear in the sample. A much larger sample (400 g in the case of rice) is, therefore, taken and the seed analyst searches it for weed seeds, objectionable weeds, and other crop seeds and express them as number of seeds in the quantity examined. The objective of other species determination is to identify correctly the rate of occurance of those species defined by laws and regulations as noxious. The prescribed size of working samples for determining the analytical purity and species purity for different crops are given in the Table 15.1.

Table: 15.1. Working samples for purity analyses

Crop	Working sample for analytical purity (g)	Working sample for count of seeds of other species (g)
Rice	40	400
Wheat	120	1,000
Maize	900	1,000
Cowpea	400	1,000
Green gram	120	1,000
Black gram	700	1,000
Groundnut	1,000	1,000
Sesame	7	70
Cabbage	10	100
Cauliflower	10	100
Brinjal	15	150
Chillies	15	150
Okra (bhindi)	140	1,000
Tomato	7	15
Cucumber	70	150
Pumpkin	180	350

15.4.1 Test for analytical purity:

The analysis is made on the working samples as shown in the Table 15.1. This weight is determined to have about 2500 seeds in the sample. The working sample is examined visually and divided into three fractions—pure seeds, other seeds, and inert matter. For this, the seeds are placed on a board or plate glass covered with a smooth paper and is worked over with a knife or scalpel to separate pure seeds from other seeds and inert matter. Pure seeds consist of all seeds of the species under test, regardless of whether they are immature, shrivelled etc. If the fragment is bigger than half the original size of the seed, it goes into the pure seed fraction. If it is half or less of the original size of the seed, it is placed in the inert matter. Similar criterion is used for other seeds also, which are placed in a separate fraction. The third fraction is the inert matter which contains everything not already included in the pure seed and other seed fractions. This may include such things also as fungal sclerotia, nematode galls, and insects, which are not 'inert' actually. There are other special techniques of analysis also which employ sieves to remove smaller or larger particles, blowers or aspirators for removing light particles and diaphanoscopes to detect whether there is a caryopsis inside the glumes of some grasses. A duplicate test may also be conducted as a check.

The results are expressed as follows:

Pure seed—Percentage
Other seeds—Number per working sample
Inert matter—Percentage

15:5. Seed germination test

The germination capacity of the seed is determined mainly by a germination test. Germination capacity is generally expressed as the percentage of pure seeds which produce normal seedlings in a laboratory test. The seeds which give weak or deformed seedlings are not regarded as having germinated and thus, not assessed. Germination capacity indicates the seed lot's potential for establishing plants in good field conditions. However, this potential is seldom fully achieved in practice. At sowing time, some seeds fall on stones or under stones or are eaten up by birds or damaged by insects. In such cases, the seeds cannot survive, no matter how good the seeds are. Or else the environmental conditions may be adverse. However, seedlings differ in their response to these factors and some survive. In spite of all these limitations, germination capactiy is the best indication of a seed lot's ability to establish plants in the field. It means that seed lots of low germination should be rejected. Germination capacity is influenced mainly by harvest and post-harvest conditions and is extremely variable.

In a germination test, the seeds are placed under optimum environmental conditions of light, temperature, and moisture to induce germination. Several methods are used for determining germination capacity of seeds using paper, cloth, sand or soil. ISTA rules specify that at least 400 seeds should be tested for germination. These seeds should be taken from the pure seed fraction of the sample at random. The counting of seeds may be done by hand, by the aid of a counting board, or with a vacuum seed counter.

15:5.1. Methods using paper

Paper is the most widely used medium for seed germination tests. The paper used for this purpose should have certain essential qualities. It must not contain any substance toxic to the developing seedlings and is able to hold and supply to the seeds adequate moisture to imbibe and germinate. The paper should be strong enough to withstand any possible breakage while handling. It should also prevent penetration by the roots of developing seedlings. Four types of papers are generally used. They are paper towels, blotters, filter papers, or pleated papers.

Rolled paper towel test: In a rolled paper towel test, the seeds are germinated *between paper*. This method is particularly suitable for medium to large seeded crops such as cereals and grain legumes. Blotters which are similar in quality to filter papers, and paper towels which are used in wash rooms can be used in this procedure.

Paper towels of size 30 x 25 cm are generally used. The towels (4 numbers) are soaked in water, taken out, and gently wrung between the hands, until no more water is squeezed out. Three towels are laid on top of one another. The seeds are then placed on top of the uppermost sheet in a regular pattern, so that they are approximately equidistant with each other. The seeds should not be placed within 5 cm of the basal longer edge of the paper and 3 cm of the other three edges. A fourth towel is then placed on top of the seeds and basal 2–3 cm of the longer edge of all the four towels turned up to form a lip to prevent the seeds falling out. The towels are then gently and loosely rolled to form a tube of about 5–6 cm diameter. Tight rolling should be avoided, as it prevent air circulation between them and results in poor or abnormal germination. The friction between seed and towels is sufficient to prevent the seeds from falling from their positions, when the rolled towel is stood upright (Fig. 15.1). Once the towels have been rolled, these are placed in a germinator or incubator, where the temperature, moisture, light etc. can be controlled for germination.

Filter papers: When filter papers are used, the seeds are germinated on *top of paper*. They are used for germination tests in petridishes. Normally, 9 cm diameter filter papers are used. Because of the small size of working area, smaller seeds are usually tested using this method. The filter papers can be moistened in two ways. They may be soaked in water for 10 minutes and then hung upto dry, or

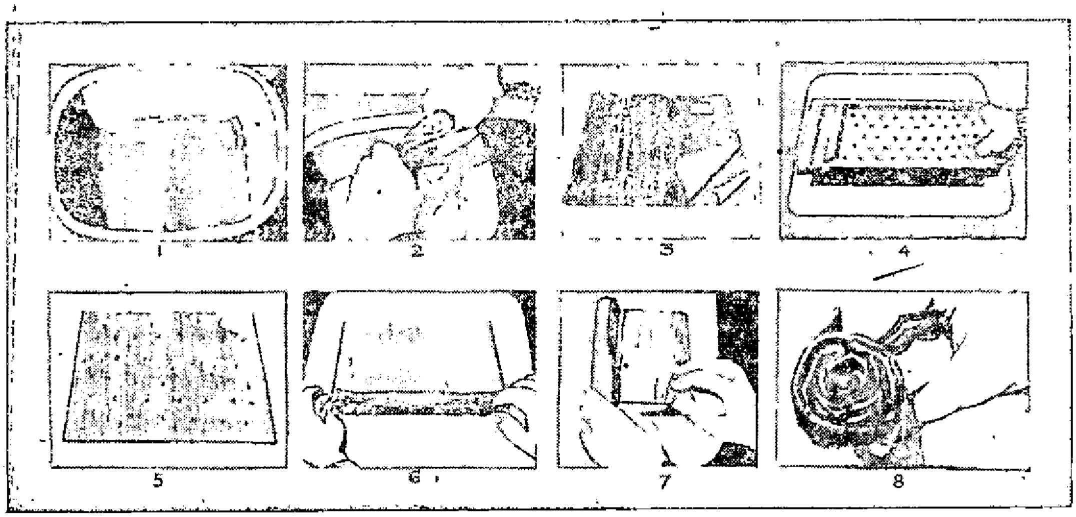

Fig. 15.1. Seed germination test between rolled paper towels

1. The towels (4 Nos.) are soaked in water; (2) Then, the towels are wrung by hand; (3) Three towels are laid as the base, and keep a label; (4) Count the seeds using a counting board or spatula; (5) Seeds are arranged on the top of the third paper; (6) A moist towel is placed on the top of the seeds, and turn up the bottom 2.5 cm of all the 4 paper towels; (7) Gently roll the towels. (8) Rolled towels.

(Partially adapted from 'Hand book of seed Technology for gene banks Vol. I. Principles and methodology, IBPGR, Rome).

they can be moistened after placing the paper in the petridish by means of an automatic syringe.

Place the filter paper in the smaller of the two halves of the dish and firm down using an upside down 9 cm funnel. Normally, two filter papers are required for each dish. The seeds are then distributed on top of the filter paper, petridish closed, and allow it for germination.

Pleated paper: This is nothing but a long piece of paper which has been repeatedly folded in a concentric fashion to provide many pleats into which seeds can be placed. These are useful in cases where an individual seed need to be identified from an intermediate count of germination to another and where it is necessary to keep seeds isolated, for instance pelleted seeds.

15:5.2 Methods using cloth

Wet flannel cloth can be used in a similar fashion to that of paper towels. Flannel cloths of size 35 cm x 27.5 cm are convenient. After soaking the cloth in water, wring gently between hands until no more water is squeezed out. The cloth is then spread on a flat surface. Afterwards, count exactly 100 seeds and distribute them evenly in rows of 10 on the cloth, leaving about 2 cm from each border. A bamboo stick of about 40 cm length is then placed along the longer border of the cloth. Press the border of the damp cloth against the stick and simultaneously roll the stick with the cloth. The cloth is then secured in place by tying both ends with rubber bands or twines. This test is variously called Wet cloth rolling method, Rolled cloth towel test or the Rag doll method.

The *rag doll* containing the seeds are to be moistened by dipping in a pail of water occasionally. About three dippings per day are sufficient to keep the seeds continuously moistened. The rag dolls are to be stored in a shaded place at room temperature (about 28°C). Care should be taken to protect the rag dolls from rats. The seeds will germinate in 4 to 5 days. As in the other tests for germination, the test is to be replicated four times. This method can be easily adopted in farmer's conditions since laboratory conditions are not necessary for the test.

15:5.3 Methods using sand

Sand is not normally used in laboratory tests for germination. However, it may be necessary to use it where there are difficulties in obtaining suitable paper for the tests. The washed sand must consist of uniform particles. Its pH should be between 6.0 and 7.5. Use sand particles which are in between 0.8 mm dia. and 0.05 mm dia. size. The sand must be sterilised before use. Great care should be taken while adding water to the sand. The exact quantity of water to be added depend upon the size of the seeds under test and the characteristics of the sand, especially water holding capacity.

For germination tests using sand, aluminium dishes of size 15cm dia. at the top, 12.5 cm dia. at the base and 4 cm deep are generally used. The seeds are sown on top of the sand and then covered with 1-2 cm of loose sand. However, in a few cases, especially with small seeded ones, the seeds are only pressed into the surface of the sand and not covered. The dishes are then placed in a germinator.

15:5.4. Methods using soil

Soil, compost or peatmoss may be used instead of sand. However, it is generally not easy to standardise the procedures and therefore liable to cause greater variations between results. These tests are useful when abnormal germination is observed on paper or sand, especially from seeds which have been treated with fungicides or insecticides.

15:5.5 *Appraisal of germination tests*

A germination test usually takes ten days to four weeks or even longer period. We have to take in to account only 'normal' seedlings as having germinated. A normal seedling should have a well developed root and shoot. In the seed lot, there may be abnormal seedlings, hard seeds, dormant seeds, and dead or decayed seeds. Abnormal seedlings, may result from the decline in seed viability due to a variety of causes such as age, poor storage condition, insect attack, diseases, mechanical injury, fungicide and insecticide toxicities, frost damage, mineral deficiencies, and toxic materials present in germination trays, medium, tap water etc. Dormant seeds can be distinguished from non-viable seeds as the fomer are firm, swollen and free from moulds. Any ungerminated seed should be examined to find out the possible reasons

Seed dormancy of the freshly harvested seeds poses difficulty in direct testing and may prolong the testing period, and sometimes affect the reliability of the test. Methods of breaking dormancy will have to be adopted depending on the dormancy factors in such cases.

Minimum germination percentages

For seed certification, minimum germination percentages are prescribed. The germination percentage is calculated on the basis of two counts or observations. The number of days required for first and final counts and the minimum germination percentages prescribed for a few important crops are given below

Crop	First count days	Final count days	Minimum germination percentage
Rice	5	14	80
Cowpea	5	8	75
Green gram	3	7	75
Black gram	4	7	75
Groundnut	5	10	70
Okra (bhindi)	4	21	65
Sesame	3	6	80
Chillies	6	14	60
Tomato	5	14	70
Cucumber	4	8	60
Bittergourd	4	8	60
Pumpkin	4	8	60

15:6. Seed viability

The possession of those processes essential for a seed to germinate is referred to as seed viability. Viability is the ability of a seed to germinate. This means all viable seeds are alive. However, it is not essential that all the viable seed will germinate, for instance, the dormant seeds. Though a germination test is the best method of estimating its germination capacity, it is not reliable in all the cases. A germination test can function as a viability test only if all the seeds are non-dormant, or special treatments are applied to remove dormancy. Difficulties will also be there with regard to empty seeds, slow germinating seeds etc. Moreover, the relatively long period of time required for the completion of germination test is also a problem. This necessitated the development of rapid methods for establishing or predicting germination capacity or seed viability. Two methods are available for this purpose—the Topographical Tetrazolium Test and the Excised Embryo Test.

15:6.1. *The Topographical Tetrazolium Test (TZ Test)*

The tetrazolium test is a biochemical method in which viability is determined by the appearance of red colour when the seeds are soaked in a 2, 3, 5 triphenyl tetrazolium chloride (TTC) solution. In the cells of living tissues, it is changed to an insoluble red compound; non-living tissues remain uncoloured. The reaction can take place both in dormant and non-dormant seeds. Results are available within 24 hours of the test–sometimes even within 2–3 hours.

15:6.2 The Excised Embryo Test (EE test)

The excised embryo test is normally used to test the germination capacity of seeds of woody shrubs and trees, whose embryos require long periods of after ripening before germination can take place. It can also be applied to determine quickly the viability of seeds which germinate slowly. In this test, the embryo is excised from the seeds and germinated under sterile conditions. A viable embryo will either germinate or sometimes show some signs of activity. In contrast, a non-viable embryo becomes discoloured and deteriorate.

15:7 Seed moisture

The moisture content in a seed has strong influence on the length of time it remains viable or keeps its germinability. Seeds may sprout or moulds start to develop at higher moisture levels and the seeds may lose viability in a few days. The lower the moisture content of any kind of seed, the greater the time it remains viable.

There are several methods of determining seed moisture content. Important among them are

1. Air-oven methods
2. Using desiccants or drying agents
3. Lyophilization
4. Re-drying
5. Karl Fisher-titration method
6. The toluene distillation method

15:7.1 Air-oven methods

Air-oven methods are the basic methods of determining moisture content of seeds in Seed Testing Laboratories. A weighed sample is heated in an oven at a specified temperature for a specified time, untill they attain a constant weight. The loss in weight as a result of heating is taken as the moisture content of the seed material. Various types of ovens are used and various temperature and time of heating are specified.

The procedures suggested by ISTA are summarised below:

Determinations are to be made on duplicate samples

The moisture determination is to be made in duplicate on two independently drawn samples. The rules prescribe 4-5 g for each of the duplicate samples with two exceptions. If the diameter of the drying container is greater than 8 cm, then 10g is required for each duplicate sample. If pre-drying is required (see below), then at least 25 g of seeds must be taken.

Pre-drying

If the sample is too moist, then it should be pre-dried. If moisture content is more than 30 percent, the previously weighed samples are left overnight on top of a heated oven. If the seeds are large and the moisture content is between 17 percent to 30 percent (10 percent to 30 percent for soybean or 13 percent to 30 percent for rice), then the pre-weighed samples are first placed in an oven at 130°C for 5to10 minutes, and subsequently exposed to the room temperature for 2 hours. To determine the loss in moisture during pre-drying, the samples (at least 25 g) are first weighed, pre-dried, and the loss in weight determined by substraction. This forms the first step in a two stage seed moisture determination.

Dry the drying containers before use

The drying containers must be dried before use. For this, they are placed in an oven at 130°C for an hour, and then allowed to cool in the desiccator for a further one hour. This is particularly important in humid regions.

Weigh the containers

The containers, usually dishes and lids, are then weighed. The sample—pre-dried, ground or not—is then placed in the container, the lid is replaced, and the weight of dish+lid+seeds is taken. Normally, all weighings are to three decimal places.

Large seeds are to be ground

Large seeds are to be ground before subjecting it to final drying. However, grinding is not recommended for seeds that have a very high oil content which makes them difficult to grind. A few examples of crops that require grinding are groundnut, bengal gram, soybean, peas, beans, cotton, barley, rice, wheat, sorghum, maize etc. For cereals and cotton, fine grinding is necessary and for leguminous and tree seeds, fine grinding is not necessary.

For non-oily seeds, high constant temperature oven

Dishes containing non-oily seeds are then placed in an oven maintained at 130°C-133°C, after removing the lids. The samples are then dried for four hours (maize), two hours (other cereals), or one hour (all other non-oily seeds). This drying period commences when the oven temperature has attained 130°C to 133°C, and after placing the samples in the oven and closing the oven door. Normally, it takes 15 minutes for this. At the end of the specified drying period, each lid is placed back on the dish and the container is allowed to cool in a desiccator for about 45 minutes. After the cooling, the containers along with the contents are weighed. eg. rice, wheat, sorghum, maize, cucumber, pumpkin etc.

For oily seeds and seeds of all tree species low constant temperature oven

This method is carried out in the same way as the above method for non-oily seeds, except that the oven is maintained at a temperature of 103°±2°C for 17±1 hours.

eg. sesame, groundnut, soybean, chillies etc.

Calculation of seed moisture content

The moisture content in the seeds is expressed as a percentage of the original weight of seeds, and is calculated upto one decimal place using the following formula. This is known as moisture percentage on wet basis.

$$Wb = \frac{M_2 - M_3 \times 100}{M_2 - M_1}$$

where Wb—moisture percentage on wet basis.

M_1—Weight of the container (with cover)

M_2—Weight of the container + contents before drying.

M_3—Weight of the container contents after drying.

In a two stage drying procedure where pre-drying is employed, the moisture lost in each stage can be determined as above on the wet basis. If S_1 and S_2 are the percentage of moisture in the first and second stages, then the original percentage moisture content (wb) will be

$$Wb = (S_1 + S_2) - \frac{(S_1 \times S_2)}{100}$$

ISTA rules specify that the difference between the duplicate samples tested for moisture should not be greater than 0.2 percent. If it is greater, the determination should be repeated.

15:7.2 *Other moisture determination methods*

Using desiccants or drying agents: In this method, the samples are dried in vacuum using phosphorus pentoxide (P_2O_5) as a desiccant.

Lyophilization: Here, the seeds are frozen and the water content removed by sublimation in vacuum.

Karl–Fisher titration method: In this method, the water content is extracted from finely ground seed with methyl alcohol. The water is then determined by titration by special reagent.

Toluene distillation method: In toluene distillation method, a weighed portion of the finely ground seed is boiled in toluene in an apparatus, which collects the condensed water in a tube and returns the condensed toluene to the boiling flask. The moisture in the seed is calaulated from the volume of water condensed.

15:7.3 *Secondary or practical methods of moisture determination*

All the methods of moisture determination mentioned above form the basic methods. Since the basic methods take too much time to get results in particular occasions, practical methods are standardised. The practical methods are standardised against one or more of the basic methods. This include Brown-Duvel distillation method, method using calcium carbide, infra-red moisture meter, Relative humidity method, nuclear magnetic resonance, electrical moisture meter etc.

16. Quality control of seeds

II. Seed certification and seed laws

16:1. Introduction

The genetic purity in commercial seed production is often regulated through a system of seed certification and seed law enforcement. Seed certification is a legally sanctioned system for quality control in seed multiplication and production. The principal objective of seed certification is to protect the genetic qualities of a cultivar. To achieve this, the seed certifying agency determines the eligibility of particular cultivars to get certified, and sets up standards for isolation distance, roguing and quality of harvested seeds. There are also provisions to make regular inspections of the particular fields to see that the standards are maintained. Supervision of seed processing is also involved. The provisions of the seeds act and its enforcement is also directed towards the production and distribution of quality seeds in the country.

16:2. Classes of seeds

The genetic purity of seeds is maintained by utilizing certain classes of seeds which designate the generations allowed away from the original source. Four classes of seeds are generally recognised in seed certification.

Breeder's seed

Breeder's seed or nucleus seed is that seed or vegetatively propagated material, which originate with the sponsoring plant breeder or institution, and provides the initial source of all the certified seeds. It has the maximum genetic purity.

Foundation seed

This is the progeny of breeder's seed and it is handled in such a way as to maintain the highest standard of genetic identity and purity. It is the source of all other certified seed classes. However, it can also be used to produce additional foundation seed plants.

Registered seed

This is the progeny of foundation seed or sometimes breeder's seed or other registered seed that is produced under specified standards, approved and certified by the certifying agency to maintain genetic identity and purity.

Certified seeds

Certified seeds are the progeny of registered seed or sometimes breeder's, foundation, or other certified seeds. Normally, certified seeds are the class of seeds which is produced in the largest quantity and sold to growers.

Certified seed produced from certified seed shall not be eligible for further multiplication under certification rules. However, in the case of highly self pollinated crops, certification of one more generation may be permitted.

Bags of the different seed classes are identified by different colour tags, so that they are difficult to remove without defacing the bags.

Certified seeds—blue tags

Registered seeds—purple tags

Foundation seeds—white tags

The certification tag shall contain the following particulars.

1 Name and address of the certification agency
2 Kind and variety of seed
3 Statement to the effect that the seed of the variety is genetically pure
4 Lot number or other identifying mark of the seed
5 Name and address of the certified seed producer
6 Date of issue of the certificate and its validity.
7 An appropriate sign to designate certified seed
8 An appropriate word denoting the certified class designation of the seed
9 A statement to the effect that no one should purchase the seed if the seal or the certification tag has been tampered with.
10 Any other statements if needed

The container of the certified seed shall carry a seal as prescribed by the certification agency. Such containers should also carry a label under the labelling specifications.

Truthfully labelled seeds

The Seeds Act, 1966 provides for yet another class of seeds. According to the act, the seeds of notified kinds or varieties, in their notified area, can be sold only in containers, and it should meet seed standards, especially for purity and germination, and be labelled. Such seeds are known as truthfully labelled seeds. The following information should be recorded on the label.

1 Kind
2 Variety
3 Lot number
4 Date of test
5 Pure seed percentage
6 Inert matter percentage
7 Other crop seeds
8 Weed seeds
9 Germination percentage
10 Net content
11 Seller's name and address
12 Whether treated or not

If treated, the word' POISON' or the warning 'Do not use for food, feed, or oil purposes' should be written on the label.

16:3. Steps in seed certification

In seed certification, there is a checking of quality at each stage of seed production, processing etc. The following are the various stages in seed certification.

1 Administrative check: This means verification of seed source.
2 Field inspection to prescribe field standards: This is to prescribe standards for isolation, roguing etc.
3 Supervision of the operation of harvesting, storage transport, processing etc.
4 Seed analysis to verify conformity to prescribed seed standards.
5 Tagging and sealing.

The seed certification standards for paddy are given in the Table 16.1.

Table 16.1: Seed certification standards for paddy

Quality traits	Foundation seed	Certified seed	Truthfully labelled seed
Pure seed (minimum)	98%	98%	97%
Other crop seed (maximum)	10 No./kg	0.10%	
Weed seed (maximum)	10 No./kg	0.10%	
Inert matter (maximum)	2%	2%	
Objectionable weed seed (maximum)	2 No./kg	5 No./kg	
Germination (minimum)	80%	80%	70%
Moisture content (maximum)			
Ordinary container	12%	12%	
Vapour proof-container	8%	8%	

Source: Indian Minimum Seed Certification Standards (1971), Central Seed Committee, Department of Agriculture, Ministry of Food, Agriculture, Community Development and Co-operation, New Delhi.

16:4. Seed Legislation in India

The Seed Act passed by the parliament in 1966 has been in force since 1969, to regulate the quality of certain seeds and matters connected there with. Under section 3 (1) of the Act, a Central Seed Committee has been constituted to advise the centre as well as the states on the administration of the Act. Formulation of standards for certification and the minimum limits for labelling is an important task of the committee. The Act also provides for the formation of a Central Seed Certification Board, State Seed Certification Board, State Seed Certification Agencies, a Central Seed Testing Laboratory and State Seed Testing Laboratories.

A Central Seed Testing Laboratory is in existence. The Seed Testing Laboratory at the Indian Agricultural Research Institute (IARI), New Delhi has been notified as the Central Seed Testing Laboratory. According to the Act, the State Government may also establish one or more State Seed Testing Laboratories. There are two notified Seed Testing Laboratories in Kerala State, viz., the Seed Testing Laboratory attached to the Regional Agricultural Research Station, Pattambi and another one at Alleppey.

The Central Government is empowered to notify the kinds or cultivars of seeds, to specify the minimum limits of germination and purity, to regulate certification agencies of states, and to grant certificates to any person dealing in any seed of notified cultivar. The State Government is competent to appoint Seed Analysts and Seed Inspectors to enforce the provisions of the Seed Act in the State.

16:5. Seed law enforcement

Seed law enforcement is a post production system involving more of quality evaluation, in contrast to certification and other quality control systems which operates along with the production of seeds.

In Kerala State, the Additional Director of Agriculture (Crop production) of the Directorate of Agriculture is the State Seed Certification Officer. In all the districts, a district level officer is declared as the Seed Inspector and he has jurisdiction over the entire district. Besides, four Assistant Directors (Quality control) attached to the offices of Joint Directorate of Agriculture at Trivandrum, Alleppey, Calicut and Palghat are also declared as Seed Inspectors in their respective jurisdiction. In all the districts, the Principal Agricultural Officers are declared as the licensing authority for the area within their jurisdiction.

16:6. Seed certification in Kerala

The Department of Agriculture from 1976–77 onwards is issuing certified seeds to the farmers which are produced in the State Seed Farms. One of the District level officer is declared as the Field Inspection Officer of each Seed Farm to ensure the quality of seeds.

The State Seed Certification Officer will issue authorisation for the procurement and distribution of seeds. This is based on the inspection reports of the Inspecting Officers pertaining to individual seed farms and registered seed grower's plots. While doing this, the analytical reports of the seeds obtained from the notified Seed Testing Laboratories in the state will also be examined.

The following are the minimum certification standards fixed for the certification of paddy seed in the state.

16:7. National Seeds Corporation

The National Seeds Corporation (NSC) Ltd. is a Government of India undertaking, established in 1963, to organise the development of a sound and viable seed industry in India. The Corporation is under the administrative control of Ministry of Agriculture, Government of India, and got jurisdiction all over India. It functions as a foundation seed production, stocking, and supply organisation. The main objectives behind the formation of such an organisation are the following.

1. To carry on the production, processing, drying, storing, transportation and distribution of crop seeds.
2. To enter into agreement with individuals, co-operatives, corporations, and Govt. Agencies, in the production, processing, drying, storing, distribution, and transportation of crop seeds.
3. To undertake seed quality control measures by inspection in all the facets of seed business, carried on behalf of the Corporation or in co-operation with the Corporation.
4. To store and stock file reserve supply of any seed needed for improvement of agriculture in India.

NSC handles foundation and certified seeds of nearly 230 cultivars of 70 crops.

Quality factors	Certified seed	Truthfully labelled seed
Pure seed (Minimum)	98%	97%
Other crop seeds (Maximum)	2 seeds/40 g.	—
Inert matter (Maximum)	2%	—
Weed seeds (Maximum)	0.1%	—
Germination (Minimum)	80%	70%
Moisture (Maximum)	13%	—

Source: Farm Guide, 1986, Farm Information Bureau, Trivandrum.

National Seed Corporation is also helping State Seed Corporations in procuring materials for establishing seed processing facilities under the National Seed Project Phase-I and II.

NSC has established a Regional Office at Trivandrum with the jurisdiction of State of Kerala and Union Territory of Lakshadweep.

The Services rendered by the National Seeds Corporation can be summarised as follows:

1. Production of foundation seed.
2. Production of certified seeds.
3. Seed certification.
4. Seed quality control.
5. Seed processing, handling, and packing.
6. Seed marketing.
7. Information, communication, and public relations.
8. Sales promotion and advertising.
9. Project formulation and management.
10. Training.
11. Consultancy services in all the above fields.

17. Tillage and tillage implements

17:1 Introduction

For sowing or planting a crop, we have to prepare the field. There may be differences in the method or in the extent of preparation for a particular crop. However, in any case, we are working with the soil in order to have better plant growth and yield. The practice of working the soil with certain implements for the purpose of bringing about more favourable conditions for plant growth is usually referred to as tillage. All the operations which we do on the earth surface for the purpose of agriculture such as stirring, fining, firming, and inverting come under the purview of this term.

In olden days, it was not actually known why we are doing tillage. However. it was a known fact that loosened soil produced good crops. Some light was thrown on the art of tillage by 1731 with the publication of the book 'Horsehoeing Husbandry' by Jethro Tull, and he was rightly called the father of modern tillage. He put forth a theory of tillage. According to him, tillage is manure, and the advantage resulting from working the soil was a freeing of the soil particles. Jethro Tull believed that earth was the only food for plants, and that the plants are fed from the minute particles of soil that were secured around the soil grains. Accordingly, the more finely divided the soil, the better the plant would be nourished and hence the tillage. Our knowledge on tillage has improved much than the above according to the recent findings. Now, it is generally conceded that tillage fulfils several purposes. According to Cole and Mathews (1938), tillage is done to prepare a suitable seed bed, to eliminate competition from weeds, and to improve the physical condition of the soil, These three basic reasons are commonly accepted.

17:2 Objectives of tillage

The objectives of modern tillage can be listed as follows:

To prepare a suitable seed bed

Seed bed is the place where the seeds germinates and the medium from which the resulting plants draw moisture and nutrients. The several operations in connection with the preparation of a seed bed are aimed at the preparation of soil in such a way that it would be favourable physically, chemically, and biologically for plant growth. For this, it may be necessary to destroy native vegetation, weeds, or even another crop. Removal or incorporation of crop residues may also be involved. In some cases, the surface will have to be loosened, mellowed or compacted before sowing according to the type of crops.

To minimise resistance to root penetration

It is a known fact that loosened soil offers little resistance to root penetration. The main purpose of intercultural operations is to minimise the resistance to root penetration.

To improve humus and fertility status of soil

The addition and incorporation of organic matter in the soil or leaving it on the surface as in stubble mulch farming, is necessary for improving the humus and fertility status of soil. Organic matter also brings about several desirable benefits to the soil.

To control weeds

The menace of weeds in crop production and the use of tillage in controlling weeds is discussed in detail elsewhere.

To aerate the soil

Loosening the soil with tillage implements improves soil aeration. Soil aeration is necessary for many of the chemical and biological activities taking place in the soil.

To increase water absorbing and retention capacity of soil

Tillage has a marked influence on the water absorbing and retention characteristics of the soil. Tillage affects the infiltration, run off, temporary surface storage, internal storage, and availability of water to plants. Surface loosening of the soil also act as a soil mulch and conserve soil moisture.

To minimise soil erosion

Tillage is also helpful in minimising soil erosion. For details, see the chapter on soil erosion.

To prepare the land for water management

For providing irrigation water to the crops, we have to prepare the land according to the method of irrigation. For example, the method of preparation of land for check basin differs from that of furrow method of irrigation. Similarly, for providing drainage also, field preparation is necessary.

To destroy insects and plant pathogens

Tillage operations such as summer ploughing destroy harmful insects and their eggs present in the soil.

17:3 Soil tilth

While describing the physical condition of the seed bed for a particular crop, it is quite common to use a term, 'soil tilth'. Soil tilth is a collective term indicating the whole of the physical conditions of the soil. In a soil, the higher the degree of aggregation of soil particles and the higher the percentage of crumbs or granules, the better would be the soil tilth. An rmproved soil tilth indicates that conditions are more favourable for aeration, drainage, soil erosion control, plant nutrient availability, and high yields.

Usually, tilth is estimated by the farmer by feeling the soil. The farmer strains the soil through his fingers and look at the aggregates. If the clods break down easily and are mellow, he would say that it is with a good tilth. Tillage alter the tilth or fabric of soil, so that water, air, temperature, and strength conditions of soil are improved for plant growth.

Generally, tilth is described for crops in two ways—*fine tilth* and *coarse tilth*. In alluvial soils and sandy soils, it is easy to have fine tilth by way of tillage. Fine tilth is necessary for small seeded crops such as tomato, chillies, amaranth, sesame and tobacco. In clayey soils and black cotton soils, the tillage operations result in small clods. It will not break into fine granules. However, by repeated tillage, it can also be possible to break these. But in such cases, after the receipt of rains, the surface may get hardened and a thin hard membrane may be found on the surface, which result in reduced infiltration and increased run off.

In such situations, coarse tilth is desirable and large seeded crops such as cotton, maize etc. are grown.

Soil tilth is dynamic in nature. Mechanical forces may change the roughness of the soil surface, total porosity, aggregation and clod size. Tilth is also dependant on soil structure, texture, soil moisture, air, drainage characteristics, and such other physical characteristics of the soil. Soil tilth once established may further improve or degenerate by the forces of water and wind. It may be deteriorated by heavy rainfall and erosion. The action of drying, wetting, freezing, and thawing of soil often improves the soil tilth.

17:4. Types of tillage

Tillage can be of many types. Based on the timing of tillage operations for a particular crop, we can have two types of tillage—*preparatory cultivation* and *after cultivation*. All the tillage operations which we do in a field after the harvest of a crop and before the actual sowing or planting of the subsequent crop is termed as preparatory cultivation. In other words, these tillage operations are done in preparation to sow or plant a crop. Preparatory cultivation ends by the formation of a good seed bed. The tillage operations performed for a crop after sowing or planting till its harvest is known as after cultivation. All the intercultural operations including earthing up, weeding etc. come under this.

Tillage can also be classified based on the type of equipment used and intensity of tillage. If we follow this criterion, we can have *primary tillage* and *secondary tillage*. The primary operations performed to open up any cultivable land with a view to prepare a seed bed is termed as primary tillage, for example, ploughing and digging. Primary tillage implements include country ploughs, mould board ploughs, bose ploughs, disc ploughs etc. All the lighter tillage operations performed on the soil after the primary tillage operations are known as secondary tillage. Secondary tillage operations are done on the surface soil only with very little inversion and shifting of soil, for example, harrowing, hoeing etc. The implements such as cultivators, harrows, hoes, levellers, etc. are secondary tillage implements.

17.5 Tillage implements

The very definition of tillage indicates that it is working the soil with some implements. The farmer uses a variety of implements for tillage purpose from the preparation of seed bed to the harvesting of the crop.

Tillage implements are usually classified into certain broad groups based on different criteria.

a) Based on the type of tillage for which they are used
   1. Primary tillage implements eg., ploughs.
   2. Secondary tillage implements eg., cultivators, harrows, hoes etc.

b) Based on the source of power used
   1. Hand operated tools eg., *Thoomba*, spade etc.
   2. Animal drawn implements eg., country plough, Bose plough etc.
   3. Tractor drawn implements eg., rotary cultivator, tractor drawn disc plough etc.

c) Based on the specific purpose for which they are used.
   1. Ploughs — eg. country plough, mould board plough, Bose plough, disc plough etc.

2. Cultivators — rigid tyne, spring loaded tyne, spring tyne etc.
3. Rotary cultivators
4. Harrows — toothed type harrows, disc harrows etc.
5. Hoes — *Thoomba. Mammatty*, spade, hand hoe etc.
6. Seed sowing devices — Seed drills, planters etc.
7. Special purpose implements. eg: leveller, roller, clod crusher, bund former, basin lister, green manure trampler, wet land puddler, etc.

The most commonly used tillage implements which fall under the above categories are described in the following pages.

17:3.1. *Ploughs*

Ploughing is a primary tillage operation carried out for preparing seed bed for crops. Four main types of ploughs are used in India. They are the country plough or the *Desi* plough, the mould board plough, the Bose plough and the disc plough. The primitive model of all the present day ploughs might have been a thick crooked twig or a branch of a tree drawn by human beings. Later on, this model might have been subjected to various improvements with the advancement of agriculture. However, the basic design remains more or less the same. The plough was believed to have evolved as more or less a common prototype over the several parts of the world independently as the only implement to start with field preparations. All the other implements were evolved for completing the work commenced by the plough. Suitable modifications in dasign of the original plough for performing specific purpose of work have contributed to the evolution of several implements that are used today.

The country plough

The country plough (Fig. 17.1) or the *Desi* plough or the indigenous plough is being used by by Indian farmers from time immemorial. It was developed in our villages through years of experience. In the country plough, excepting the share portion, all the other parts are made of wood. A country plough has the following parts—(1) share (2) shoe (3) body(4) handle and (5) beam. The country plough has certain modificatons from place to place in India. The model which is commonly seen in Kerala is described below.

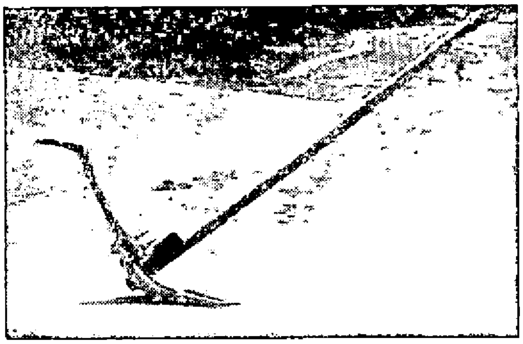

Fig. 17.1 The country plough

Body and shoe: The body is the central portion of a plough. To this is connected the beam, the handle and the shoe. In the country plough of Kerala, the shoe and body are in one piece, ie., there is no joint between them. This construction is mainly adopted in gravelly soils where stones and other obstacles are generally encountered while ploughing. A joint between shoe and body is purposefully avoided with a view to make the plough rigid and strong. The body is made with a bent piece of hard wood with the two arms making an angle of 135°. The body is usually having a wedge shape with an isosceles triangular section.

Share: A small piece of flat iron serves as the share, the piercing point of the plough. The share is fixed on the shoe.

Beam: The beam attaches the body of the plough and the yoke, The beam end is provided with grooves for proper hitching.

Handle: The handle is fixed behind the body to direct the movement of the plough.

Method of operation

The ploughs are worked usually with a pair of bullocks. In certain cases, he-buffaloes are also used. The plough is hitched to the yoke with the help of beam and ropes. For this, the yoke is provided with grooves or notches or both. The yoke rests on the neck of the bullocks. The ploughman controls the plough with one hand and drives the animal with the other.

When the plough is worked in the soil, the shoe and share enters the soil under the wedge action of the body, and make 'V' shaped furrows. The soil is split and pushed on both the sides to make room for the body. Since the furrows are 'v' shaped, unploughed ridges of land are left in between adjacent furrows, and the land is completely stirred and moved only when the plough is worked over the land twice or thrice. The furrows usually would have a depth of 10 cm and a width of 15 cm on the top of the furrows. The depth and width of furrows are more or less constant for each plough, though the depth of penetration can be increased a little by pressing the implement, by increasing the angle between the body of the plough and the yoke, and/or by hitching the beam under the yoke. By reversing these adjustments the depth of cut can be reduced.

In general, the ploughing method with a country plough is as follows: The ploughman takes the first furrow with the plough about 10 m away from one side bund and parellel to the longer sides. After completing this furrow, he goes through the head end, turns back, and take a second furrow by the side of the original side bund. Then, the ploughman goes through the tail end, turns back and take the third furrow adjacent to the first furrow in the inner side, Likewise, after ploughing about 3 m away from one side, the plough man takes a new furrow about 8 m from the original first furrow, and he goes on ploughing as a continuation of the last ploughing. In this way, the ploughing of a new piece of land before completing the original one and continuing ploughing as a single unit is the most common method of ploughing prevalent with a country plough.

The mould board plough

The mould board plough (Fig. 17.2) has been introduced to India by the end of 19th centuary. Excepting the beam, all the other parts are made of iron, and hence, the plough is also known as iron plough. A mould board plough, in general, is having a plough bottom, a standard, a handle and a beam.

Plough bottom: The plough bottom is the most important part of a mould board plough. This consists of four parts viz., the body or the frog, the share, the landside, and the mould board.

Frog or body: This part is seen in the central portion of the plough. To this are fixed the share, the mould board and the land side.

Share: The share is that part of the plough which actually cuts the soil. Since this is the cutting portion, it is subjected to heavy wear and tear. The share penetrates the soil, cuts the soil in a horizontal direction, and separates the

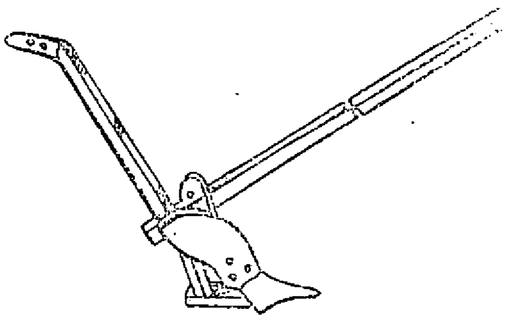

Fig. 17.2 The mould board plough (Diagramatic)

furrow slice from the ground. This separated furrow slice is transferred through the side of the landside to the mould board. The share has four parts; the share point, the wing of share, the throat or cutting edge, and the gunnel.

Shares can be of different types and shapes, based on the nature of soil and the purpose for which it is used. Slip share is the most commonly used one. Prominent among others are slip nose, shin, and bar share.

Mould board: The mould board is also known as breast or wing. This is fitted in the plough bottom immediately before the share. Mould board is usually fitted on the right side of the plough. It receives the furrow slice from the share, lifts, breaks, and inverts, it. The mould board is provided with a curvature for this purpose. As in the case of share, there are different types of mould boards also, for various purposes. The general purpose mould board is the most commonly used one which slowly inverts and pulverizes the soil. Other types include stubble mould board, sod mould board, and slat mould board.

Land side: Land side or slade is the part which stabilizes the plough. This part of the plough bottom slides against furrow wall and counteracts the turning movement of the plough. The portion of the land side which always slide with the furrow behind is called the heel of the land side.

Beam: This part of the plough connects the power source to the plough bottom.

Standard: This connects the beam with the plough bottom. Its main purpose is to adjust the height of the beam according to the height of the animals.

Handle: Handle is provided to control the plough. It is fitted on the land side.

Plough accessories:

In addition to the parts described above, some ploughs may be having certain additional parts for specific purposes.

Jointer: It is a miniature plough located in front of the plough bottom and closer to the gunnel side. It turns over a small strip of furrow slice in front of the plough.

Coulter: Coulter is a device very commonly used in ploughs to cut the furrow slice vertically from the land ahead of the share. It helps the plough to move easily. The coulter may be either a knife (skim coulter) or a steel disc (disc coulter) which is free to rotate.

Bridle: This is fitted in front of the beam. The yoke and the plough are jointed by means of a rope or chain tied on the bridle. Bridle is useful to adjust the depth and width of the furrow.

Wheel: The wheel is suspended from the beam and partly supports the weight of the plough, and maintains a uniform depth of cut.

Adjustments of mould board plough for proper functioning

In a mould board plough, the share is designed to penetrate the soil by some sort of adjustments. These adjustments would be provided while manufacturing the plough. Two suctions, viz., the horizontal suction and the vertical suction are important.

Vertical suction (share pitch) When the mould board plough is resting on a horizontal plane, a vertical clearance could be seen between the plough and the plane starting from the share point to the heel of the land side. The clearance is maximum at the point where share and land side unite (3 mm to 5 mm). This clearance is formed due to the slight down ward bending of the share. The vertical clearance or the share pitch helps the share to penetrate the soil in the required depth.

Horizontal suction (lead-to-land) Horizontal suction is the maximum horizontal clearance between the land side and a vertical plane touching the heel of landside and the point of share at its gunnel side when the plough rests on a horizontal plane. This usually varies from 3 mm to 8 mm. This clearance is formed due to the slight bending of the share to one side. Horizontal suction helps to maintain a uniform width of cut, and also to pull in to the unploughed land. Hence the suction is also known as 'lead-to-land'

There is one more term worth mentioning in this connection—*the size of plough* The perpendicular distance between the wing of share and a line connecting the point of share to the heel of land side at the gunnel side is the size of plough. It is also called the furrow width or width of cut, since it determines the width of cut of a particular plough.

Nosing

When the share point is subjected to heavy wear and tear due to continuous ploughing the suctions as described above may not be effective to have a good penetration or a uniform width of cut. In such cases, the plough man lifts the plough a little at the hind portion and makes the share point to penetrate the soil. This is known as nosing.

Ploughing methods with mould board ploughs

Generally, two methods of ploughing—*gathering* and *splitting*—are followed with the use of a mould board plough. Before starting the ploughing operations, the field is first divided into convenient small plots. The division of fields into convenient small plots is known as *feering*. After feering, *gathering* or *splitting* is done. In *gathering*, a plough furrow is taken first in the middle of the field. Then the plough man turns back the plough to the side of mould board, and takes the second furow adjacent to the first furrow. After completing this, the plough is again turned back to the mould board side, and third furrow is taken in the other side in first furrow. Likewise ploughing is continued. This method of ploughing which starts from the centre, and subsequently ploughing around the first furrow is known as *gathering*. When ploughing is over, there will be a slightly raised ridge in the centre. This ridge is known as *back furrow*.

In *splitting*, ploughing starts from sides. After ploughing the full length of a side, the plough is turned to the opposite side of the mould board, continued ploughing through the sides, and end up in the centre. After the completion of ploughing in this method, there will be a furrow in double the size of a plough furrow in the centre. This is known as *deadfurrow*.

Bose plough

Bose plough (Fig. 17.3) can be considered as the modified version of a country plough, suited for our conditions. However, it inverts and pulverizes the soil just like a mould board plough. Here, the mould board and share are in one piece of metal. Excepting this mould board cum share, all the other parts of the plough are made of wood.

Bose plough has become much popular among Kerala farmers. It is rapidly replacing the old model country plough. The plough can go as deep as 10 cm in dry lands and 12.5 cm in wet lands. The width of cut is about 15 cm. It may take about 27-30 hours to plough an area of one hectare. The ploughing method adopted is similar to that of a country plough.

Disc plough

In a disc plough. instead of mould board and share, the plough bottom consists of one or more steel concave discs with their plane of cutting edge set at an angle with the direction of travel. The discs are mounted on a frame. The discs cut the soil, break it, and push it side ways.

Here, the plough bottom is a rolling one instead of a sliding one. The principle is that the rolling friction is lesser than the sliding friction. Penetration of soil is effected mainly due to the weight of the plough and the angle of the disc. Animal drawn ploughs usually weigh about 30 kg and tractor drawn ploughs about 150-250 kg per disc (Fig. 17.4). Disc ploughs are especially suited in hard, dry soils where mould board ploughs may not penetrate.

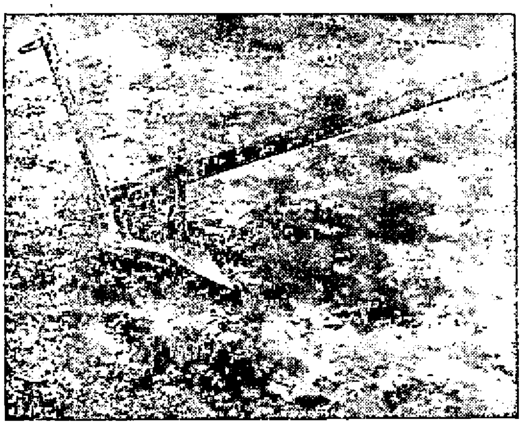

Fig. 17.3 Bose plough

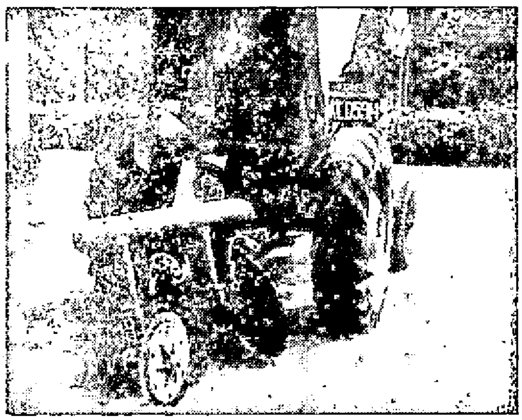

Fig. 17.4 Tractor drawn disc plough

17:5.2. *Cultivators*

Cultivators perform functions intermediate between those of ploughs and harrows. While preparing a seed bed, the ploughs are first used as a primary tillage implement. The plough cuts the furrow, and the mould board inverts it. Cultivators are then used principally to pulverize the soil, and to comb out the weeds Cultivators are used mainly to break down the furrow slice so that the harrow can work, and further refine the soil. Besides, cultivators are also used widely for interculture operations in between rows.

A cultivator is operated by the action of a number of tynes which break up the soil, but perform no inversion. When the tynes are drawn through the soil, the larger clods of soil are shattered on contact; while some of the smaller clods are pushed aside. The cultivator has a shattering and stirring effect on the soil.

The major parts of a cultivator are shovel, tynes, main frame and cross bars. Many of the cultivators in use are tractor drawn implements with 9-13 tynes fitted in two rows.

Cultivators are usually classified into three types by the design of their tynes; *the rigid tyne*, the *spring loaded tyne* and the *spring tyne* cultivator. The rigid tyne cultivator consists of a number of vertical rigid tines clamped firmly to the frame. Rigid tyne cultivators are used for general cultivation to a depth of 10-60 cm. In a spring loaded cultivator, the tynes are held in a position by strong springs, and if they meet an obstruction, they can spring back out of the way. When the obstruction is cleared, the springs return the tynes to their position. So spring loaded cultivators are more suitable in gravelly or stony soils· Most of the tractors are fitted with spring loaded implement; usual depth of cut is 22.5 cm to 30 cm. Yet another type is the spring tyne cultivator, wherein the tynes are made of spring steel. As the tyne are drawn through, they vibrate the soil, shattering the clods better than rigid tynes. However, these are suitable for light work only.

17:5.3 *Rotary cultivators*

Rotary cultivators are now widely used as an alternative to ploughing. It is capable of producing a seed bed in a fewer operations than ploughing. They produce the combined effect of ploughing and cultivating. Rotary cultivators can be either *pedestrain-operated* or *tractor mounted*. The working of a pedestrain-operated, rotary cultivator is described below.

The implement essentially consists of a rotating shaft—the rotort—on which are bolted a series of 14–20 'L' shaped blades, which can be changed when worn. The shaft and the tynes together is called the *rotovator*. There is a shield around the rotor which controls the type of tilth produced, and protects the operator from flying stones and clods. The blades rotate in the direction of forward travel, and cut out slices which are pulverized against the shield and by other blades. It may loosen soil upto 15-20 cm. The depth of cut is controlled by an adjustable skid which enters the soil and prevents the rotovator going too deep.

17:5.4 *Harrows*

Harrows are also secondary tillage implements and normally follow the cultivators in sequence for seed bed preparation. The harrow supplements the work of a plough and a cultivator for preparing the seed bed for crops, and for covering the seeds after sowing. Harrowing, after ploughing and cultivating, provides a proper tilth of soil. The uses of harrows can be summarised as; to break the clods in a ploughed soil, to remove weeds, to stirr the top soil, to level the field, to cover the seeds after sowing, and to mix the fertilizers with the soil.

Harrows widely differ in size and shape. The blade, the toothed, and the disc types are the most common forms. However, harrows are not popular in Kerala. A few important forms are described below.

Spike tooth harrow

This type of harrows are seen in certain parts of Kerala, especially in Quilon region. There, it is called *'Palli'*. This is mainly used for seed bed preparation of paddy. On a wooden frame, about 30–35 wooden spikes are fitted. The beam is fixed at the centre of the frame. The harrow is drawn by yoking to a pair of bullocks. The depth of penetration varies from 5–7.5cm.

Blade harrows (Bakhar, Guntaka)

They are popular in North Indian States. Blade harrows are generally used in clayey soils. It consists of a blade like cutting edge which is fixed horizontally. It brings about pulverization of about 5–8 cm of top soil. Certain types are used for the harvesting of groundnut also. Tractor-drawn blade harrows are also available.

Disc harrows

Disc harrows can be conveniently used as an alternative to cultivators, when the surface trash is more. They consist of a series of concave saucer shaped discs mounted on a shaft. All the discs mounted on a shaft are together called a gang. Two or four gangs will be mounted on a frame as a set. In animal drawn harrows the number and size of discs will be less. Tractor drawn harrows are usually with four or two gangs.

The discs are positioned equally along each shaft by spacers, and an adjusting mechanism enables each shaft angled in relation to the direction of travel. As the discs rotate, they cut into the soil. The discs throw a small furrow. In order to keep the land level, the rear discs return the soil thrown out by the front discs. The depth of cut can be increased by adding weights on the frame.

In certain disc harrows, the discs may be having notches. These type of notched disc harrows are more suitable in grassy situations.

Based on the number of gangs and their settings on the frame, disc harrows can be *single action double action or offset*. In single action types two gangs are placed end to end. Both gangs throw soil either towards the centre or away from the centre, based on the fixing of discs on the frame. In the double action types, there are four gangs. The discs on the two gangs placed in the front would be in one direction, and the discs on the two gangs placed behind, in the opposite direction. As a result, it throws soil in both directions. In the offset type (Fig. 17.5), there are only two gangs placed one behind the other. Similar to double action types, offset harrows also throw soil in both directions.

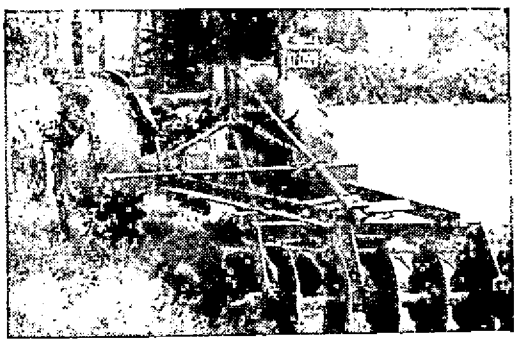

Fig. 17.5 Tractor drawn disc harrow

17:5.5 *Hoes*

Hoe is an instrument used for scraping or digging up weeds and loosening the earth. Though many of the hoes available are designed for removal of weeds only, many multi-purpose designs are also available. In general, hoe in its various forms can be used for preparing seed beds, forming ridges, bunds, water courses, and channels. Certain forms are also useful for harvesting crops such as ginger, turmeric, potato, groundnut etc. Many of the hoes available are hand operated.

We may see here a few important hoes (Fig 17.6) used by farmers.

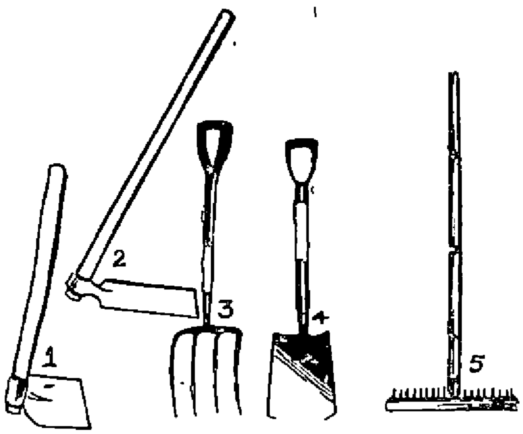

Fig. 17.6 A selection of hoes
1. Mammatty 2. Thoomba 3. Digging fork 4. Spade 5. Garden rake

Thoomba (Pick): This implement is a multi-purpose one used almost all over Kerala. The *Thoomba* is a two handed hoe, and consists of a wooden handle of varying lengths to which a flat iron blade is attached at nearly right angles. The size of the handles as well as the size and shape of blades show considerable variations. For heavy digging, the blades are longer and narrower with thicker sections. The operator lifts the implement with both hands and by the application of force the cutting edge penetrates into the soil.

In Kerala, the *Thoomba* is mainly used for digging purposes in dry and garden lands, where ploughs cannot be worked. It can also be used for making bunds, furrows, ridges etc. Besides, it is also suitable for hoeing purposes. *Thoomba* can also be used for harvesting purposes such as ginger and turmeric.

Mammatty: The *Mammatty* used in Kerala is also a two handed hoe very similar to *Thoomba*. However, the width of blade is more and length less. The length of wooden handle is also less. *Mammatty* is used to work the soil for seed bed preparation after the *Thoomba* is used. It is also suitable for intercultivation and weeding in dry and garden land crops. The implement can also be used for removing soil just like a spade.

Spade: The spade is maily used for removing soil. It can also be used for digging and trenching. Spade handles are made out of light, but strong wood and the end may be 'D' or 'T' shaped. The 'D' shaped handles are commonly available. The blade is connected straightly to the handle unlike the *Mammatty* wherein the blade is connected at right angles to the handle.

Digging fork: Digging forks are usually used for digging over the soil already turned by the spade, *Thoomba*, or *Mammatty*. They normally have four prongs which vary in size and shape.

Hand hoe (*Khurpi*): This implement is a small one with a sharp edged triangular or sickle shaped blade fitted on a wooden handle, operated in a sitting position. Several size and shapes are available. It is pushed into the soil to dig the roots of weeds.

Japanese hoe: This hoe is designed to use in row sown paddy crop. It consists of two rollers with pointed fingers and are pushed in between the rows of paddy when water is standing in the field. This weeder buries the weeds in the mud.

Garden rake: Garden rakes are normally used for gathering stones, weeds and hedge clippings in a garden. They usually have 10 rigid teeth with a long handle.

17:5.6. *Seed sowing devices*

Seeds are sown either by broadcasting, dibbling or by drilling. Sowing seeds by drilling is prevalent in many parts of India for several crops such as paddy, cotton, jowar, groundnut etc., and the devices used for drilling seeds are known as seed drills. Seed drills are popular in many parts of India. However, the devise is not popular in Kerala. These are generally operated by attaching to country ploughs.

A seed drill, in simple design, consists of a vertical tube with a seed bowl, and is fitted with a shoe piece and a wearing point at the lower end. This arrangement is tied by a thin rope, and is dragged behind the country plough. The country plough is adapted to line sowing by attaching the seeding tube directly to the body of the plough, or to a hole drilled in the shoe piece of the plough.

Seed drills designed for sowing more than one row simultaneously are also available. The most widely used type is basically a bullock drawn hoe or harrow having two to twelve tynes, each carrying a seed tube attached to a common seed bowl.

Nowadays, a large number of improved seed drills, both automatic and hand operated, are available. Among the automatic seed drills, the Mc-Cosmic seed drill, the Master seed drill, the Gunti seed drill and the Kirloskar seed drill are a few to mention. A low cost hand pulled paddy seeder designed for row seeding on puddled soils developed at the International Rice Research Institute, Philippines, is ideally suited for small farm holders.

Nowadays, seed cum fertilizer drills are also available. However, these types are not popular in India.

Transplanting devises are also becoming popular. Paddy transplanters developed by the International Rice Research Institute are examples.

17:5.7. *Special purpose implements*

Leveller

Levellers are of different types and shapes. They are used for levelling. The leveller commonly used in Kerala is *Gnavari* or *Maram*.

Gnavari is used in many parts of Kerala for levelling in wet lands. This implement is used before wet sowing or transplanting of paddy. All parts are made of wood. Its main part is a plank of about 1.5 m length, 37.5 cm height, and 5 cm thickness. The lower edge of the plank which touches the soil is serrated. The implement is connected to the yoke with the help of two iron rings and fastened with ropes. It is operated by a person who keeps standing on the flat surface of the leveller. He-buffaloes are commonly used instead of bullocks on a *Gnavari*.

Clod crusher

Clod crushers are used to break the clods after ploughing or harrowing. According to the soil types, different types of clod crushers are there. In heavy soils, a hand operated, mallet shaped log is used. In Onattukkara light soils, a planker is prevalent for this purpose. It consists of a plank of about 1.5 m length, and 10 cm width and 7.5 cm thickness. It has got a beam too. The beam is connected to the yoke, and when the implement is dragged by the animals, the man stands on the plank and the clods get crushed. It also helps to compact and level the top soil.

Roller

Rollers are used widely in dry farming areas to compact the seed bed. In lawn making also rollers are used. It crushes clods and smoothens the surface soil. Wood, stone, or concrete are used for its construction. Animal drawn and tractor drawn rollers are available. Small sized rollers which can be drawn by human beings are also in use.

Wet land puddler

This implement is used to puddle the wet lands after the initial ploughings. It essentially consists of a number of blades fitted on a common axis. The axis rotates when drawn by the animals. This action breaks the clods and mix the soil with water and the field get puddled. Puddling destroys weeds, reduces the leaching of water, and soften the soil for transplanting.

Green manure trampler

Green manuring is a common practice adopted by farmers to enrich the organic matter content of soil and to provide plant nutrients. To have proper decomposition of green manures, it has to be mixed with soil thoroughly. Tramplers are used to facilitate this. It consists of four to five circular discs of about 25 cm diameter attached to a horizontal axis. After spreading the green manures on the surface, the implement is drawn over it. As it moves, the discs are rotated, and they cut and incorporate the manure with soil.

Bund former

Bund former can be used to make separating bunds in a field, to make ridges for planting, and for making bunds along the contour as a soil conservation measure. The main part of the implement is a pair of mould boards fitted face to face. When the implement is pulled, soil from both sides are pushed towards the centre of the mould boards and a bund or ridge is formed.

Basin lister

Basin lister is mainly used for soil and water conservation purpose, especially in dry land farming areas. Rainfall is collected in small basins formed by the basin lister. It consists of two mould boards and a tyne attached to that. Due to a mechanism fitted behind the implement, it is lifted intermittantly, so that alternate basins and bunds are formed.

17:6 Tractors and tractor drawn implements

Mechanical power is increasingly used in modern agriculture. Mechanically powered implements are now available for almost all the agricultural operations such as land preparation, sowing, transplanting, interculture, weeding, irrigation, harvesting and post-harvest operations. However, unlike Western countries, these implements are not so popular among Indian farmers due to various reasons. Since agriculture has almost transformed to a business rather than simply a way of life, labour saving and money saving machines should be welcomed and accepted. Tractors and power tillers have become a common sight in Kerala. These are not only used for usual agricultural operations but also for transportation of farm produces. The demand and use of these machines are also rising. So, an attempt has been made here to have a general discussion on tractors and tractor drawn implements.

17:6.1 Tractors

Tractors can be defined as machines capable of pulling, carrying or operating a variety of agricultural implements and machines. A tractor is a 'prime mover'. The farmer, according to his requirement, attaches different types of implements to this and carry out various agricultural operations. Since more power is generated in a tractor, it can do more jobs, which cannot be done by using bullock power. The tractor is actually a modification of a motor car to perform agricultural operations. However, its wheels are bigger, speed slower, and is more sturdy, so that it can work in rough fields. Arrangements will also be there to attach different implements to it, and also for running stationery machines by using the power take off.

Tractors are divided into two broad classes, viz., ride-on tractors (tractors on which the operator rides) and pedestrian-operated tractors (the operator walks behind or beside and controls the work).

Ride-on tractors

Ride-on tractors may be with four wheels or three wheels. However, most of the agricultural tractors are four wheeled ones with an average horse power (HP) of 30-35. Ride-on tractors with 15-60 HP are usually classified as large tractors, and those with 5-15 HP are known as small tractors. The tractors are fitted with pneumatic tyres. They can be used for ploughing, cultivating, harrowing, sowing, harvesting, transporting and for belt work. They can also be used for intercultivation in row crops by making use of an arrangement by which the width between the wheel can be changed. By attaching trailors, tractors can also be used for transporting manures, fertilizers, seeds and other farm produces. Belt works such as lifting water, hulling coffee etc. can also be done.

In certain situations, ride-on tractors may be fitted with tracks instead of wheels, which provide better traction and exert lower ground pressure. This tractors are known as *crawler tractors* or *track layers*. These are suitable for relatively high draft, and for low speed work. Track layers are useful on uneven ground or on soft marshy land, where the wheels would not work. The HP ranges from 60-500. They are employed for reclaiming large pieces of barren land, for levelling the land, for preparing barriers or bunds, and for draining away excess water.

Pedestrian-operated tractors

Pedestrian-operated tractors are popularly known as 'power tillers'. A power tiller is also a small tractor but with two wheels or one axle. Power tillers are generally made as single purpose units with equipment such as rotary cultivators permanently fitted. The handle bars on pedestrian controlled machines are usually adjustable in height to suit different operators. They may also be movable to either side so that the operator can walk to one side when it is undesirable or uncomfortable for him to walk behind the machine.

Power tillers can also be fitted with seats mounted on an extra pair of wheels or rollers, so that the operator can ride. A trailer can also be attached so that farm produces can be transported. Power tillers are useful instruments under Indian conditions, and can be used for several operations such as ploughing, harrowing, puddling, transporting, pumping water, spraying insecticides, hulling coffee etc.

When the four wheeled ride-on tractors, or the two wheeled power tillers are used in wet lands, *cage wheels* have to be used instead of pneumatic tyres. Cage wheels are otherwise known as skelton wheels. These wheels help the tractor to distribute its weight, and do not allow it to sink. Cage wheels are also useful in puddling.

17:6.2 Tractor drawn tillage implements

Tractor-drawn implements generally fall into two broad categories. One group of implements is for tillage operations such as ploughs, cultivators, harrows, seed drills, combines, harvesters etc. The second group is stationery equipments such as pumps, stationary threshers, winnowers, hullers etc. In addition, tractor can also be used for transporting manures and fertilizers, farm produces etc., by attaching a trailor to it.

Ploughs: Mould board ploughs and disc ploughs are used in tractors. They cut two to five furrows at a time depending on the number of bodies composing the plough. The correct speed of the tractor is important for good ploughing. The best speed is around 2.4 km/hr depending upon soil and other field conditions.

Cultivators and harrows: Cultivators are used for heavy work, and harrows for lighter operations. Spring loaded cultivators with 9-11 tynes are most oftenly seen in tractors. These types are quite often used for primary tillage operations also, especially in light soils. The average out put of a 2.5 m wide cultivators with 11 tynes is about 0.6 ha/hr.

Among the harrows, disc harrows—both double action and offset types—with or without notches are commonly used in tractors.

Rotary cultivators: Rotary cultivators can be used as an alternative to ploughing and cultivating. It can either be mounted on ride-on tractors or on pedestrian operated tractors.

Rollers. Many of the bigger rollers are tractor drawn.

Seed drills: Seed drills are drawn by wheel or crawler type of tractors. They can sow upto about 12 ha in a day depending on soil conditions.

Planters: Sugarcane planters, potato planters, and paddy transplanters are examples.

17:7 Newer concepts in tillage

Before concluding this chapter, we may also see some new thinking on tillage.

In the conventional system of tillage commonly followed all over the world, the general practice is to have a fine seed bed by ploughing a number of times. Clean cultivation is also followed traditionally. This practice of giving maximum tillage operations was developed mainly because of the fact that the cost of upkeep of draft animals was practically the same whether they were working in the field or were stalled. Farm labour was also cheap. However, after the commercialization of agriculture, these concepts are being questioned. The cost of tillage operations had become a substantial part of the overall production cost. It indicates that a little change in the number and depth of tillage operations could make considerable saving. Since the beginning of the present century, many experiments have been conducted on the effects of tillage on crop production. Results indicated that numerous tillage operations as were done in the past was not necessary. Such findings paved the way for many new concepts in tillage such as stubble mulch farming, minimum tillage, and no tillage.

Stubble mulch farming

In the traditional concept of clean cultivation, the farmer frequently undertakes intercultivation operations and completely bury the weeds and crop residues. However, in stubble mulch farming, the soil is protected at all times by a growing crop or by crop residues. It was observed that the rates of erosion of a mulched surface were about 1/5th only of those resulting from clean tillage. The stubble mulches also improved penetration of water and infiltration besides reducing evaporation. This system of farming has been found to be most effective and beneficial in regions and seasons of low rainfall.

Minimum tillage

Minimum tillage can be defined as a method aimed at reducing tillage to the minimum necessary for ensuring a good seed bed and favourable growing conditions. Several minimum tillage methods have been developed and is practised. Wheel track planting, plough plant system, combined tillage and planting etc. are examples.

In wheel track planting method, the field is ploughed initially as usual, but instead of using the conventional methods of seed bed preparation, the seeds are planted in the area compacted by the wheels of the tractor. The soil between the rows remain rough and loose, and therefore, able to absorb moisture and to reduce run off. This method is found to save about 40 percent of tillage cost.

Zero-tillage or no-tillage

In the no-tillage system, tillage operations are reduced to the barest minimum or practically nil. The system usually consists of killing of weeds and other undesirable vegetation over the area with herbicides, and planting seeds like maize by removing soil plugs with a soil sampling tube. The seeds are dropped in the holes, and filled the holes with soil. No aftercultivation is given except spraying herbicides and perhaps other plant protection chemicals. In many experiments with these systems, yields were comparable with the conventional methods.

18. Weeds and weed ecology—an introduction

18:1 Introduction

The control of weeds is of great concern to farmers. Weeds have been a serious problem in crop production, and they cause considerable difficulties to the farmers by way of interfering with agricultural operations and increasing labour, thereby adding to the cost of cultivation, and finally reducing the yield of crops. Weeds compete with the crop for soil, water, nutrients, light and space. Weeds have also been reported to create health hazards both to animals and human beings. They are also a threat in lakes, rivers and other water ways and aquatic systems; forests, ornamental gardens and lawns; and non cropped situations like industrial areas, road sides, railway tracks, airfields, premises of buildings etc. Thus, it may be seen that the problem of weeds is not limited to cropped situations alone, but to other human activities as well.

18:2 What is a wead?

A weed is a plant where it is not desired to grow, or in simple terms, a plant out of place. Whether we consider a particular plant to be a weed is dependant on its characteristics and relative position with reference to other plants which we are growing. Thus, a crop plant in the field of another crop, where it is not wanted, is a weed. For instance, a sesame plant in the field of ginger is a weed with respect to ginger and have to be removed. However, when we refer to weeds, usually we mean undesirable, injurious and troublesome plants which interfere with cultivated crops and affect human affairs.

Weeds, insects, nematodes, rodents, disease causing pathogens, and all other organisms causing damage to crops are collectively known as pests. However, an estimate shows that losses due to weeds are greater compared to other pests. About 45 per cent of total crop losses in India are reported to be due to weeds alone. This shows the importance of weeds and weed management in crop production. The study of weeds and weed management—the weed science—has thus developed as a distinct and significant branch of agronomy. It has made considerable progress during the last few decades, assuming almost an independant status and importance similar to other pest sciences like entomology, plant pathology etc.

18:3 Characteristics of weeds

Weeds have certain characteristics in common compared to crop plants. They grow in an undesired location competitive in habit, and aggressive in nature. Weed seeds germinate earlier and their seedlings grow faster compared to crop plants. Besides, they have got high fecundity. They flower and form seeds in plenty and mature ahead of the crop they infest. Mother nature has bestowed these qualities on weeds so that their seeds are collected along with the produce of the crop at harvest and get distributed along with the produce of the crop to other places where the produce may be taken. Some weed seeds are provided with hairy or spiny appendages, and thus, they are carried to long distances by man and animals. eg: The seeds of *Abutilon indicum* and many grasses stick to clothes and animal bodies and are carried to distant places.

Weed seeds may germinate under varied conditions. However, they are generally season bound and the peak period of germination always takes place in certain seasons in regular succession. The possession of seed dormancy which resists germination is another characteristic enjoyed by most weed seeds. Weed seeds, in general, do not lose their viability even under adverse conditions.

A number of weeds can spread vegetatively, even if they are prevented from producing seeds. The tubers of nutgrass (*Cyperus rotundus*) and runners of bermuda grass (*Cynodon dactylon*) produce new plants, in addition to plants from seeds. Similarly, many perennial weeds are able to regenerate lost parts.

Another important characteristic of weeds is the possession of certain modified structures. These enable them to successfully compete with cultivated crops by sustaining adverse circumstances. Sticky materials, pubescence, spines, thorns, and other such devices protect the weeds from destruction by animal and human beings.

18:4 Origin and distribution of weeds

Weeds have been a problem eversince man started to cultivate crops. The majority of present day weeds are the products of the 'survival of the fittest'. Weeds as a class represent the most successful form, that have evolved simultaneous with the destruction or disruption of the indigenous vegetation and its habitants. The Darwinian concept of the struggle for existence is well applicable in the case of origin of weeds.

It is often observed that weeds, when form part of the introduced flora, are more aggressive and troublesome than when they form part of the native flora, eg., *Eupatorium*, *'African payal'* etc. It appears that a sizeable proportion of the weeds exist in their present form today, as a result of their use by man sometimes during the past ages. In most cases, they were originally members of the native vegetation. However, with removal from this environment, and to some extent, their selection and dispersal into man created habitats, certain types among this population persisted and thrived under the new condition. The disturbed habitats with its peculiarities resulted in more aggressive and successful form of plants—in most cases, weeds.

As we have seen earlier, weeds are now a problem in cultivated fields, waste places, roadsides, lakes, rivers—everywhere and his struggle to control and eradicate weeds will continue in pace with the struggle for existence of the weeds.

18.5 Harmful effects of weeds

The harmful effects of weeds are summarised below.

Weeds reduce crop yield.

Weeds compete with crops for moisture, nutrients, soil, space and light. Being vigorous in growth habit, they may soon smother the crops and consume large amounts of water and nutrients, thus causing heavy lossess in crop yields.

Weeds increase cost of cultivation

For removing weeds, we have to engage labourers or use herbicides. This operation consumes considerable amount of money, which ultimately increases the cost of cultivation and thereby reduces the net returns.

Weeds limit the selection of crops.

Some crops may not compete effectively against heavy weed growth. So we have to avoid selecting such crops in places where heavy weed growth is expected. Similarly,. some weeds are specific parasites of certain crops.

Weeds reduce human efficiency.

Weeds affect human efficiency mainly by causing allergy and poisoning. Weeds such as *Parthenium* cause itching, hay fever, and allergies. The presence of spiny and thorny weeds like *Amaranthus spinosus, Mimosa pudica* etc. may restrict movement of farm workers in carrying out farm operations efficiently.

Weeds reduce the land value.

Heavy infestation by perennial weeds may make the land unsuitable or less suitable for cultivation resulting in loss in its market value.

Weeds reduce the quality of farm produces.

The quality of vegetables, especially leaf vegetables, may suffer on accounts of weeds. Presence of weeds and weed seeds in grains and other farm produces may impair the quality of the produce which result in low price in the market. This can also cause spoilage in storage. Similarly, weeds may also reduce the quality of animal products such as milk, hyde etc. Presence of spiny weeds may reduce the quality of hyde. Likewise, feeding on certain weeds may impart an off flovour or distaste to milk and meat products.

Weeds harbour insects and diseases.

Weeds may either give shelter to various insects and disease pathogens or serve as alternate hosts and thus help in perpetuating the problem of insects and diseases.

Weeds contaminate water bodies.

The presence of African payal (*Salvinia* sp.) Water hyacinth (*Eichornia* sp.) etc. in rivers and back-waters create severe problems. Water transport, drinking water etc. are affected. It may also create certain health problems.

Weeds create difficulties in water management.

Weeds create problems in irrigation and drainage systems also. Channels are choked. and water carries weed seeds to different fields where irrigation water is taken. Besides, aquatic weeds are well known to create problems in irrigation tanks, ponds etc.

Allelopathic effects of weeds on crop plants.

The harmful effects of weeds include its allelopathic effects too. The phenomenon of one plant having detrimental effect on another through the production of certain chemical compounds is known as *allelopathy*. These compounds are proved to be toxic to plants. These are known to inhibit seed germination of crop plants The growth of plants is also affected due to the influence of these chemicals. These materials may be exudates from the roots, leachings from the foliage or even vapour from the plants. There are many reports of allelopathic effects of weeds on other plants. Thatch grass (*Imperata cylindrica*) and quack grass (*Agropyron repens*) are good examples of weeds which cause allelopathic effects on other plants.

18:6. Uses of weeds

Weeds. though notorious for their harmful effects, possess certain beneficial attributes as well. However, in most situations the harmful effects mask the good effects. The beneficial effects are briefly mentioned below.

Weeds as a source of manure

Many weeds are excellant green manure yielding plants. eg: *Tephrosea purpurea, Eupatorium odoratum* etc. Weeds as green leaf manure or when ploughed *in situ* add nutrients to the soil and increase organic matter content of the soil. For compost making also weeds are good. Composting is particularly effective to reduce the threat of certain problematic weeds like water hyacinth. Methods have been developed to make these weeds into compost. Several terrestrial weeds like *Tephrosea, Eupatorium, Clerodendron* etc. are also used for compost making.

Weeds as soil binding agents

Weeds are well known to check erosion in areas which are not under cultivation. They act as soil binding agents.

Weeds as food for human beings

Some of the weed seeds are good for human consumption. For instance, the grains of jungle rice(*Echinochloa colonum*) is sometimes eaten by human beings. Some weeds are good green vegetables, eg., *Amaranthus viridis.*

Weeds as forage for animals

Many weeds are eaten by cattle and form good forage.

Weeds as medicinal plants

A good number of weeds have medicinal properties and are also used for certain aromatic preparations. eg. *Sida rhombifolia, Leucas aspera, Phyllanthus nirurii* etc.

Weeds as indicators of soil conditions

Several weeds are used as indicator plants for detecting specific soil conditions like salinity, acidity and alkalinity. eg., alkali grass (*Puccinallia* spp.)—alkalinity; salt grass (*Distichlis strica*)—salinity.

Weeds as waste water cleaning agents

Some aquatic weeds are found to scavenge inorganic and some organic compounds from wastes The weeds absorb and incorporate the dissolved materials into their structure. Effluents renovated by the plants is stripped of its pollutants and when released into water ways, cause less environmental damage. eg: water hyacinth (*Eichornia crassipes*), duck weed (*Lemna* spp. *etc.*

Weeds for making paper and pulp

Several problematic weeds can be effectively utilized this way. eg: water hyacinth.

Use of weeds in plant breeding

Certain weeds are utilized in the plant improvement works especially for imparting certain qualities like pest and disease resistance, drought resistance etc. Wild relatives of crop plants are usually employed in hybridisation programmes.

18:7. Classification of weeds

For the study of weeds and to suggest suitable methods of weed control, a grouping of weeds is essential. Weeds are usually classified into different groups based on certain characteristics in common like life cycle, growth habits, growth season, habitat, mode of reproduction etc. Important systems of classification of weeds are given below.

18:7.1. Classification based on life cycle

This classification is the important one and most widely used. According to this system, weeds are grouped into three principal groups, viz., annuals, biennials, and perennials.

Annuals: Annuals complete their life cycle in a year or in a season. After producing the seeds they die. Most common field weeds are annuals and due to their abundance of seed and fast growth, they are very persistent. eg: *Amaranthus viridis, Emalia sonchifolia* etc.

Biennials: Biennials have a life span of two years or two seasons. In the first year or season, the plants grow vegetatively and store food in the underground portions, and in the second year or season, reproductive phase starts, seeds are produced, and the plants die. Only a few weeds fall in this group. Wild carrot and wild parsnip are examples.

Perennials: Perennials live for more than two years and sometimes persist for many years. It is divided into two groups based on the hardiness of the stem, viz., herbaceous perennials and woody perennials.

Herbaceous perennials: The plant body is herbaceous in nature. This group is further divided into simple perennials, bulbous perennials, and creeping perennials based on the mathods of propagation.

Simple perennials reproduce mostly by seeds. However, vegetative reproduction can also take place when roots and stem are cut mechanically. Bulbous perennials propagate mainly through parts like bulbs, bulbils, etc., and also by seeds. Wild onion and wild garlic are examples for this. Creeping perennials are able to propagate by means of rhizomes, stolons, offsets, spreading roots etc. and also by seeds. Examples are *Cantella asiatica*, and *Convolvulus arvensis*.

Woody perennials: As the name indicates, the plants are woody in nature. These are generally shrubs, trees or woody climbers. They may not produce seeds for the first few years and continue the vegetative growth. However, once the plants mature, seeds are produced annually. eg: *Lantana camara*.

18.7.2 Classification based on the morphology of leaves

Based on the size and shape of leaves, weeds are classified into *broad leaved weeds* and *narrow leaved weeds*. Most of the monocot weeds, especially grasses and sedges are narrow leaved weeds.

18.7.3 Classification based on habitat

Certain weeds may like specific habitats. On the basis of the habitat, weeds can be classified as terrestrial weeds, aquatic weeds and semi-aquatic weeds.

Terrestrial weeds: All the weeds found on land surface are included in this category. Terrestrial weeds include weeds of cultivated l ands, lawns, orchards and waste places. All the dry land weeds come under t his group.

Aquatic weeds: Aquatic weeds include weeds of aquatic environments and those that are seen in water saturated environments. Aquatic weeds are further classified into three types, viz,. submerged. emerged and floating aquatics.

Submerged aquatics are anchored to the bottom of the habitat, say a ditch, and grow entirely beneath the surface of the water, eg: *Vallisnaria, Elodea* etc. Emerged aquatics have their roots beneath the surface of the water but the leaves and stems are above the water line. eg: water lotus (*Nelumbo* sp). water primrose *Jussiaea* spp.) etc. Floating or surface aquatics either float freely on the water like *'African payal'* (*Salvinia* sp.), water lettuce (*Pistia* sp.) etc., or float only in a limited area like water hyacinth (*Eichornia crassipes*).

Semi-aquatic weeds: Semi-aquatic weeds are, in general, of amphibious type which can live both in water or land. Certain weeds of rice fields such as *Cyperus iria*, wild rice etc. are examples.

18:7.4 Classification based on the association with the crop:

Based on this criterion, weeds, are classified into season bound weeds, crop bound weeds and crop associated weeds.

Season bound weeds: They grow only in specific season of the year, disregard to the crop grown in the field. For instance, Johnson's grass is seen only in Kharif season.

Crop bound weeds: Weeds which are parasitic on crops are crop bound weeds. These parasitic weeds are of two kinds, the total parasites like *Cuscuta* and partial parasites like *Loranthus.* They directly atack the plants and deprive them of water, nutrients and assimilates.

Crop associated weeds: These weeds are always seen associated with certain crop plants only. However they are not taking or deriving food from the host plants. eg: Wild rice.

18:7 5 Botanical classification of weeds

We have seen that any plant out of of place is a weed. So, it is quite natural that any system of classification of plants is applicable to weeds also. Plant taxonomy or the classificatory system of plants is mainly based on a natural relationship between the individual plants. For the scientific study or the understanding of any plant, the taxonomical features are made use of. There are several systems of classification based on many concepts and features. A most commonly followed system, based on natural relationships, is briefly outlined below.

All the plants on earth come under the kindgom of plants or *Plant kingdom.* The kingdom is divided into two divisions —the *Cryptogams* and the *Phanerogams.* The Cryptogams represent the lower group of plants and Phanerogams, the higher group of plants. Majority of crops and weeds belong to the division Phanerogams. Each division is again divided into sub classes; sub classes into orders and orders into families; families into genera and genera into species. Species is usually the ultimate point in plant taxonomy, though in certain cases, species is also divided into sub species and botanical varieties.

An outline of the system is shown here:

Plant Kingdom

- Cryptogams
  - Thallophyta
    - Algae
    - Fungi
    - Bacteria
    - Lichens
  - Bryophyta
    - Hepaticae (liverworts)
    - Musci (mosses)
  - Pteridophyta
    - Filicinae (ferns)
    - Equisetinae
    - Lycopodinae
- Phanerogams
  - Gymnospermae
  - Angiospermae
    - Monocotyledonae (Monocots)
    - Dicotyledonae (Dicots)

Almost all the weeds belong to the class *Angiospermae*, though the class *Filicinae* (ferns) is also important in certain situations. The class Angiospermae consists of two sub classes, *Monocotyledonae* (monocots) and *Dicotyledonae* (dicots), based on the number of cotyledons present in the seed. While describing weeds, the terms monocots and dicots are frequently used.

Naming of weeds

Like any other plant, the *binomial nomenclature* is to be followed for weeds too. For this, the rules given in the *International Code for Botanical Nomenclature* is to be followed. The complete scientific name of any plant should include the genus, the species, and the subspecies or the variety name, if any. When the scientific name has two parts, it is abinomial, eg., Nut grass--*Cyperus rotundus*; and when it has three parts, it is a trinomial, eg., wild rice— *Oryza sativa* var. *fatua*. All the parts of the scientific names are to be written in Latin forms.

18:8 Persistance of weeds in soil

Several factors determine the occurance and distribution of weeds. Weeds persist in environments created by man such as crop lands, orchards, gardens, lawns etc. They withstand all the extremes of soil and climate, better than the crop plants. The persistence of weeds is due to different mechanisms associated with the weeds. These are briefly discussed here.

18:8.1 Adaptive potential of weeds to grow in any environment

Adaptive potential of weeds to grow in any environment is largely influenced by many climatic, soil, and biotic factors.

Climatic factors like light, rainfall, humidity etc. affect the persistance of weeds. Some weeds adapt to grow in shade which is responsible for its persistance. Similarly, rainfall and water availability in an area determine the occurrence and distribution of weeds. Wind is one of the effective source of occurrence and distribution of weeds. It has been found that some of the weed seeds are carried a long way by wind, and the distribution of the weed plants is effected in this way.

Soil factors like soil, water, air, temperature, pH, fertility etc. influence weed population. Some weeds can thrive in water logged areas; some others tolerate alkali soils; while some others tolerate acidic soils.

alkali loving plants — eg: Quack grass
(pH 7.4 — 8.5)
acid loving plants — eg: Bermuda grass
(pH 4.5 — 6.5)
water logged areas — eg: *Salvinia*, *Eichornia*

Biotic factors include both plants and animals. Crop plants affect the weed population and persistance by competing for the available resources. Some plants secrete root exudates that influence other plants (allelopathy). Soil flora, fauna, insects, grazing animals, man etc. affect the weed persistance directly or indirectly.

18.8.2 Survival mechanism of weeds

There are several mechanisms for weeds to survive and persist. Important among them are discussed below:

Prolific seed production: Annual weeds survive principally by means of seed only. Biennial and perennial weeds reproduce vegetatively also, in addition to seeds. Most of the weeds are prolific seed producers, which ensures their survival.

Vegetative reproduction: Biennial and most perennial weeds can reproduce vegetatively also. The rhizomes, tubers, corms, cormels, buds, bulbs, bulbils, stolons, offsets, stem pieces etc. are examples. Many of these parts are located very deep in the soil, which help them to withstand adverse weather conditions and to survive.

Seed dissemination: Almost all weed seeds are having highly developed mechanisms like wing or hairy or thorny appendages for dispersal by wind, animals and by other means.

Evasiveness: Many weeds are capable of escaping from animals and man, due to their bitter taste, spiny nature, causing allergy etc.

Seed dormancy: Weed seeds germinate only when the condions for its growth are favourable. The possession of seed dormancy is probably the single most important characteristics of weeds that enables them to survive.

Numerical impact: There are ever so may types of weeds, and even if one weed is destroyed, several other weeds are there to take its place.

18:9. Weeds and seed dormancy

Seed dormancy is a state in which viable seeds fail to germinate even when favourable conditions of moisture, temperature, and oxygen are there in the environment. (For details on seed dormancy, see the part on seed dormancy in this book).

Many annual weeds produce dormant seeds that germinate under a narrow range of environmental conditions. Thus, seed dormancy is an efficient survival mechanism of weeds. Seeds of several weed species of the plant families, Boraginaceae, Convolvulaceae, Cucurbitaceae, Fabaceae (Leguminosae) and Poaceae (gramineae), have a longer dormancy period, often runing into several months or even years.

18:10. Germination of weed seeds

Germination of any seed takes place, only if the environmental conditions required for the mechanism are favourable. The seed must have adequate moisture, favourable temperature, and a supply of oxygen. However, weed seeds possess special germination mechanism adapted to changes in temperature, soil moisture, aeration, exposure to light, depth of burial of weeds etc. When conditions are unfavourable for germination, they remain dormant or delay germination. Those weed seeds, that germinate under the same conditions and at the same time as crop seeds, are the most persistant and successful.

Seeds of many weeds require an exposure to light for germination. This is regulated by a pigment called phytochrome which is responsible for the seasonal changes in light sensitivity of seeds.

Many weeds germinate under aerobic conditions, while some others require anaerobic conditions. The stirring of soil while ploughing and other land preparations increases oxygen availability and an exposure to light, which induces germination.

Periodicity of germinatian is also found in weed seeds. Summer annuals favour higher temperatures for germination, while winter annuals germinate at lower temperatures in the autumn or winter. Certain others germinate freely throughout the year.

19. Weed management

19:1. Introduction

The concept of weed management is a much broader one than simply weed control. The term 'weed control' is used to denote the process of controlling weeds from cropped or non-cropped situations by employing mechanical, cultural, biological, or chemical means. The control of weeds may be for the time being. Weeds may again re-infest the area, and again, control measures have to be employed. Our aim should not be to control the weeds for a short period only. It should have a long range effect. That is to say, our aim should be to maintain an environment as detrimental to weeds as possible. The concept of weed management takes into account this objective and employs preventive, control, and eradication measures. We shall distinguish this three terms and study their significance in weed management.

Prevention means preventing a weed species from establishing and contaminating a new area. Prevention may be the most practical means of weed control. *Control* is the process of limiting weed growth in an area. In crop situations, the weeds are restricted by employing different means of control, either mechanical, cultural, biological, chemical, or a combination of these, so that there is minimum of weed competition. *Eradication* means complete eradication of all weeds, weed seeds, plant parts etc., from an area. This is often a laborious and costly affair, and we may not aim at this except in particular situations. Eradication should be our aim with regard to noxious and problem weeds like *Parthenium, Salvinia* etc.

The concept of weed management is to be applied on a co-ordinated basis. A control measure should be undertaken with efforts to prevent further infestation of weeds. Preventive and usual control measures should go hand in hand so as to have a long term impact. The effect of a chemical control measure can be reinforced by employing certain cultural or mechanical measures, and vice versa. A successful weed management system takes the entire farm instead of a portion as a unit and design the management of weed problem. This new concept helps in reducing the ill-effects of over dependance on chemical control methods, and thus ensure a better ecological balance.

19:2. Prevention of weed infestation in new areas

As we have seen earlier, mother nature has provided weeds with a number of devices that help them to be disseminated widely. As weed seeds are easily dispersed by natural agencies like water, wind, animals and by the farmer himself, it is important to prevent weeds from flowering and setting seeds. As the famous proverb 'prevention is better than cure' says prevention is often the most practical means of controlling weeds. Preventive methods include using clean seeds not contaminated with weed seeds, using manures, irrigation water and agricultural implements not contaminated with weeds, enforcing weed control laws, insisting seed certification, quaratine laws etc. Various preventive measures are noted below.

Use weed free crop seeds for sowing

There may be chances of weed infestation in a cropped area from the crop seeds itself. The weeds, associated with a crop, have life cycles similar to that of the crop, and they set seeds at the same time as the crop. In certain cases, seeds of some weed species resemble crop seeds in size and shape. In such cases, crop seeds are easily contaminated with weed seeds. The presence of a little amount of weed seeds alone is enough to pose a problem in a new area. Therefore, as far as possible, use certified seeds only for sowing.

Use weed free manures

The use of fresh farm yard manure or cowdung is to be discouraged. Use only well decomposed weed free farm yard manure and compost. The weed seeds can pass through the digestive tract of animals without losing their viability. Composting and allowing time for decomposition destroy most weed seeds.

Use clean agricultural equipments

Weed seeds and vegetative propagating parts adhere to *Mammatties*, ploughs, harrows, drills, hoes etc., during the preplanting and post-planting operations and get carried to new fields. Therefore, it is essential that these equipments should be cleaned before using them.

Use irrigation water not contaminated with weeds

Avoid the chances of carrying weed seeds and vegetative parts along with irrigation water to the cropped fields. By using screens and other such devices at the diversion points in the irrigation channel, the farmer can eliminate this possibility of weed spread to a large extent.

Take appropriate measures during harvesting, threshing and storing to get pure crop seeds

When the crop is for seed production purposes, we have to take extra care. We have to provide the crop good crop-management practices, so that it exert a check on the spread of weeds. Vigorous and fast growing crop cultivars compete effectively with weeds, by giving better leaf canopy and covering the ground rapidly. *Rouging* is another important practice to be followed scrupulously, to eliminate weeds. Roguing at the time of harvesting, is very important to eliminate weed seeds. While harvesting, threshing and before storing, separate crop seeds from weed seeds based on seed size, shape, surface area, density, stickiness, pubescence, colour and other such notable properties. Several mechanical devices are also available to distinguish weed seeds from crop seeds based on these properties.

Seed certification

Seed certification measures are to supply genetically pure seeds and propagating materials of crops to farmers. For certifying seeds, there are certain standards prescribed for pure crop seeds, weed seeds, moisture content etc. For details on seed certification, see the section on seed certification in the chapter, Quality control of seeds-II. Enforcing seed certification will ensure, to a greater extent, weed free crop seeds.

Weed laws

Enforcing weed laws is important in reducing the spread of weeds to new areas. They help in protecting the farmers from using mislabelled and contaminated seeds, and legally prohibiting seeds of noxious weeds from entering the country or a region. However, there are no weed laws applicable all over India. Perhaps, excepting Karnataka, no other states have made weed laws. In Karnakata, they have declared *Parthenium* a noxius weed. The weeds like *'African payal'*, water hyacinth, nut grass, thatch grass, wild rice, *Panicum repens, Parthenium* etc. are causing great problcms to our farmers and public, and suitable weed laws should be enacted to eradicate these weeds.

Quarantine laws

Quarantine laws restrict the entry and movements of imported plants capable of spreading plant diseases and insects in a country. There are also provisions to isolate an area in which a severe weed has become established, and prevent the movement of the weed into an uninfested area. However, these laws do not always restrict import of weed seeds, either separately or in the form of admixture, with crop seeds.

The spread of *African payal* and several other imported weeds point out that our quarantine laws are not effective. Actually, *African payal* came to India as an ornamental plant, and that too, for experimental purposes. From there, it escaped and created a big problem for us.

19:3. Weed control methods

The common methods of weed control include mechanical, cropping and competition (cultural), biological, and chemical methods. Each of this method has certain merits and demerits, and the farmer can make use of one means or a combination of them to control weeds efficiently and econmically.

19:3.1 Mechanical methods

Mechanical or physical methods comprise of hand weeding, hand hoeing, tilling, sickling, burning, mowing, flooding etc. These are briefly mentioned below:

Hand weeding: Hand weeding is, perhaps, the oldest method of controlling weeds, and it is still a practical and efficient method of control, especially in cropped areas. It is done by pulling out weeds from the fields by hand. Hand weeding is found to be very effective against annual weeds, as they do not recover from the remnants of plants left behind in the fields. In Kerala, hand weeding is widely practiced in paddy crop to control weeds.

Hand hoeing: The hand hoeing is an age old practice in many parts of India. It is an appropriate method to eliminate weeds from the rows of crops. It also helps in stirring the soil for soil aeration. This method is effective in annuals, biennials, and shallow rooted perennials.

Digging: Digging is very effective in the control of perennial weeds, as this helps in removing the underground propagating parts of weeds from the soil. Digging followed by hand pulling or collecting and removing weeds from the dug soil is the usual method. This method is found to be more effective than hand weeding, especially against perennial weeds. However, digging is a labour intensive and slow process, and hence, restricted to perennial weed situations only, and that too, when other methods are likely to fail.

Sickling: Sickling or sickle weeding is done by means of a sickle, and the top growth of weeds are removed to prevent seed production and to starve the below ground portions. Sickling is popular in slopy areas. As the top growth alone is removed, leaving the root system and a little portion intact to hold the soil in place, possible soil erosion is also prevented. In certain cases, where application of post-emergence herbicides require greater quantity because of excess foliage, these are sickled first, and then, herbicides are applied.

Tilling: Tilling is a practical and economical method of controlling weeds. The plough (country, mould board, Bose etc.), the harrow (disc, spike, spring tyne etc.), and the cultivator are the common implements used in tilling. This method helps to burry all the annual weeds. Tilling also disturbs the root system of most perennial weeds though complete control is not possible.

Mowing: Mowing is a machine operated process, and the machine amployed is called 'mower'. It is mainly practised along roadsides and lawns. The purpose is same as that of sickling.

Burning: Burning is a useful method of controlling undesirable weed species in roadsides, fallow lands, ditches, and other waste places. This process also destroys insects and disease pathogens present in the soil and plants. When burning is used for selective control of annual weeds in crop rows, it is known as *flame cultivation*. Cotton plants can resist controlled flame, and hence, flame cultivation is adopted in cotton. Different types of flame throwers or flame torches are available for the operation. Noxious weeds like *Cuscuta* which is a problem in many parts of Wynad can be destroyed by burning.

Flooding: Flooding is generally used for controlling weeds which are sensitive to water stagnation. In rice, it is successfully employed. The low weed growth observed in the *Mundakan* and *Punja* seasons is mainly because of maintaining a satisfactory level of standing water in the field.

Grazing: Prolonged grazing of the tops of weeds by animals like cattle, sheep, goats etc., prevents the flowering and seed formation in weeds, which eventually exhausts the underground parts, and the weeds are controlled. It is suitable for non-cropped areas.

19:3.2. Cropping and competition methods

The cropping and competition methods or the *cultural methods* of weed control play an important role in weed management. Weeds are found to be in better competition with crop plants for light, water, nutrients, soil, space etc. However, by employing suitable cultural practices which help the crop plants to compete with weeds more effectively, the menace of weeds can be reduced to minimum. The important practices which come under these are discussed hereunder.

Crop competition:- This is one of the cheapest and most useful method of weed management. Seeds with good germinability and vigour give the crop a vigorous and close stand which enable them to have an edge over the weeds. Crop cultivars which are well adapted to a region defenitely compete better with the weeds than cultivars poorly adapted to it. Some crops are found to be better competitors than weeds. For instance, crops like cowpea, sorghum, cover crops like calapagonium etc. are good competitors and are called *smothering* crops; while, crops like groundnut, tapioca etc. are poor competitors with weeds. So, growing of smothering crops will be of great advantage in controlling weeds. They grow rapidly and fill the inter row space with their canopy, faster than weeds, which give a smothering effect on weed growth. However, one disadvantage is that their seedlings in the initial stages grow slowly. Therefore, we have to find some other methods to control weeds in the early stages of growth.

Crop rotation:– Crop rotation means growing of different crops in the same field in rotation. A good rotation system certainly results in reduced weed growth. It has been observed that the continuous growing of a crop in a field could result in an increase in the population of weeds that are associated with it. Certain weeds are more common in some crops than others. Several annual weeds like wild rice in rice, and parasitic weeds like *Striga* in sorghum and *Orobancha* in tobacco are associated with crops. In such cases, crop rotation may pay the desired effects.

Mulching:– Mulching refers to the application of some materials like plant residues,green leaves, straw or even polythene sheets over the surface of soil to prevent evaporation from the soil surface, to have desired soil temperature, and of course to reduce weed growth. Mulches smother weed growth by preventing light from being fallen on the photosynthetic parts of the weeds which eventually inhibits its growth. This is an effective method in most annual weeds and many perennial weeds. Commonly available materials like straw, plant residues like paddy husks and coffee wastes, dry or green leaves, saw dust etc. are usually employed for mulching. Black polythene sheets, tar paper etc. are also used. However, since polythene sheets and paper are too expensive they are used only in high value crops.

Close planting:– Closer planting of crops in weed prone areas give the crops a competitive edge over weeds. It also produces a smothering effect on weeds, and reduces weed emergence and establishment. This is especially suitable for poor competitive crops like groundnut.

Minimum tillage or Zero tillage:– In the recent years, there is a growing trend towards reducing the amount of tillage in crops. It is a common fact that tillage, other than for weed control, is of little benefit to the crops, especially in light soils. However, in heavy soils tillage may have some other benefits too.

Studies showed that in crops like maize, sorghum etc., innovative practices which involve killing the existing weed growth by translocated herbicides and planting the crops immediately thereafter with minimum or no tillage is favourable compared to the conventional methods.

19:3.3. Biological methods:

In biological method of weed control, a natural enemy of the plant is used— which is harmless to the desired plant. Insect pests and plant pathogens are the usual natural enemies. Parasitic plants, fishes, and other animals are other forms of biological agents.

The first attempt on biological control of weeds was made in Hawaiian islands in the early 1920's to control *Lantana camara* which was introduced there around 1860 as an ornamental plant. They tried the larvae of *Crocidosema lantana* (tortricid moths), *Agromyza lantana* (seed fly), and larvae of *Thecla echion* and *Thecla bazochi.* All these insects were effective in controlling the weeds. The success in the case of *Lantana camara* led to many other investigations on the bio-enemies of other noxious weeds. In recent years, plant pathogens are also used as good biological agents.

The selection of a particular bio-agent should be based on certain criteria. They are–

1) The agent should be host specific which would not attack other economically important plants. It should feed only the particular weeds to be controlled.
2) The bioagent can be multiplied in large numbers. The control of weeds take place, only if there are enough population to feed on the weeds. This

is possible, only if the bio-agents are multiplied fast.

3) The bio-agent should feed the weeds fast.

The agent should be a voracious feeder on the weeds. Then only, the control of weeds is done quickly.

A few examples of biological means of weed control are given below:

Name of weed — Name of bioagent

Examples of insects as bioagent

African payal	—*Cyrtobagous salviniae* (weevil),
	—*Paulinia accuminata* (grass hopper).
Opuntia spp.	—*Cactoblastis cactorum* (moth borer)
Imperata cylindrica	—*Orseoliella javanica* (gall midge)
Cuscuta	—*Melanagromyza cuscutae.*
	—*Smicronyx cuscutae.*
Nut grass	—*Bactra vermosana* (plant feeder),
	—*Athesapeuta cyperi* (rhizome and stem boring weevil).
Loranthus	—*Delias hyparete* (caterpillar of a butterfly)

Examples of plant pathogens

Water hyacinth	—*Cercospora rodmanii* (fungus)
Hydriila	—*Fusarium roseum* (fungus)

Examples of fishes as bio-agent

Aquatic weeds	—*Tilapia*, common carp

Biological control of African payal

The control of African payal was a serious problem in Kerala. It was everywhere–in lakes, streams, backwaters, and in cultivated paddy fields ('Fig. 19.1'). We have tried every possible method to check the spread of this noxious weed, but of no avail. However, the recently tried method of biological control has shown much progress in this direction. The control of *Salvinia* by the release of *Cyrtobagous salviniae* weevils is gaining momentum in Kerala, and the weed is being kept at bay.

In places where *Salvinia* is a problem, the weevils can be released. Even one pair of weevils is sufficient for the establishment in an area. However, usually, 50-100 weevils are recommended for release in an area. If the collection of weevils is difficult, even 1 kg of infected *Salvinia* will do the purpose. The weevils are released on tender *Salvinia* for easy multiplication. Almost 100 percent control of weeds would be possible in a time span of 12-18 months.

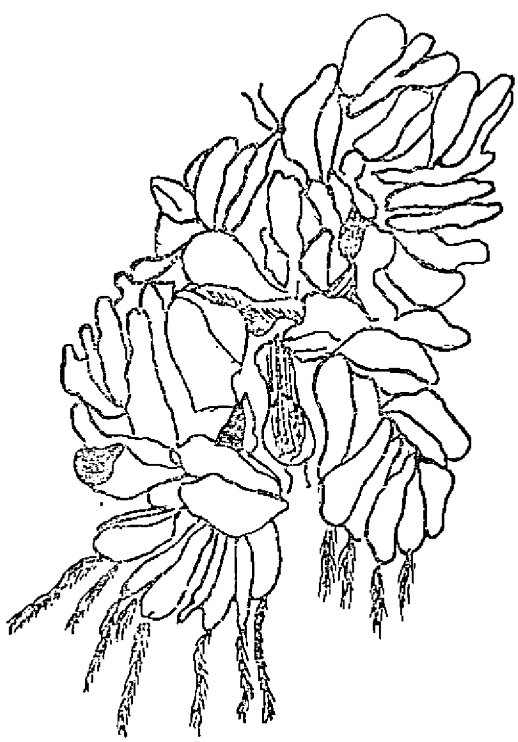

Fig. 19.1 *Salvinia molesta (African payal)*

20. Chemical methods of weed control

20:1. Introduction

The use of chemicals for weed control has developed rapidly since 1940's, especially after the Second World War. Weed killing chemicals are usually known as herbicides. In some cases, the term weedicide is also used. However, herbicide is the apt term, since the chemical may have got action not only on weeds but on all herbs. That is to say, if the weed killing chemical is not properly used, it may even kill the crop, besides weeds. A herbicide is any chemical that kills the plant or inhibit its growth.

Chemical weed control has got certain advantages over other methods. It can be adopted in situations where manual or mechanical weeding becomes difficult. Another advantage is that it kills the weeds in crop row or in the immediate vicinity of crop, where intercultivation is not possible. Moreover, the chemical method is easier, less time consuming, and less costly than weeding by other means. It also reduces the need for heavy preplanting tillage. Herbicides are found to be of much use in minimum tillage or no-tillage practices. In addition, chemical methods are found to be effective against many perennial weeds which are not easily amenable to other methods of control.

20:2. Classification of herbicibes

Several criteria are used to classify herbicides. One may group herbicides into catogories based on chemical similarities, method of application, mode of action, selectivity, or time of use. An outline of the most common classifications is given below:

Based on the chemical similarities

- Inorganic herbicides
- Organic herbicides.

Based on the method of application

- Soil applied herbicides.
- Foliage applied herbicides.
- Aquatic herbicides.

Based on the mode of action

- Contact herbicides.
- Translocated herbicides.

Based on the selectivity

- Selective herbicides
- Non-selective herbicides.

Based on the time of use

- Pre-plant herbicides.
- Pre-emergent herbicides.
- Post-emergent herbicides.

These classes are not mutually exclusive always. For instance, an organic herbicide may be a soil applied, translocated, selective, pre-emergent one.

20:2.1 *Classification based on the chemical similarities*

Based on the chemical similarities, all the herbicides are grouped into two, viz., inorganic and organic herbicides. Inorganic herbicide are acids or salts of inorganic compounds and includes chemicals like sulphuric acid, copper sulphate, sodium chloride etc.

Almost all the modern herbicides belong to the group of organic herbicides.

Organic compounds may also be sub-grouped based on their chemical similarities such as chlorophenoxy compounds, substituted phenols, amides etc.

20:2.2 Classification based on the method of application

Applying this criterion, a herbicide may be a soil applied, a foliage applied, or an aquatic herbicide. Foliage applied materials must be able to enter the leaf and must be able to contact and wet the leaf. Soil applied herbicides are taken up by the roots, or they may be fumigants killing a variety of living objects in the soil. Examples of soil fumigants include chemicals like methyl bromide, vapam etc. Soil sterilants are herbicides used to stop growth for a number of years. Sodium arsenates, borates, sodium chlorite etc. are specifically used as soil sterilants. Compounds like monuron, simazinc etc, at higher doses act as soil sterilants. A number of chemicals are used for controlling aquatic weeds by dissolving or emulsifying them in water channels, ponds etc. Such chemicals are known as aquatic herbicides and include aqualin, copper sulphate, 2, 4-D etc.

20:2.3 Classificaiion based on the selectivity

On the basis of the selectivity, selective herbicides and non-selective herbicides are there. Selective herbicides are selective in action and kill plants of only certain species while the plants of another species survive. Biochemical differences in plant tolerance to herbicides is the main basis for selectivity. For instance, the biochemical differences in tolerance between monocots and dicots enable chlorophenoxy acids like 2,4-D fo remove dicots from grasses; and dalapon to remove grasses from dicots. Within the grasses itself, DSMA is selective against certain species.

Selective herbicides with biochemical selectivity cause differential injury to different parts. The desired plants may also be damaged if the herbicides are used at incorrect rates or in advese soil or climatic conditions. Selective herbicidal action may be due to a multiplicity of factors. It may be due to differential wetting of leaves due to the morphology of leaves, physiological differences, differential absorption, differential translocation, morphological selectivity, or biochemical selectivity.

Non-selective herbicides are, however, effective against all plants which include weed oils, sulphuric acid etc. Non-selective herbicides are often used to control roadside weeds, playground weeds etc.

20:2 4. Classification based on the mode of action:

According to this criterion, herbicides belong to two groups. viz,. contact (non-systemic) and translocated (systemic). The contact herbicides do not move into the plant far beyond the point of contact. Only plant tissues touched by the herbicides are killed, and the roots and rhizomes protected by the soil may regenerate in due course. Contact herbicides are usually used around buildings, fences, non-cropped situations and other waste places. eg: paraquat (Gramaxone), cacodylic acid (Ansar, Arsan etc), propanil etc.

The translocated herbicides, which enter a plant, move into the plant and affect the tissues at a distance from the point of entry. Usually. the entry of herbicides to the plant body is through leaves. In certain cases, it may enter through stem and roots also. The translocation is through the vascular system to the growing points of both shoots and roots. eg: Chlorophenoxy acids (2,4-D, 2,4,5-T, MCPA etc), dalapon, simazine etc.

20:2.5. Classification based on the time of use

A herbicide may be a pre-plant, pre-emergent or post-emergent one, applying this criterion. The time of application of herbicides is determined by the weed species, time of germination of weeds and crop plants, and growth stages of the weeds.

Pre-plant herbicides are those which are applied to soil before the crop is planted. Herbicides which have greater toxicity on the emerging crop seedlings are usually applied before the crop is planted Similarly, chemicals which need to be incorporated in the soil are also applied before planting the crop. eg: calcium cynamide, methyl bromide, vapam etc.

Pre-emergent herbicides are applied before the crops or weeds have emerged. eg: diuron, bromacil. In the case of annual crops, these are applied after seeding or transplanting the crops, but before the weeds emerge. In the case of perennial crops, these could be applied only after completely removing the existing weeds by some other methods.

Post emergent herbicides are those which are applied after the emergence of a weed. eg: paraquat, glyphosate.

20:3 Herbicide formulations

The term formulation refers to the way in which the basic herbicide chemicals are prepared for practical use. It is essential that the basic ingredient must be amenable to application in an effective manner, so as to come into contact with the soil or the foliage. In usual cases, only a small quantity of the basic chemical (active ingredient) is required for the use in a large area. *Active ingredient* is that part of the formulated product that is directly responsible for herbicidal effects. It may be a solid, liquid, or a gas. Herbicides are usually formulated to get solution, emulsion, or suspension so as to apply as a spray in the field. It is also formulated as granules, but not generally as dusts due to the danger of drift. The important herbicide formulations are:

Water soluble powder (*WSP*): Soluble materials such as dalapon, sodium methyl arsenates etc. can be prepared for spraying in the field by dissolving in water. The salts of most herbicide chemicals are in a powdery form and are soluble in water. They are dissolved in the required amount of water and sprayed.

Water soluble concentrate, (WSC): Chemicals such as 2,4-D amines and dicamba form soluble liquids and formulated as such. These chemicals are easily miscible with water.

Wettable powder (*WP*): Wettabie powder is prepared by absorbing the herbicide is an inert carrier together with an added sufface acting agent. It is then finely ground, so that it form a suspension when agitated with water. Examples are monuron, diuron and simazine.

Emulsifiable liquid concentrate (*ELC*): An emulsion is a liquid dispersed in another liquid, each maintaining its original identity. The two liquids are prevented from reacting each other by the addition of an emulsifying agent. Herbicides such as 2,4-D esters are soluble in oil only and not in water. In such cases, it is formulated as ELC in a light oil with an emulsifying agent. When ELC is mixed with water, it forms a milky liquid. The mixture is to be agitated from time to time to avoid separation.

Granules: In this type, the herbicide is adsorbed or impregnated into an inert material (carrier), so that the final formulation consists of granular particles. Granular herbicides can be applied as such or by mixing with soil or sand. Carriers such as clay, sand, vermiculite, or finely powdered vegetable parts such as corncobs and tobacco leaf debris are generally used. Granules are always soil applied.

20:4. Important herbicides

A few of the important herbicides commonly used in crops are discussed below:

2,4-D (2, 4-Dichlorophenoxy acetic acid)

2,4-D is a selective, translocated, post emergent, foliar applied herbicide. Sometimes used as an aquatic herbicide also. It is generally used to control broad leaved weeds in narrow leaved crops. Grasses usually have narrow and erect leaves, the leaf surface is rough and waxy; and the growing points are located in the crown of the plant below the soil level and are protected by the surrounding leaves. Broad leaved plants, on the other hand, have leaves that are smooth. The growing points are exposed at the tip of the shoots and in the leaf axils. The droplets of 2, 4-D bounce off the leaves of grasses and wet them only in spots. Whereas, the droplets stick to the broad leaved ones and completely wet them. That is why, 2, 4-D is toxic to broad leaved plants.

2, 4-D is available in salt and ester formulations Salt formulations are usually with sodium and amines. It is recommended for the control of many broad leaved weeds in crops like rice, sugarcane, rubber, and in non-crop areas.

Common formulations:
2, 4-D sodium salt—Fernoxone 80% WP
2, 4-D ethyl ester—Weedone concentrate 34% EC
-do- —Weedone 18% WP
Recommended dosage(ai.)—0.5-2.0kgha^{-1}

Recommendation for rice: The recommended dosage for rice is 1 kg ai.ha^{-1}. Apply 2, 4-D at 1 kg ha^{-1} in 400 litres of water, 25 days after transplanting. Wherever the field is level, 2, 4-D at 1 kg ha^{-1} can be mixed with 10 kg urea, and apply on the 20th day after sowing or transplanting, which saves spraying charges.

Dalapon (2, 2-Dichloropropionic acid)

Dalapon is a selective, translocated herbicide. It is both soil and foliage applied, either as pre-emergent or post-emergent. It is used for the control of annual and perennial grasses. Dalapon is found to be effective against thatch grass (*Imperata cylindrica*) and quack grass (*Agropyron repens*). The chemical has proved to be highly resistant to break down in plants. It is most effective in young plants in active growth and on plants receiving an adequate water supply. Dalapon is absorbed through both the roots and the foliage rapidly reaching all plant parts within an hour of application. However, 2-3 weeks may take to show injury symptoms. Dalapon causes leaf chlorosis and necrosis and eventual growth inhibition by systemic action.

Dalapon is available as sodium salt which readily dissolves in water (soluble powder). It is hygroscopic. and therefore, must be stored in moisture proof containers. Commonly applied in sugarcane, grapes, tea, orchard crops etc. Recommended dosage is 2-5 kg ha^{-1}, and generally available in the trade name Dowpon.

Butachlor

Butachlor is a translocated herbicide. It affects seed germination and seedling growth by inhibiting root and shoot growth. It is applied pre-or post emergence. The chemical is available in EC and granular formulations. Generally, EC is used as pre-emergence and granular form as post-emergence. However, EC can also be used as post-emergence by mixing with sand, and then throwing the sand plus herbicide mixture as in a granular herbicide. It controls most annual grasses like *Echinochloa crusgalli, E. colonum* and some broad leaved weeds.

Commercial formulations—Delchlor, Machete, Butachlor; Dosage (both pre- and post)—1-3 kg ha^{-1}.

Recommendation for rice: Spray at 1.0 kg ai. ha^{-1} immediately after transplantation (Delchlor @ 2 l ha^{-1}). Maintain water level at 5 cm at the time of application and 5-10 cm for 3 consecutive days. When granules are used, spread the granules (Machete 5%) @ 20 kg ha^{-1} evenly on soil surface 7 days after sowing or 4-8 days after transplanting. However, caution should be taken not to trample the soil after spreading the granules.

Benthiocarb

Benthiocarb is a selective, pre-emergence, and early post-emergence herbicide used in rice for the control of many annual and broad leaved weeds. It can control aquatic weeds in rice too.

Commercial formulation—Saturn 50 EC
Dosage —2.0 kgai. ha^{-1}

Recommendation for rice: Dry sown crop—pre-emergent spray of Saturn 50 EC @ 4 l ha^{-1}, on the day of sowing or immediately after sowing, effectively controls all types of weeds. Transplanted crop—Spray Saturn 50 EC @ 4 l ha^{-1} on the 6th day after transplanting.

Propanil

Propanil is a post emergent herbicide applied for the selective weed control of *Echinochloa spp.* (barnyard grass and jungle rice) and sedges in rice. Usually applied at 4th leaf stage of rice seedlings and usual dosage is 1.75 kg ha^{-1}.

Commercial formulations: Stam F 34, Hexanil 35% EC.

To cover one hectare, five litres of the commercial formulation is needed. Certain precautions are to be observed while spraying this chemical in rice. Dewater the field prior to application. After 48 hours of applying the chemical, reflood the fields. Caution may also be taken not to use insecticides within 10 days of applying the herbicides, since there is every possibility of propanil-insecticide interaction.

Penoxalin

Penoxalin or pendimethalin is a soil applied systemic herbicide. In rice, it has to be applied on the 6th day after transplantation of seedlings. Recommended dosage for rice is 1.5 kg ha^{-1} Commercial formulations available are Stomp 50 EC and Pendimethalin 50% EC, which means 3 l ha^{-1} of the commercial formulation is to be used.

Nitrofen

It is used as a pre-emergent contact herbicide to control many annual grasses and broad-leaved weeds. It is highly efficient for the control of *Echinochloa crusgalli* and *Phalaris minor.* Nitrofen is a popular herbicide for weed control in dry sown crop of rice. Commercially available as Tok E 25. For dry sown crop nitrofen at 1.5 kg ha^{-1}(Tok E25 at 6 lha^{-1}) is to be sprayed on the same day of broadcasting.

Paraquat

Paraquat is one of the most widely used herbicides. It is a post emergent contac t broad spectrum herbicide in crop and non-crop situations. Paraquat is a popular herbicide for the control of weeds in plantation crops like rubber, tea and coffee.

Commercial formulations — Gramaxone, ortho paraquat.

Recommended dosage—0.2-0.75 kg ha^{-1}

Diuron

Diuron Is a pre-emergent selective herbicide used for controlling grasses and broad leaved weeds, especially in crops like coffee, tea, and citrus. It is extremely persistant in soil. At higher rates, diuron will behave just like a non-selective herbicide. It has got some post-emergent action also and shows some synergestic action when mixed with paraquat, and this helps in better control of perennial weeds.

Commercial formulation — Agromex-diuron

Recommended dosage — 0.5-3.0 kg ha^{-1}

Glyphosate

It is a selective post emergent herbicide used effectively against rhizomatous and deep rooted perennial weeds like thatch grass (*Imperata cylindrica*), quack graes (*Agropyron repens*), and torpedo grass (*Panicum repens*). Glyphosate is to be applied on the foliage when there is active growth. It is extensively used for the weed control in crops like coffee, tea, rubber, oil palm, pineapple, citrus, and other orchard crops.

Commercial formulation— Roundup, Glycel weedoff

Recommended dosage — 0.5-2.0 kg ha^{-1}

20.5 Methods of application of herbicides

Herbicides are generally applied as a spray or as granules. Spray is most common by using the formulations WP, WSP, WSC, and ELC. Granules are applied by hand or with the help of a granular applicator. Sometimes, the formulations like WSC and ELC are also applied just like granules by mixing with sand eg: 2, 4-D and Delchlor may be mixed with sand and applied in rice.

Spraying is done with the use of sprayers just like insecticide or fungicide spraying. However, special types of nozzles are to be used. The nozzle influences uniformity in spraying, spray pattern, and droplet size. Though there are different types of nozzles available (Fig. 20.1), herbicide spraying is mostly done with floodjet fan or floodjet deflector nozzles, as they produce a more even distribution of spray and uniform coverage than the usual cone types.

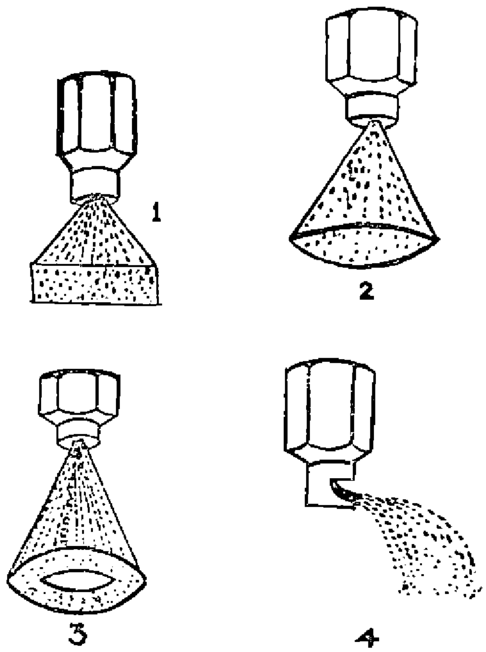

Fig. 20.1 Different types of spray nozzles.
1. Floodjet Fan 2. Solid cone
3. Hollow cone 4. Floodjet deflector

In the case of floodjet fan nozzle, the tip has a rectangular orifice behind which two streams of liquid meet, because of the shape of the bore. In the floodjet deflector types of nozzles (also known as flooding, anvil, or impact nozzle), a jet of liquid passes through a relatively large orifice and strikes a smooth surface at a high angle of incidence to form a fan shaped spray pattern. This type of nozzles deliver coarse droplets of spray fluid under pressure, thus minimizing drift. Clogging is also reduced as the nozzle orifices are large.

Our farmers, usually use the same sprayer for spraying insecticides, fungicides and herbicides. In such cases, he should take extra care in cleaning them. The equipment should be thoroughly cleaned with water or preferably with one percent ammonia before it is used for other purposes. When an ester is used, the equipment should be rinsed with kerosene before it is washed with water. After use, fill the sprayer tank and lance with water and keep it overnight, and the other day, give thorough rinsing with water.

20:6 Spray calibration

For effective and safe use of herbicides, accurate calibration of sprayer is essential. A sublethal or an overdose would work contrary to our objectives. A sub-lethal dose fails to give satisfactory control of weeds. An overdose increases costs, besidues killing a crop or resulting in the accumulation of toxic residues in the soil. The nozzle type, nozzle orifice, spraying pressure, spraying speed etc. determine the desired rate. So, we calibrate the sprayer by spraying in a known area. We have to take into consideration average walking speed of the individual also. The area covered per hour by the individual can be calculated as follows:

Area covered in one hour (m^2) =
=Walking speed x Spray width
($m\ hr^{-1}$) (m)

eg: Suppose a person is walking at 1 km hr^{-1} covering a strip of 0.6 m width. The area covered per hour is = 1 x 1000 x 0.6 = 600 m^2 = .06 ha

That is to say, the individual will cover an area of 600 m^2 in an hour. At this rate, he takes 16 hr 40 mt. to cover an area of one hectare. In normal courses, 300-500 litres of spray fluid is required to cover an hectare. In the above example, if the discharge rate of sprayer is 30 l hr^{-1} it would require a spray volume of 500 l ha^{-1}, which means we should determine the spray volume based on walking speed and discharge rate.

ie., spray volume = the time required to cover an hectare x the discharge rate.

20:7. Calculation of the dosage levels:

As stated earlier, herbicide recommendations are generally given as active ingredient per ha. In some cases, acid equivalents are also used. Acid equivalent refers to that part of a formulation which can be theoretically attributed to the acid. In such cases, ai. is given in acid equivalents eg 2, 4-D, MCPA etc.

The percentage of ai. or ae. is given on the label. To calculate the quantity of commercial product required for a particular area, the following formula can be made use of

$$\text{Weight of commercial product} = \frac{\text{Weight of the ai to be applied}}{\text{Percentage of ai. in the commercial product}}$$

eg: Say, we have purchased Delchlor 50% EC.

For applying the chemical at 2 kg ai. ha^{-1} we have to calculate as follows:

Weight of Delchlor 50 EC required for 1 ha. $= \frac{2\ kg \times 100}{50} = 4\ kg\ ha.^{-1}$ □

21. Important weeds of Kerala

21:1 Introduction

In this chapter, we shall see some of the common and troublesome weeds of Kerala. The descriptions are given under two heads—monocots and dicots. All the 25 weeds described are of common occurrence and can be easily identified. The botanical name of the weed is given first followed by its family name. Popular common names in English and Malayalam (Malayalam name in italics) are also given in brackets.

21:2. Monocot weeds:

Cynodon dactylon. Fam. Poaceae (Gramineae)
(Bermuda grass, Doob grass, *'Karu-kappullu'*)

Bermuda grass (Fig. 21.1) is a perennial grass commonly seen all over Kerala.

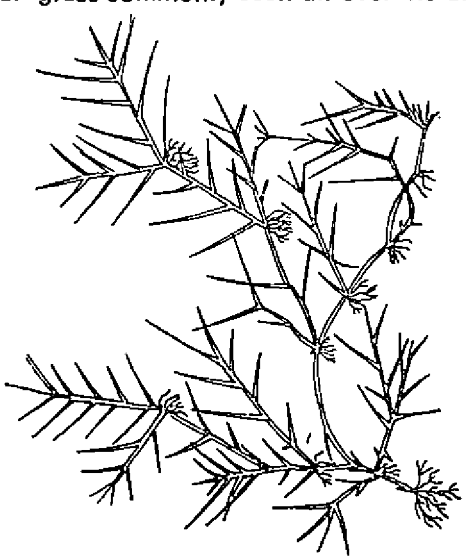

Fig. 21.1 *Cynodon dactylon*

This grass has got long runners which strike roots at the nodes. Certain cultivars of *Cynodon* are used for lawn making. Propagation is mainly by seeds and stem pieces. Repeated ploughing or digging helps in the control of this weed. Summer cultivation is much effective, since it exposes the plant parts to the sun and kill the grass. Post-emergence application of herbicides such as glyphosate, dalapon etc. are found effective. Bromacil is also effective, either pre-or post-emergence.

Cyperus rotundus. Fam. Cyperaceae
(Nut grass, *'Muthanga'*)

Nut grass (Fig. 21.2) is one of the most troublesome weed in crop and non crop situations. The weed produces quite a lot of seeds, which are capable of reproduction. Besides, it has got a net work of tubers in the soil, which also act as propagating material. Usual chemical or mechanical measures are ineffective to destroy these tubers. So, the most effective method is to check and suppress the aerial growth of the weeds by mechanical methods and by the use of herbicides such as 2, 4-D. A pre-emergence spray of 2, 4-D or MCPA (2 to 5 kg ha^{-1}) delays the germination of tubers, thereby, preventing the early competition with the crop. If eradication is aimed at, digging, collecting and destroying tubers have to be undertaken and repeated. It has been reported that deep cultivation in summer followed by 2, 4-D sodium salt at 4 kg ha^{-1} is effective in controlling this weed.

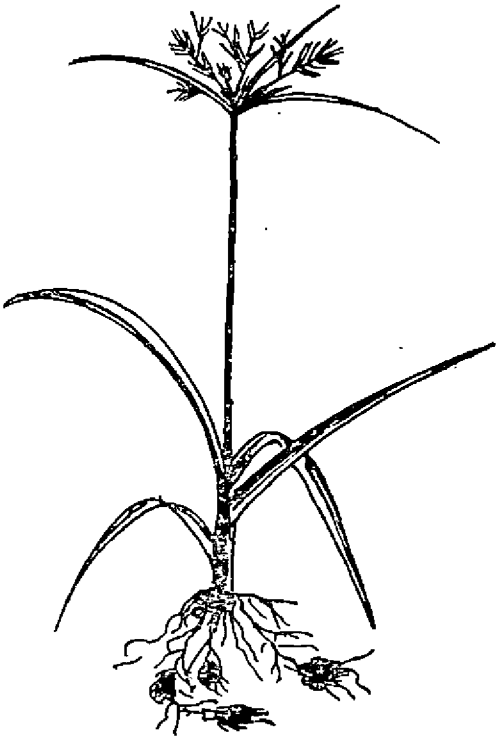

Fig. 21.2 *Cyperus rotundus*

Fig. 21.3. *Echinochloa crusgalli*

The tubers have certain medicinal uses. It is a diaphoretic and astringent.

Echinochloa crusgalli: Fam. Poaceae (Barn yard grass, '*Kavada*')

This is a major weed in rice fields (Fig 21.3). It emerges almost with the crop, and difficult to identify in the early stages. However, in the later stages, it is distinguishable and can be easily removed. Unlike rice plant, the ligules are absent and this peculiarity may be made use of to distinguish them from rice in the early stages. Reproduction is by means of seeds only. Hand weeding and roguing are the usual control measures against this weed. Pre-emergent herbicides such as alachlor, diuron, atrazine, simazine, benthiocarb, butachlor etc. are effective.

Echinochloa colonum: Fam. Poaceae (Jungle rice, *Kavada')*

Echinochloa colonum is very similar to barnyard grass. However, the prominant awns are absent here. It is also a major weed of rice. Propagation is mainly by seeds, though vegetative propagation by separated shoots is also possible. Control measures are similar to *E. crusgalli*.

Eichornia crassipes: Fam. Pontederiaceae

(Water hyacinth, '*Kulavazha*')

Water hyacinth (Fig. 21.4) is a floating aquatic weed. The shoots and leaves are very spongy in nature. It remains either creeping or rooting in the mud or float about on the surface of water. It is a fast growing, troublesome, and indestructible

Fig. 21.4. *Eichornia crassipes*

weed. It can be a problem in village ponds, tanks, streams, drainage ditches, irrigation canals and water ways. However, man succeeded in getting some benefit out of this troublesome weed. It is a good source of animal feed, organic fertilizer, biogas and fibre. It can also be used to make pulp, paper, and even human food. The plant also acts as an efficient scavenger of pollutants, when grown in waste waters.

Chemical control measures involving 2, 4-D is effective. Within two or three weeks, the plants are killed, decayed and sunk to the bottom.

Fimbristylis miliacea: Fam. Cyperaceae
'Mang'

It Is a fine leaved sedge found in both low land and upland rice fields. Propagation is through seeds. (Fig. 2.5)

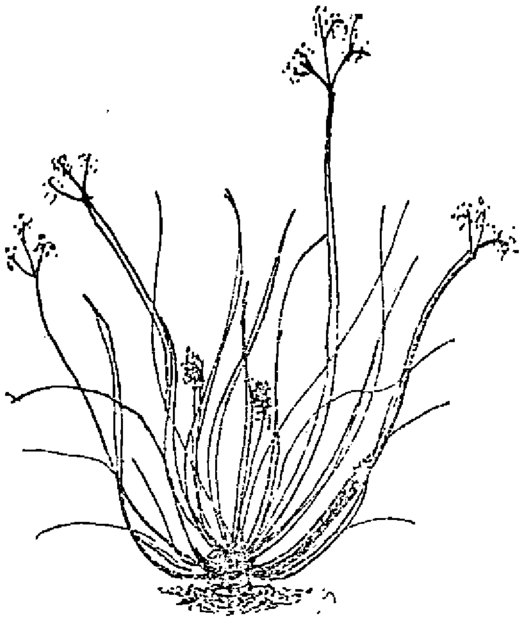

Fig. 21.5. *Fimbristylis miliacea*

Imperata cylindrica: Fam Poaceae (Thatch grass, *'Tharippa' 'Dharpha'*)

Imperata cylindrica is a perennial grass having an extensive and deeply penetrating system of rhizomes. Propagation is by rhizomes and seeds. The shoot grows to a height of about 60-120cm depending on the growrh conditions. It is a troublesome weed in perennial crops, especially plantation crops such as tea, rubber and coffee The grass is sometimes used as a thatching material for houses and hence the name thatch grass.

The weed is very difficult to get eradicated due to deep rhizomes. However, chemical control with glyphosate (0.8-1 6 kg ha $^{-1}$) has been found to control the weed effectively when in active growth.

Monochoria vaginalis: Fam Pontederiaceae.

(Water hyacinth, *'Neelolpalam' 'Karimkoovaiam'*)

This weed is also a floating aquatic, similar to *Eichornia*. However, the leaves are small and narrow; and linear or lanceolate in shape. Thay are also leso abundant in nature, unlike *Eichornia*, and less troublesome. It is a weed of rice fields and seen in ditches and small streams. Propagation is through the creeping rhizomes. It has got several medicinal properties and used in Ayurveda (Fig. 21.6).

Oryza sativa var. *fatua*: Fam. Poaceae. (Wild rice, '*Varinellu*').

Wild rice is very similar to cultivated rice, and is very difficult to eradicate it from the cropped fields. However, by following certain precautions, this weed can be controlled to an extent. As far as possible, pure seed devoid of weed seeds is to be planted. If all the seed production techniuqes have been followed scrupulously, we get pure seeds. Roguing is particularly important. It is easy during later stages, since wild rice has awned panicle and have highly spreading tillers. Where wild rice infestation is severe and persistant, use coloured cultivars of rice. Transplanting method is preferred, rather than broadcasting. Leaving the land fallow for one year and frequent cultivation to kill wild rice plants is also feasible. Another method is giving irrigation to the fields, so as to effect the germination of wild rice already present in the soil and removing it by repeated ploughing before the actual sowing of the crop.

Fig. 21.6: *Monochoria vaginalis*

Panicum repens: Fam. Poaceae (Torpedo grass, '*Inchipullu*')

Torpedo grass is an aggressive creeping perennial grass which spreads rapidly in both cropped and non-cropped situations. The rhizomes are knotty and swollen and send out erect culms from the nodes. The weed is easily propagated by means of rhizomes and seeds. It is a persistant and troublesome weed in many crops such as coconut, pepper, arecanut, banana, coffee and tea.

Repeated tilling or digging, followed by collection and destruction of rhizomes, is effective to control and eradicate this weed. However, this operation is costly and laborious. Translocated herbicides such as glyphosate and dalapon are effective against this weed. These herbicides get translocated into the rhizomes, and prevent their regeneration.

21:3. Dicot weeds

Abutilon indicum: Fam. Malvaceae (The country mallow, '*Oorpum*')

This is a weed of the waste lands. Also found in cultivated lands, especially where perennial crops are grown. Propagation is by means of seeds. The seeds are sticky in nature due to the bristles on them which help its easy dispersal through animals. Sickling and deep ploughing may control the weeds. Several post-emergent herbicides are also effective.

The leaves of the plant are rich in mucilage. The bark of the stem yields fibre suitable for country rope making.

Ageratum conyzoides: Fam. Asteraceae (Compositae)
(Goat weed, *'Appa'*)

Ageratum conyzoides (Fig 21.7) is an annual weed of the waste places and cultivated lands. Propagation is by seeds. The stem is erect, hairy and usually attain 50 to 90 cm height. The weed is easily controlled by hand weeding before they set seeds. Pre-emergent herbicides like simazine, diuron, and post-emergent herbicides like 2,4-D are effective against his weed.

Certain forms of *Ageratum* are good ornamental plants.

Biophytum sensitivum: Fam. Geraniaceae
(Biophytum, *'Mukkutti'*)

Biophytum (Fig. 21.8) is a small slender herb, the leaves rising directly from a stout stock, or the leaves may resemble a crown on a hairy stem. The plant produces small yellow beautiful flowers. Propagation is by seeds. Hand weeding, digging, and ploughing are effective against this weed.

The weed has got several medicinal properties and used in Ayurveda.

Cassia occidentalis. Fam. Fabaceae (Leguminosae)
(Sickle pod, *'Thakara'*)

It is a weed of common occurrence in waste places after the receipt of rains.

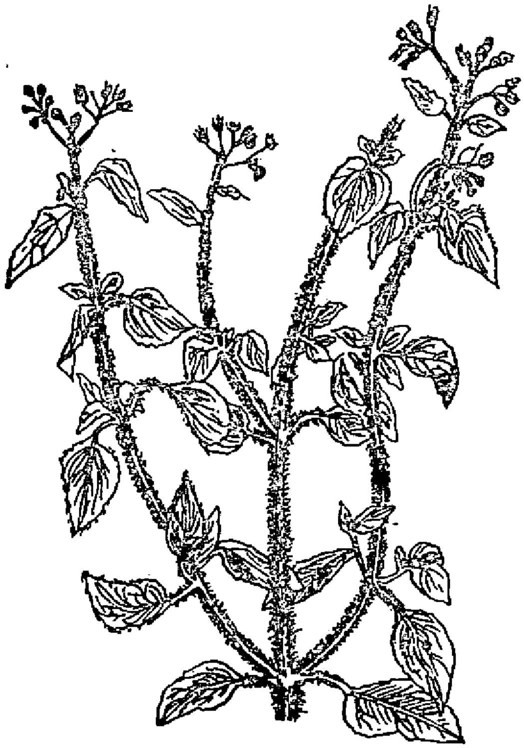

Fig. 21.7. *Ageratum conyzoides*

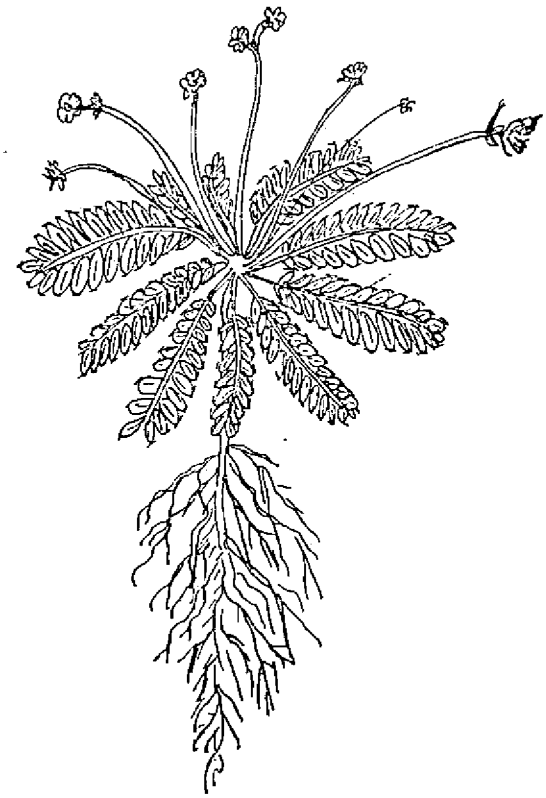

Fig. 21.8. *Biopytum sensitivum*

It is also seen in cultivated fields. The weed plants can be used for green manuring. The young leaves and pods are sometimes used as a vegetable. It has got medicinal values too.

Cleome viscosa. Fam. Capparidaceae. (Wild mustard, *'Kattukaduku'*)

A common weed found in both cultivated fields and waste places. Propagation is by seeds. It has got medicinal uses and the seeds are stimulant, carminative, and anthelmintic. Hand weeding and herbicides are effective.

Cuscuta spp. Fam. Convolvulaceae (Dodder, *'Nilamthodavally'*, *'Moodillathali'*)

This weed is a persistant one. It is a parasite which is twining and leafless. The propagation is by seeds and vegetative parts Stems closely twining and yellowish green or yellow, form dense yellow masses on trees and shrubs. The weed is usually seen on fences, hedges and trees. It is a common occurrence in Wayanad and such other places and do considerable damages to crops like coffee and pepper.

It may be controlled by pulling out the plants and burying or burning them. When on hedges or fences flame cultivation can be tried.

Emilia sonchifolia Fam. Asteraceae (*'Muyalcheviyan'*)

The leaves of the weed has a resemblance of the ear lobes of the rabbit and hence the name *'Muyalcheviyan'* in Malayalam (meaning rabbit's ear). It is a slender annual herb found both in waste places and cultivated lands. It has got medicinal uses also. Hand weeding and herbicides are effective against the weeds (Fig. 21.9).

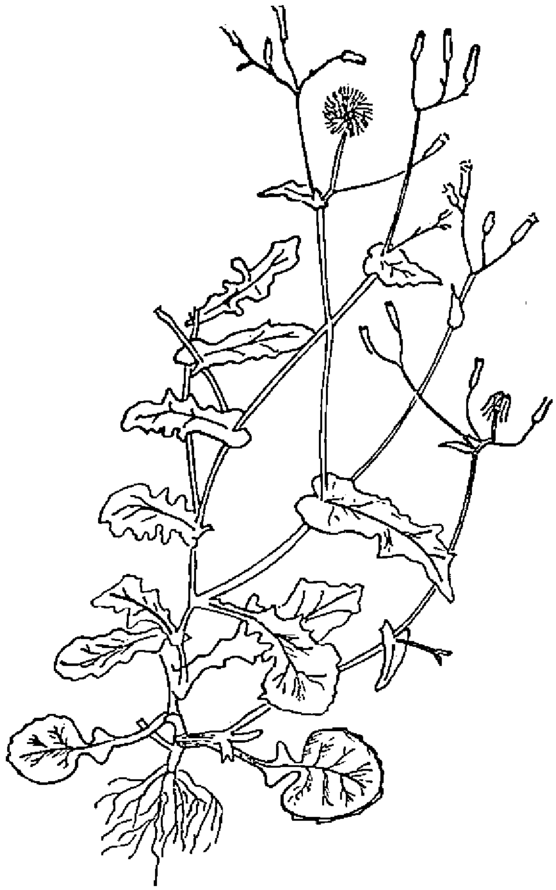

Fig. 21.9. *Emilia sonchifolia*

Eupatorium odoratum (*Chromolaena odorata*) Fam. Asteraceae (Eupatorium, *communist pacha'*)

It is a troublesome weed found all over Kerala. It is somewhat drought resistant, and thrive even in summer when all other greens disappear. It is a persistant weed of perennial crops, waste lands and roadsides. Repeated sickling, digging, and herbicidal applications are effective.

The leaves and tender portions of the stem can be used as a good green manure.

Lantana camara. Fam. Verbenaceae (Lantana, *'Konginipoovu'*)

The plant is a native of Central America which became naturalised in India as a weed, especially in waste places and roadsides. Several ornamental types are, however, there which produces beautiful flowers of yellow, red, or white. The plant is a perennial one which propagates by means of seeds and vegetative parts.

Clean cultivation is an effective step against the control of this weed. Herbicides like 2,4-D, 2,4,5-T, and glyphosate give good control.

Leucas aspera. Fam. Lamiaceae (Labiatae) (*Thumba'*)

It is found through out the yaar, and is a common weed of waste places and arable lands. Hand weeding is very effective for the control of this weed.

The plant has got medicinal properties. The juice of the weed is used against snake bite, cut injury, and ringworm (Fig. 21.10).

Fig. 21.10. *Leucas aspera*

Oxalis corniculata. Fam. Oxalidaceae (Lady's sorrel, *'Puliyarela'*)

It is a perennial and shade loving plant of gardens, road sides, waste places, and cultivated fields. It has a short, thick, tuberous or bulbous root. The propagation is by means of seeds and bulbils formed from roots. Certain forms are good ornamental plants (Fig. 21.11).

Mechanical methods like digging and turning over the soil in summer will control the weeds by killing bulbs and bulbils. Herbicides like paraquat and glyphosate are also effective.

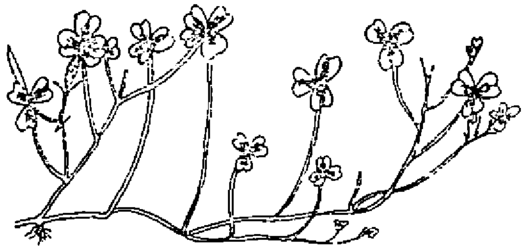

Fig. 21.11. *Oxalis corniculata*

Phyllanthus niruri. Fam. Euphorbiaceae. (*'Keezharnelli'*)

This weed is generally seen in waste and fallow lands and in cultivated fields. The plant has got several medicinal uses. It is considered deobstruent, diuretic, astringent and cooling. It is reported to be useful against jaundice too.

Handweeding and clean cultivation will keep off the weeds from the arable lands (Fig. 21.12)

Physalis minima. Fam. Solanaceae(*'Njottanjodiyan'*)

Physalis minima (Fig. 21.13) is an annual weed found in both arable and waste lands. Propagation is by means of seeds. Clean cultivation and weeding

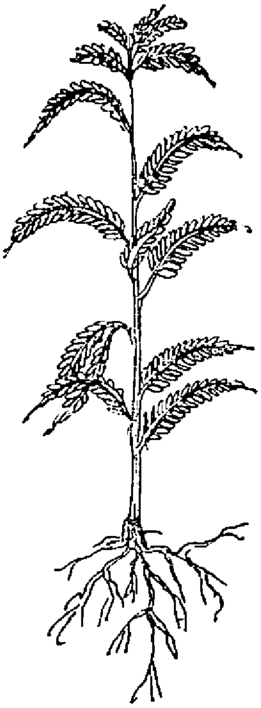

Fig. 21.12. *Phyllanthus niruri*

before the plants come to flowering will keep the weeds at bay. Ripe berries are, some times edible.

Sida rhombifolia. Fam. Malvaceae. (Sida hemp, '*Kurunthotti*')

It is a common weed of waste places. Its roots are used in Ayurvedic medicine. Propagation is by means of seed. Hand weeding, hoeing or digging, and clean cultivation will keep off the weeds from the field.

Vernonia cineria. Fam. Asteraceae ('*Poovankurunnila*')

A slender annual herb, which flowers and fruits all the year round, except in hot season. Propagation is by seeds. It is found in cultivated lands and waste places. Hand weeding is an effective method of control. It has uses in medicine (Fig. 21.14).

Fig. 21·13. *Physalis minima*

Fig. 21.14. *Vernonia cineria*

HORTICULTURE

22. Horticulture—an introduction

Horticulture is a major branch of agriculture. The term 'horticulture' is derived from two Latin words—*Hortus*, means garden and *cultura (colere)*, means to cultivate or to care for. Originally, horticulture meant cultivation of plants in a garden. Plants such as flowers, fruits and vegetables were grown in gardens (enclosed areas or protected areas), and thus, these crops acquired the name 'horticultural crops'. Horticulture may be defined as a branch of agriculture concerned with intensively cultured plants directly used by people for food, for medicinal purpose, or for aesthetic gratification (Janick, 1982). It is the art, science and business of cultivation, production and processing or utilisation of crops like fruits, vegetables, ornamental plants, plantation crops, spices, aromatic plants and medicinal plants.

The major divisions of horticulture are pomology (cultivation of fruits), olericulture (cutivation of vegetables), floriculture and land scape gardening, spices and plantation crops, medicinal and aromatic plants, and processing technology. In addition to these, nursery trade, seed production of horticultural crops etc. are developing as strong branches of horticulture with a business orientation.

Most of the horticultural crops need plant-to-plant intensive care. In most of the horticultural crops, the useful parts are highly perishable in nature and used in the fresh stage. In contrast, agronomy, another major branch of agriculture, includes cultivation of all the field crops such as grains, pulses, oil seeds, fodder crops, fibre crops etc. The field crops are cultivated extensively and they do not require the plant-to-plant attention; and in most of the field crops, the useful parts are dried or dead parts and are not easily perishable.

Importance of horticulture

When we hear the term horticulture the first feeling is about its artistic or aesthetic value. Of course, it is an art. Designing a garden or landscape, propagating plants, flower arrangement etc. require an artistic talent. Nowadays, a new technique called 'Horticultural Therapy' is getting developed to cure the abnormal minds of mentally retarded and disturbed patients through engaging them in ornamental gardens, orchards and vegetable cultivation.

In Kerala, more than 70 per cent of the cultivated area is occupied by various horticultural crops. These crops, especially the plantation crops and spices (or the cash crops) contribute to the major part of the total agricultural income of our state. Besides, the horticultural crops give a higher profit per unit area of land per annum. By export of various products like spices, we earn a good amount of foreign exchange. In recent years, the export of various fresh as well as processed fruits and vegetables to the Arabian countries has become a booming business.

When compared to the field crops, the productivity of horticultural crops, especially that of fruits and vegetables is higher. Fruits and vegetables are also important with respect to their nutritive value. They contain vitamins and minerals required for our balanced diet. Fruits and vegetables are often referred to as 'protective foods' as the vitamins and minerals present in fruits and vegetables protect us from many diseases.

As a diversified enterprise also, horticulture is important. In Kerala, a farmer may cultivate fruits, vegetables and plantation crops in a mixed manner in his homestead. The horticultural crops also provide scope for more employment throughout the year. Horticulture is also gaining importance as a specialised enterprise. The cultivation of tea, cardamom, pepper, or rubber on a large scale are examples for specialised enterprise in Kerala. The growing of oranges and mango in Andhra Pradesh, grapes in Tamil Nadu, Karnataka, Andhra Pradesh and Punjab, apple in Himachal Pradesh and Kashmir etc. are examples for specialised enterprise in other states. Landscape designing, nursery busi ness etc. are some other specialised enterprises.

23. Plant propagation—principles and methods

23:1. Introduction

For the popularisation of any new cultivar developed, its multiplication on a large scale becomes necessary. The multiplication or perpetuation of a plant to a number of individuals is called propagation.

Propagation of plants can be divided into two broader groups—sexual and asexual. Sexual propagation is done by seeds which result from the fusion of female and male gametes, known as zygotic fusion. Seedlings grown from the seeds of a cross-pollinated crop will not be true-to-type. For example, a seedling produced from the seed (under natural cross pollination) of a Neelum mango tree will not be exactly similar in its characteristics to that of the mother tree. Asexual propagation, on the other hand, is usually not by seeds. In asexual propagation, vegetative parts like cuttings, suckers, bulbs, rhizomes etc. are used, and hence, the plants produced will be true-to-type. Since vegetative parts are used, asexual propagation is also known as vegetative propagation.

23:2. Sexual method of propagation

Seeds are the propagating material in sexual method of propagation. In a cross-pollinated crop, if seeds are used for multiplication, the off-springs will not be uniform. Seed propagation is most commonly used in annual crops like vegetables and annual flowering plants. More details on seed propagation, production of quality seeds etc. are given in the chapters on seeds.

Some of the advantages of sexual or seed-propagation are given below:

1 Seedling trees usually have a longer life-span and they bear heavily.

2 In plants, where vegetative propagation is impossible or becomes very costly, seed propagation is the only way eg., papaya.

3 Sexual propagation is the only way to evolve a new hybrid cultivar.

4 Seedlings are deep rooted and so more hardy; and they thrive over adverse conditions as drought; wind etc.

5 Seedlings are comparatively cheaper and easy to produce.

6 Seedlings are used as root stocks for budding and grafting.

7 Occasionally, superior plants are obtained as 'chance seedlings'.

The sexual or seed-propagation has some demerits also. They are—

1 Generally, seedling trees are not uniform in their growth, yield and quality of the produce. The time of flowering and harvest may also be different for different trees, ie., not true-to-type to that of the mother tree.

2 Seedling trees take more time (years) for flowering and bearing.

3 Seedling trees are growing very tall and spreading in nature. So, pruning, harvesting, spraying etc. are difficult and become costly also.

4 It is not possible to multiply a desired hybrid cultivar through its seed since the progenies of hybrids are highly heterogenous.

23:3. Asexual methods of propagation

The various methods of asexual propagation are the following:

1) Apomictic embryos
2) Runners
3) Suckers
4) Separation
5) Division
6) Cuttings
7) Layering
8) Graftage—grafting and budding
9) Micro propagation

Advantages of vegetative (asexual) propagation

1 Through vegetative propagation, we can produce true-to-type plants as that of the mother tree. The growth, yield, quality of produce, flowering and harvesting period etc. will be similar in such plants, ie., they will be uniform or homogenous.

2 In trees, where seeds aro not formed, vegetative propagation is the only way. eg., banana, pineapple.

3 In plants where seed germination is very poor or slow, vegetative propagation will be the easiest and cheapest.

4 Some cultivars may be susceptible to certain pests/diseases. Similarly, some cultivars may not be growing well in certain soils. Successful cultivation of such cultivars is possible through vegetative propagation, if they are grafted on the pest/disease resistant root-stocks or on rootstocks which are adapted to the unfavourable soil, ie., we can impart the resistance of a root-stock on a cultivar through vegetative propagation.

5 Vegetatively propagated plants come to flowering and fruiting earlier than that of seedlings.

6 Vegetatively propagated plants are often dwarf in stature. So, it is easier and cheaper to conduct various operations like pruning, spraying, harvesting etc., and it is also possible to accommodate more number of plants per unit area.

7 Some plants are dioecious (male and female plants are septate), eg., nutmeg. In such cases, the useful female plants can be multiplied by asexual methods.

8 Through vegetative propagation methods like top working, even inferior plants can be changed to superior; or the male plants can be converted to productive female trees. eg., male nutmeg trees can be converted to female ones by top working.

9 Some fruits are self-unfruitful, ie., if a single variety is grown, it will not produce fruits. Only through cross pollination with other varieties, it can produce fruits. Such self-incompatible fruit plants can be made fruitful by grafting shoots of another variety on their branches.

10 Through vegetative propagation methods, it is possible to produce different varieties on a single plant. It is also possible to heal wounds caused by rodents, implements or natural damages through bridge grafting—a form of repair grafting.

Disadvantages of vegetative propagation

1. Vegetatively propagated plants are generally smaller in size, and hence, per plant yield is lower and are short lived.
2. There is no possibility of getting chance seedlings or new cultivars naturally.
3. Root system of vegetatively propagated plants is often not as deep as that of seedlings, which results in low anchorage in soil; and they are more easily damaged by winds.
4. Vegetative propagation methods cannot be used for evolving new cultivars or for breeding purposes. In breeding programmes, seed propagation is mostly used.

23:3.1. Apomictic embryos

Apomixis means the development of seeds without fertilisation. In such seeds, apomictic embryos develop into new plants. Since there is no fertilization, the apomictic embryos will be true-to-type as that of the mother plant. Plants producing only apomictic seeds are called 'obligate apomicts'. eg., Mangosteen.

Partial apomixis is seen in many fruit crops. In this case, apomictic embryos are produced along with the normal zygotic embryo and such plants are called 'facultative apomicts'. (*Polyembryony* is the phenomenon in which two or more embryos develop in a seed. A polyembryonic seed on germination gives rise to more than one seedling. eg., some mango varieties, avocado, oranges etc.). The use of apomictic embryos has got some advantages. They are—

1. The progenies will be true-to-type.
2. The root and shoot systems will be vigorous and the plants will bear heavily.
3. Virus diseases of mother plant are not transmitted through seeds into the off spring.

However, the apomictic seedlings have long juvenile or pre-bearing period, which is a disadvantage.

23:3.2. Runners

Runner is a specialised stem growing from the leaf axil and which runs horizontally along the ground. Roots are formed on the nodes of the runners. Such rooted runners (daughter plants) are separated and can be used as separate plants. eg., Strawberry.

23:3 3. Suckers

Sucker is a shoot developed from the underground stem of a plant and growing upwards. eg , pineapple, date palm, banana. In some plants like curry leaf and bread fruit, shoots develop from vegetative buds of roots, and hence, called root-suckers.

23:3.4. Separation

The process of multiplication of plants using naturally detachable structures such as bulbs and corms is termed separation. eg., onion, garlic, lilly etc (using bulbs) and gladiolus (using corms).

23:3.5 Division

When the plants are perpetuated using organs cut into pieces, the method is called division. eg., canna, ginger, turmeric, cardamom etc. (using rhizomes); sweet potato, potato, dahlia etc. (using tubers); yams (using corms).

The primary function of the structures used for separation and division is food storage.

23:3.6. Cuttings

In this method, a portion of the stem, root or leaf is cut from the mother plant and induced to form roots and shoots by placing them in some rooting medium (sand, soil, potting mixture etc.) under favourable conditions.

Based on the plant part used, the cuttings can be grouped into four—root cuttings, leaf cuttings, leaf bud cuttings and stem cuttings.

Root cuttings: In this case, roots of about 15–25 cm are cut and planted horizontally in a rooting medium at a depth of 3-5 cm under favourable conditions. When the shoot and root systems develop well, they can be transplanted. eg., bread fruit, curry leaf.

Leaf cuttings: Here, leaf blade or leaf blade with petiole is used for propagation. The cuttings are kept over the rooting medium with close contact. Root and shoot systems develop from the leaf, and thus, new plants are obtained. eg. *Begonia*, *Sansevieria*, *Bryophyllum*, *Peperomia* etc.

Leaf bud cuttings: In this method, a leaf blade with its petiole, axillary bud and a short piece of stem is used for planting. eg , lemon, tea, hydrangea etc.

Stem cuttings: This is the most popular, easy and cheap method of propagation in many plants. Depending upon the hardness or age of the shoots, stem cuttings are divided into four groups—hardwood, soft wood, semi-hard wood and herbaceous cuttings.

The cuttings taken from shoots of one year's or one season's growth are termed hard wood cuttings. eg., pomegranate, grapes, tea, *Hibiscus*, rose, *Ixora*, *Bougainvillea*, citrus etc.

The tender cuttings taken from the shoots of recent growth and with little woody tissues are the soft wood cuttings. They are taken mostly from the soft, terminal or central portion of the shoot. Usually leaves on the top of the cuttings are retained when they are planted for rooting. eg., jasmine, passion fruit, oleander etc.

The cuttings which are partially matured, or which are intermediate to the hard wood and soft wood cuttings are termed semi-hard wood cuttings. eg., *Acalypha*, croton etc.

Herbaceous cuttings are taken from the succulent herbaceous plants. eg. coleus, geranium, dahlia etc.

Method of taking cutting and planting for rooting

The maturity of shoot and season of taking cuttings depend on the type of plant. In the case of hard wood cuttings, well matured healthy shoots are to be selected, and the leaves are removed. Cuttings of 15-25 cm length and pencil thickness are to be taken from the middle or basal portion of the shoot. Each cutting should have at least two or three good buds. The cuttings are to be prepared using a sharp knife to avoid damage of tissues on the cut end. The cuttings are made into small pieces by giving a slanting cut of about 1.5–2.0 cm. long just below the node at the basal portion and a cross-cut is given about 4–6 cm above the node of the top portion. The slanting cut is given to get more area for large and quick absorption of water and nutrients, and to induce more roots. The transverse cut at the top is given to reduce the area of exposure, which will help to reduce the loss of water from the cuttings. Always use fresh cuttings for planting and avoid wilted or dried ones. While planting, polarity should be maintained, ie., cuttings should not be planted in the inverted position; the basal part of the cutting should be in the soil.

Growth regulators to induce rooting

Plant growth regulators or plant hormones can be used to induce rooting in many of the difficult-to-root cuttings. Indole Butyric Acid (IBA), Indole Acetic Acid (IAA), Naphthalene Acetic Acid (NAA) etc. are the common growth regulators used to promote rooting. Depending on the type of cutting, these chemicals are used in very low concentrations. The chemicals can be applied in different methods like powder application, dilute solution (20 to 200 ppm) soaking method, or quick dip method using concentrated solutions of 500 to 10,000 ppm. (One milligram of the chemical dissolved in one litre of water gives one ppm solution).

The powder preparations are easier for application. Commercial formulations like Seradix-B are available in the market for the purpose. Seradix B-No.1 is used for soft wood cuttings, No.2 for medinm cuttings and No.3 for hardwood cuttings. The bottom end of the cuttings are to be treated with the hormone powder. For this, fresh cuts are to be made at the bottom. If the cut ends do not have enough moisture, they may be dipped in water and tapped with finger to remove the excess water. Then the cuttings are dipped in the hormone powder. The excess powder is removed by tapping the cuttings gently with the fingers. The cuttings are ready for planting.

23:3.7 Layering

In layering, rooting is made to occur on growing/intact shoots, stem or branches of the mother plant. After the formation of root, the shoot is cut off from the parent plant to get the new plant. This method is used in plants, where the cuttings do not root easily by the usual methods. Since the layered shoot is attached to the mother plant, it gets nutrients, and the rooting is enhanced.

Priciples of layering

One important feature of layering is that the stem used for rooting is intact or attached to the mother plant. While layering, some notching or bark-ringing treatments are usually given on the shoots. The food materials and plant hormones produced by the leaf and shoot are translocated and get accumulated at this cut portion. This accumulation of food and hormones initiate rooting. At the same time, the top portion of the shoot gets water and nutrients through the undisturbed xylem vessels (wood portion).

Methods of layering

The various methods of layering are (Fig. 23.1)—

1) Tip layering
2) Simple layering
3) Serpentine layering
4) Trench layering
5) Mound or stool layering and
6) Air (pot or chinese) layering.

These methods are briefly discussed below.

Tip layering: In this method, the tip of a current season's shoot is burried in soil. The tip grows first into the soil and then comes above the soil surface. Rooting takes place from the nodes burried in soil. Then the rooted shoot cut off from the mother plant to get the new plant. This method is not usually practised in tropical crops. In black berries and rasp berries, tip layering is practised.

Simple layering: Here, the low-lying one year old branches of the mother plant are bent to the ground, partially covering it, leaving about 15- 30 cm of shoot-tip above the soil surface. To induce better rooting, a slight slanting cut

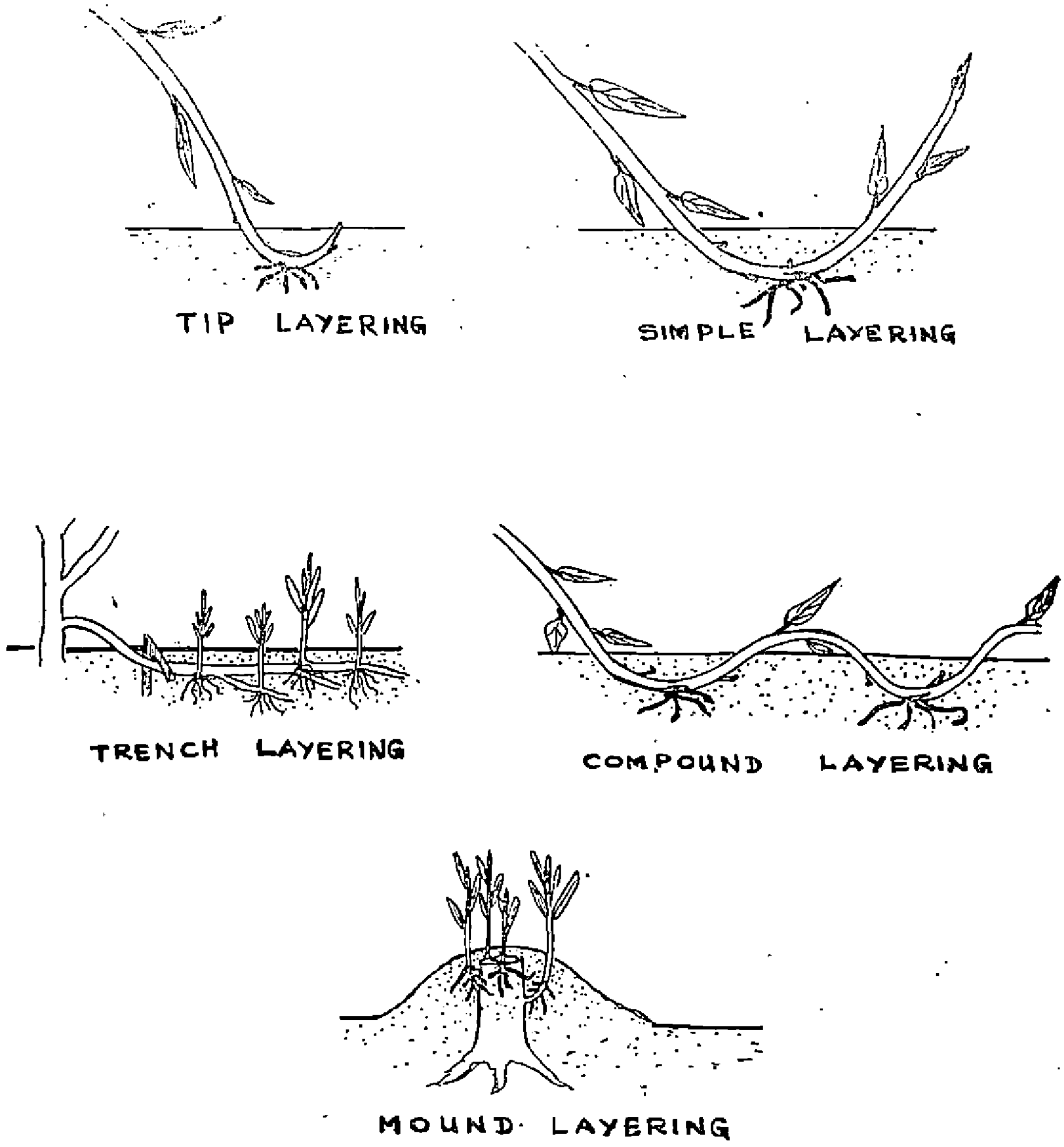

Fig. 23.1 Principal methods of layering

is given on the portion of the stem covered with soil; or a ring of bark of about 2-3 cm length is removed and covered with soil. Irrigate them daily at the place of layering. Roots develop within 45 to 60 days from the injured portion. Then, it is detached from the mother plant and used as the new plant. eg., guava, litchi, limes, lemons etc.

Serpentine or compound layering: This method is suited to creepers and climbers like pepper, jasmine etc. The method is same as in simple layering but the long stem is injured and buried in soil at a number of places. So, we will be able to get a number of new plants from a single shoot.

Trench layering: The branches of the mother plant are bent downwards and placed horizontally in a trench of 10-15 cm deep and covered with soil. Such trenches will be irrigated daily. After some months, roots and shoots develop, and the shoots grow above the soil surface. Then, the soil is removed carefully, and each rooted stem is detached and planted. This method is not common in India.

Mound or stool layering: In mound layering, the top portion of the mother plant is cut off about 20-30 cm above the ground level. When new sprouts develop from the stump, earthing up is done. As the shoots grow, the amount of earthing up will be increased gradually for three or four times, and regular irrigation is also given. Each sprout forms roots at its base in the soil. After about three to four months, the soil is carefully removed and each rooted plant is separated from the mother plant. This method is usually practised in plants like guava, papaya, azalea etc.

Air layering: Air layering is known in various names such as chinese layering, pot layering, circumposition layering, marcottage and gooteeing.

In air layering, the rooting medium or soil is taken to the branches instead of bringing the branches to soil as in other methods. The shoot, at a point about 20-30 cm from the tip, is injured either by giving an upward slanting cut or by removing a ring of bark of about 2-3cm length. This portion is then enclosed in a ball of moist sphagmum moss or layer mixture, and covered with a polythene sheet, and tied well at both ends. After about 45-60 days, when roots are seen through the polythene sheet, the shoot is detached from the mother plant and it can be used as a separate new plant (Fig. 23.2). Layering would be successful, if done in rainy days.

Earlier, gunny pieces or cloth pieces were used for covering the rooting medium around the wounded portion of shoot. In such cases, due to the loss of moisture from the medium, regular watering was necessary. For this, pots were used. Pots filled with water were tied above the layer and a piece of cloth-string was strung from the hole made at the bottom of the pot to the rooting medium.

It is advisable to cut-off the rooted layer gradually, ie., give a slight cut at first, and then, gradually deepen it at weekly intervals. In this way, the layers are separated after three or four cuttings.

Merits and demerits of layering

Layering is successful in many plants where cuttings do not root easily. By using large branches for layering, we get bigger plants as compared to other

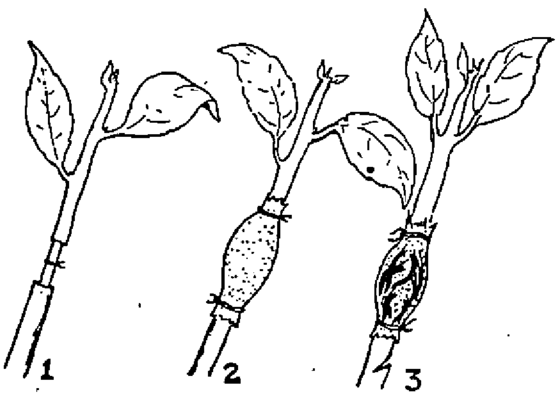

Fig. 23.2. Steps in air layering

methods. Since the rooting takes place on the unseparated shoot of the mother plant, the rooting will be quicker than in cuttings. But layering has a disadvantage that it requires some hardening process between the stage of separation and planting in the main field.

Methods to induce better rooting in layers:

As in the case of cuttings, rooting can be enhanced in layers also, by the application of growth regulators. Growth regulators are applied in the form of a paste. For this, the chemical is mixed with lanolin paste or petroleum jelly at the required concentration and this is applied on the bark above the ring or notch for about 2-4 cm in length. Then perform the layering as described above.

Etiolation is another method used to induce better rooting in layering. It is the practice of covering a part of shoot with some materials, which prevent the entry of light. In trench layering, the whole branch is covered with soil; so also in stool layering—the base of all new sprouts. This practice induces better rooting. In air layers, etiolation can be done by covering a portion of branch of 5-8 cm length with black polythene sheet or paper or cloth for about 2 to 3 weeks before layering. Then ringing/notching is done on the etiolated portion after removing the black covering, and the layering is done as usual.

23:3.8. Graftage:

In certain plants, cutting, layering or other simpler methods of vegetative propagation are not found to be successful. Under such situations, graftage may be a practical method. Graftage is an art of joining parts of plants together so that in due course they unite and grow continuously as a single plant. Graftage includes two methods—grafting and budding. Since there are quite a lot of methods of grafting and budding and require an elaborate treatment, they are presented separatety (See the next chapter).

23:3.9. Micro propagation:

The method of micro propagation is of recent origin. Micropropagation is the development of plants from very small plant parts in an artificial medium under aseptic conditions. This method is based on the principle of *'totipotency'* of cells. Totipotency means the ability of a single cell to divide, grow and differentiate to form a complete plant.

Depending on the plant-parts used, the micropropagation can be grouped as organ cultures, embryo cultures, and callus cultures.

In organ culture, plant organs like root tips, shoot tips, leaf primordia, immature flowers, anthers, pollen, ovule, immature fruits etc. are used for the development of plants. In embryo culture, mature or immature embryos (embryoids) are used. Callus culture is also known as tissue culture. Callus is a mass of undifferentiated cells, capable of growing and dividing fast. Such undifferentiated tissues are aseptically cultured in callus culture technique.

In micropropagation, depending upon the plantpart used, either shoot system or root system or both are developed from the tissues, and thus, a complete plant is obtained. All the processes are done under strict aseptic and controlled atmospheric conditions. The room, equipments, glass wares, culture medium etc. are sterilised to avoid possible contamination of fungal, bacterial and other pathogens.

The tissues are cultured in artificial medium. The essential ingredients of a tissue-culture medium include minerals, sugar, growth regulators, vitamins, organic complexes like coconut water etc. Depending on the type of organ/tissue and the plant species used, the composition of medium varies. Similarly, the atmospheric condition such as temperature, humidity, light intensity and duration etc. are also controlled in a tissue culture laboratory.

The plantlets obtained by tissue culture technique are first transplanted into small pots filled with sterile medium. Then the plants will be hardened gradually so that they will be able to withstand and thrive under normal atmospheric and soil conditions.

Micro-propagation techniques are used for many purposes like-

1) To study the fundamentals of plant physiological, pathological and genetical aspects,
2) To screen or isolate pathogen-free plants,
3) To screen or isolate plants which are resistant/tolerant to adverse soil conditions,
4) To enable rapid multiplication under conditions that maintain freedom from diseases etc.

Micro-propagation techniques are commercially employed for the multiplication of orchids. Methods of micropropagation have been standardised and developed in many crops like banana, citrus, papaya, jack, cardamom, tea, coconut etc. Micropropagation techniques are employed for multiplication of banana and cardamom by some private firms in Kerala and in future we expect many such developments on a commercial basis.

24. Grafting and budding

24:1. Introduction

Grafting and budding are techniques of graftage, ie., joining two separate plant parts together in such a way that healing occurs between them and they grow together as a single plant. The art of graftage is also called 'plant surgery'. In this connection, we should be familiar with two words—scion and rootstock.

Scion (or cion) is the plant part used for graftage which grows as the upper portion, say, the shoots of selected varieties used for graftage. The scion after graftage develops into the shoot system. We should select high yielding mother plants free from pests and diseases to take the scion.

Root stock (understock or stock) is the plant part of a graft or budling which provides the root system. In other words, rootstock is the basal part of the graft or budling on which graftage is performed. It is the rootstock which absorbs and translocates the water and nutrients to the scion for its growth and development. Depending upon the plant species we can use a seedling (sapota, mango, rubber etc.) or cutting (rose) or layer as the rootstock.

In grafting, the scion used will be a short piece of shoot or twig with many buds. But in the case of budding, a single bud is taken as the scion. This is the main difference between budding and grafting. Budding is also known as bud-grafting, and budlings as bud-grafts.

24.2 Principles of graftage

The principles of graftage is based on the process of healing wounds in plants. If the longitudinally split branch of a plant is tied tightly together, a large number of parenchymatous cells (callus) are produced from the outer layer of cambium from both the split pieces. From this, cambium cells are developed along the line of cambial layers of the split pieces. This cambial layer produces xylem (wood) and phloem (bark) tissues, which intermingles with the wood and bark of the split pieces of the branch. Thus, the healing process is completed. The same process takes place in the healing between the cut ends of rootstock and scion to form a single plant.

24:3. Merits and demerits of graftage:

The merits or advantages of graftage are—

1 Graftage can be practiced successfully, when other simpler methods of vegetative propagation are failures in a plant.

2 In graftage, it is possible to get the desirable effects of a particular root stock on a particular variety.

3 Through graftage, it is possible for top working to obtain special forms of plant (eg. with fruits and flowers of different cultivars in a plant), to repair damaged trees, to study the details of virus diseases (eg. indexing) etc.

The demerits or disadvantages of graftage are—

1 Graftage is not successful in monocots. It can be used only in dicots.

2 We have to select suitable scions and stocks (for the type and physical maturity) for graftage. Otherwise, incompatability and failure to form graft union may result. Similarly the season or atmospheric condition also has profound fluence on the success of the graftage.

24:4. Grafting:

There are several methods or techniques of grafting. Some common methods are—

1 Splice or whip grafting
2 Tongue or whip and tongue grafting
3 Cleft or wedge grafting
4 Saddle grafting
5 Side grafting
6 Veneer or side veneer grafting
7 Approach grafting

Splice or whip grafting:

This is a simple method of grafting (Fig. 24.1). It is commonly practised in apple. In this case, the rootstocks and scions selected should be of the same thickness— say, pencil thickness to finger thickness. First, a slanting cut of about 4–5 cm is made at the bottom of the scion. Then, a similar cut is given on the top of the rootstock. They are placed together in such a way that their *cambium* tissues are in close contact with each other. Afterwards, it is firmly tied together using waxed cloth. For tying, the usual plaster used in hospitals for bandage of wounds can also be used. The cuts unite in a few months and the scions grow. The grafts are ready for planting in the field.

(Cambium is a thin layer of tissue present in between the bark or phloem and the wood or xylem. The graft union starts first by the union of cambial layer of scion and stock. So, the success of any grafting or budding depends on the preparation of proper cut surfaces and placement of scions and stocks so that the cambial layers are in close contact with each other).

Tongue or whip and tongue grafting:

This method is similar to that of splice grafting described above. But, in addition to the slanting cut, an inward second cut to get a 'tongue', is also made both in the scion and stock (Fig. 24.1). The scion and stock are joined together so that their tongues fit into the slits made. Then, the united portion is tied well.

Cleft or wedge grafting:

In this method, the bottom of the scion is cut to the shape of a wedge (Fig. 24.1). The stock is horizontally cut (cross-cut) first, and then, a 'V' shaped slit (cleft) is made. Then, the scion is insterted into the slit so that their cambial layers come in a line. eg: apple, mango.

Saddle grafting

In this case, first give a cross-cut at the bottom of the scion. Then two slanting cuts are made upwards so that a cleft is formed. After this, the top of the rootstock is cut to form a wedge, which fits correctly into the cleft of scion. Then, the scion is placed over the stock and tied firmly. This method is successful in apple, pear, papaya etc., but not commonly practised.

Side grafting

In side grafting, the rootstock will not be cut on the top. At the bottom of the scion, two slanting cuts are made,

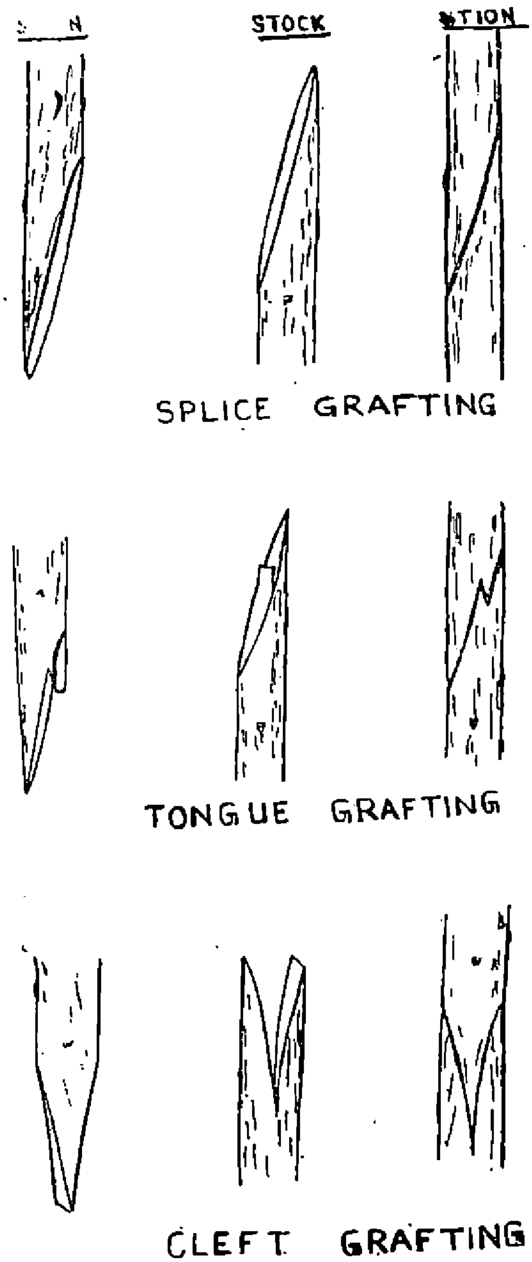

Fig. 24.1. Principal methods of grafting

of which one cut is slightly longer than the other. On the stock, an incision is made at 20-25° and the wedge of scion is inserted into it. The union is tied well. When they unite well and scion starts sprouting, the rootstock is cut at about 3-5 cm above the graft union (Fig. 24.2).

Veneer or side-veneer grafting

This is a modified type of side-grafting. In this case, a slanting cut is made on the rootstock. At the bottom of this slanting cut, another short slanting cut is made so that a piece of bark with some wood is also removed. The scion is also prepared in such a way that its cut-ends come in close contact with the cutting given on the stock and in line with their cambial layers. That is, first a slanting cut is made at the bottom of the scion on one side. At the end of this slanting cut, a short cut is made. Then the scion is inserted tightly into the cut made on stock and tied well (Fig. 24.2).

Approach grafting

Approach grafting is employed only when other methods of grafting are not successful enough because, this requires more labour and is more expensive. Usually, we get a high percentage of recovery in this method and it can be tried even

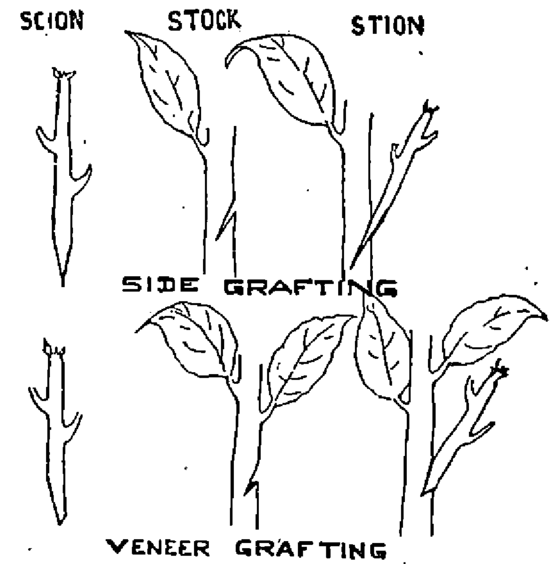

Fig. 24.2. Steps in side & veneer grafting

in dry conditions. Approach grafting is popular in Kerala for the propagation of plants like mango, jack, sapota, mango-steen and ornamental trees like 'chem-paka'.

In approach grafting, both the stock and scion grow on their own roots. In other words, the scion is not separated from the mother plant as in the case of other methods.

Fruit crops like mango, sapcta, guava etc., are mostly propagated through approach grafting. For this, rootstocks are raised in small pots or in coconut husk or in any such other containers, and grown for about 1–1½ years to get pencil thickness and 30-45 cm height. Such grown up rootstocks are taken to the mother plant. (Usually, for commercial multiplication, mother plants are grown very closely and trained to get low-lying, spreading branches for easiness of grafting. Such orchards are known as 'close planted progeny orchards'.)

From the mother plant, select an upward branch having the same thickness (girth) as that of the root stock. Make an inward 'arch'-shaped cut of 3-5 cm long on the rootstock. The depth of cutting in the centre should be about 1/3 of its thickness and a portion of wood is also removed while making such a cut. Then, make a very similar cut on the side of the selected branch (scion) of the mother plant in such a way that the cut surfaces of the stock and scion can be brought together perfectly in close contact with each other. The cambial layer should be in the same level. Then, tie the union with a good gunny twine and cover it using plaster or grafting wax or mud-mixture. Care should be taken to irrigate the stock. After about 2 to 3 months, the cut surfaces are healed, ie., the graft union is completed and the graft is ready for separation.

For separation, a shallow cut is made on the scion just below the graft union and another shallow cut on the stock just above the graft union. At an interval of 2-3 weeks, gradually deepen the cuts; and with the final cut, say the 3rd or 4th cut, separate the graft from the mother plant and keep under shade. Throughout these stages described above, the rootstock should be watered. A few days after giving the first or second cut, if the scion-branch dries, we understand that the healing of graft union was not complete or the grafting was not done perfectly (Fig. 24.3).

Sometimes, a modified method of approach grafting, known as 'tongued approach grafting' is also practised. In this case, a tongue each is made on the cut surfaces of the stock and scion to get a firm joint or union.

Approach grafting is sometimes known as 'inarching'. But the term inarching

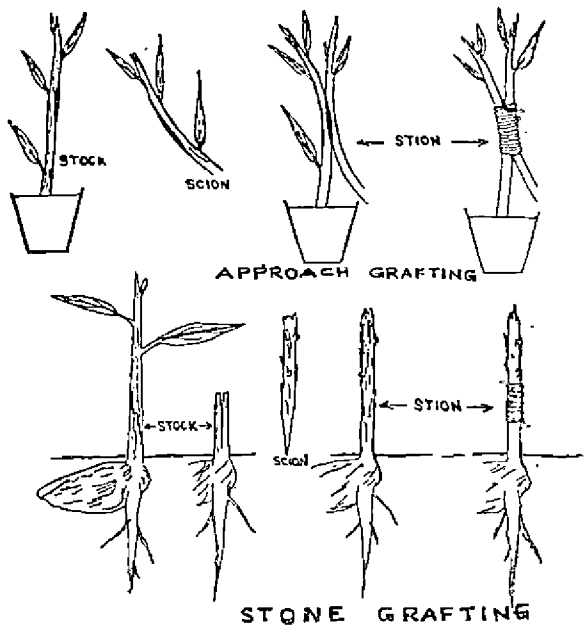

Fig. 24.3. Steps in approach & stone grafting

is also used to denote the method of grafting employed for repair work. That is, when the lower portion of a plant is damaged by pests/diseases/other causes, it can be repaired by inarching. For this, depending upon the size of the damaged plant, 3-6 rootstocks are planted around the damaged tree. The rootstocka are cut above the height of the damaged portion of the mother plant. A slanting cut is made at the top of the cut rootstock towards the side facing the mother plant. Then the bark with some wood portion (similar to the cutting of rootstock) is removed on the mother tree at the same height as that of the stock. Fix the cut end of the stock into that on the mother-plant and it is tied and waxed well. Such graftings are made all round the damaged tree. When the union is successful, the rootstocks absorb and translocate the water and nutrients to the mother plant. The stocks provide good anchorage also.

24:5. Stono grafting

Recently, this method is gaining popularity for the multiplication of mango and cashew. In this case, seeds ('stones') are sown in the nursery and the grafting (wedge method) is done on the epicotyle region of the seedling, 7-10 days after germination. The joint is tied firmly with a polythene ribbon of 0.5-1.0 cm width, and the grafts are kept under shade and nursed well. The epicotyl region (above the cotyledons of seedling) will be soft at this stage. Graft-joints heal within a month of grafting, and subsequently the scions sprout. Since stone grafting is performed at the epicotyl region, it is also known as 'epicotyl grafting' (Fig. 24.3).

The advantage of stone grafting over the approach grafting is that, we may get the established grafts in 6-8 months from the sowing of rootstock seeds. But in approach grafting, about 2 to 2½ years will be required to obtain the established graft from the sowing of seeds, ie., stone grafting is quicker. Another merit of stone grafting is that it requires less labour and management cost, whereas approach grafting needs high labour and management cost, ie., stone grafting is cheaper and less laborious.

The demerit of stone grafting lies in the fact that the percentage of success is lesser when compared to the approach grafting. Also, the stone grafting could be done only in rainy season, or under high humid conditions; otherwise the success will be poor. Moreover the viability of seeds is also lost at a faster rate. But, approach grafting can be done throughout the year.

24:6. Budding

Budding is also known as 'bud grafting' as the physiological processes involved are same in budding and grafting. In budding, we are using a single bud as the scion, but in grafting a small shoot with a number of buds are used. It is noticed that the bud union is more stronger than graft union.

The chances of breaking graft union by wind etc., when the grafts are grown in the field would be higher than that of budlings. This is an advantage of budding over grafting. Another merit of budding is that it is more economic. A full grown plant can be produced utilising a single bud of the scion or bud wood. However, in grafting, we get only a single plant utiliing a scion-shoot containing several buds. Budding is more easier and quicker than grafting.

As in grafting, seedlings/rooted cuttings/rooted layers can be used as the rootstock for budding. The rootstock should have desirable characteristics like vigorous growth and resistance to pests, diseases, drought etc. Usually tender or current seasons' shoot is used as bud wood in order to separate out the bark with bud without damage. If the bark-peeling or barks' slipping is difficult, the bud with a piece of wood (chip bud) is used as the scion. Never select a bud, which is physiologically mature and about to sprout. Bud wood or bud stick is a piece of shoot of the mother plant from which the buds are taken for budding.

Methods of budding

Depending upon the nature of the method of taking buds from the budwood, or the method of bark peeling on the rootstock, budding can be classified into the following types—(See Fig. 24.4).

1) 'T' budding
2) Inverted 'T' budding
3) Patch budding
4) 'I' budding
5) Ring budding
6) Flute budding
7) Chip budding

'T' budding

'T' budding is also known as shield budding. This is the most popular and common method of propagation in citrus, rose etc. In this method, a well prominent round (bulged) bud with a portion of bark of about 2-3 cm length is taken out in the shape of a shield from the desired cultivar. A portion of wood will also be attached to the bud. The bud is taken from a current season's shoot using a sharp knife. For this, a slanting shallow cut is made about $1\frac{1}{2}$ to 2 cm from the bottom part of the bud towards the top. Then a vertical cut is given on the top of the bud, about one cm above the bud. The wood portion is then removed carefully without damaging the bud and the bark. For easy handling of the bud, a piece of the petiole can be retained along with the bud. Afterwards, make a vertical cut of about 2-3 cm long on the rootstock and a small horizontal cut over the top of the vertical cut in the shape of 'T'. Then, open the bark towards both sides and insert the bud into the gap formed between the wood and the bark on the stock. For this, slowly slide the bud from the top portion of the slit opened. Tie the union well with a polythene strip/tape of about 0.5 to 1 cm width. While tying, care should be taken to keep the bud portion exposed in order to facilitate its growth (Fig. 24.4).

Inverted 'T' budding

This is a modified method of 'T' budding. In inverted 'T' budding, the cutting of the bark on the stock is in a '⊥' shape. Similarly, while taking the buds from the bud wood, the slanting shallow cut is made from the top of the bud downwards and the vertical cut at the bottom of the bud. After opening the bark of the stock towards both sides, the bud is inserted from the bottom to top by light-sliding. Other practices and operations are same as that of 'T' budding. eg. citrus.

Patch budding

As the name indicates, in this method, the bud (scion) is taken out as a rectangular patch with the bud at its centre. A similar patch of bark is removed from the rootstock and the bud (scion) is placed in this portion and tied well. eg., rose, rubber (Fig. 24.4).

'I' budding

In this method, the preparation of scion bud is similar to that for patch budding. But, on the stock the cut is made in the shape of 'I' and the bark is opened to both sides. Then the scion is inserted keeping the bark of stock on it, and tied well exposing the 'eye'. eg., peach, plum, pear, mulberry etc. (Fig. 24.4).

Ring budding

In this case, the scion bud is slipped off as a ring with its 'eye' in the centre. A similar ring of bark is removed from the stock, and in this place the scion ring is fitted tightly. Care should be taken to see that the girth of the bud wood and the stock are same. Otherwise the union will not be perfect (Fig. 24.4).

Flute budding

This is very similar to patch budding. In flute budding, the bud-patch (scion) and the patch of bark removed from the stock almost encircle the stem. It can be said as a method in between the patch budding and ring budding. (Fig. 24.4).

Chip budding

Chip budding is also known as yemma budding. This method is adopted in plants, where it is difficult to slip off the bud with bark since the bark and wood are very tightly associated with each other. So, the bud is taken out with a large piece of wood and a similar portion is removed from the rootstock. The scion (chip bud) is fitted into the gap made on the stock, and tied well exposing the 'eye' to develop. eg. grapes.

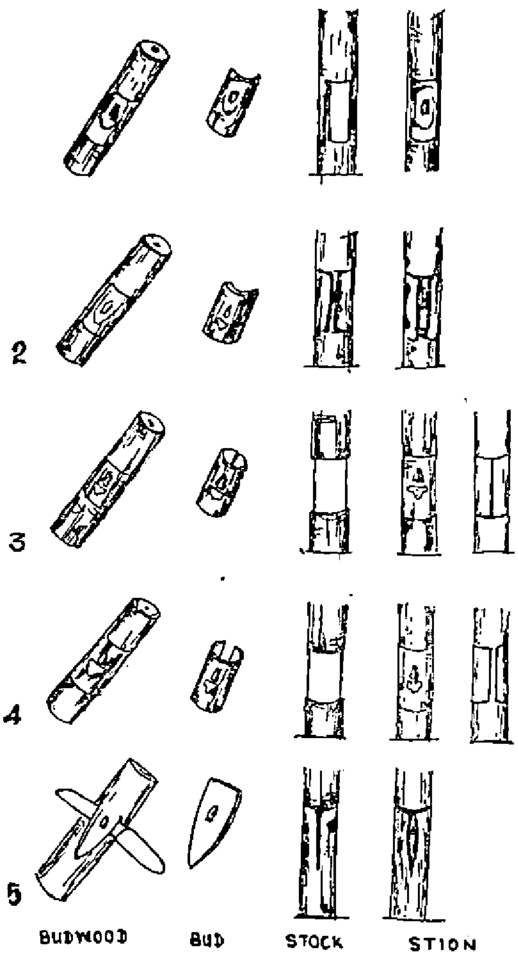

Fig. 24.4. Principal methods of budding
1. Patch budding. 2. 'I' budding
3. Ring budding 4. Flute budding
5. 'T' budding

24:7. Care of grafts and budlings

To obtain good grafts and budlings, they should be cared intensively from the day of grafting/budding. Some of the important points to be remembered in this regard are,

1) Providing regular watering and partial shade in summer months from the day of grafting till its full establishment. The rootstocks are to be irrigated daily. After separating grafts, they may be kept under shade and watered daily.
2) Periodical removal of sprouts developing from the rootstocks. Only the scion-twig or bud should be allowed to grow. All the new growths coming from the rootstock have to be removed. Otherwise, it may affect the growth and health of the scion.

3) Removal of the bandage or tying material after the perfect graft/bud union to avoid girdling at the union.

4) The rootstock portion, if any. exist above the graft/bud union may also be cut off carefully.

When the scion put forth new growth, we can understand that the grafts/buddlings are established, and such established plants can be planted in the main field in the coming monsoon season.

24:3. Top working or top-grafting

Top working is a process of grafting/budding on the cut off branches of an old tree or plant by which the cultivar is totally changed. Take the case of a mango seedling-tree of 15 years age, which has a very low yield. By adopting the method of top working, it can be changed to a good bearing Neelum or Prior tree. For this, cut off all the main branches of the tree at about 0.5 to 1.0 m distance from the main stem or trunk. On these main branches grafting is done with the scions of the desired cultivar, say Neelum, by cleft grafting or any other suitable method.

Care should be taken to see that only scion shoots are allowed to grow and develop. All the growths which arise directly from the trunk or branches of the mother plant should be removed. After some years, the entire canopy of the tree would be of the new cultivar. The top working can also be practised to change a male nutmeg tree to high yielding female plant. It is also possible to have different cultivars on different branches of a plant by top working.

Different methods of grafting like wedge grafting, splice grafting, side grafting etc. are employed for top working in different crops. Depending on the nature of the mother plant, budding methods can also be employed, and in this case, it is known as 'top-budding'. eg. nutmeg.

25. Propagation of fruit plants and nursery management

25:1. Introduction

We have seen the principles and various methods of propagation in the previous chapters. The specific methods of propagation of important fruit crops and the principles of nursery management are described in this chapter. The details of propagation of mango, jack, sapota, guava, papaya, banana, pineapple and other fruit crops are covered.

25:2. Propagation of fruit plants

25:2.1. Mango (Mangifera indica)

Polyembryonic cultivars like Bapakai, Kurukan, Muvandan, Mayilpeeliyan, Olour, Chandrakaran etc. are usually propagated by seeds, as they produce true-to-type progenies. For propagating monoembryonic cultivars, vegetative methods are employed. Approach grafting, stone grafting, soft wood grafting, veneer gtafting etc. are successfully practised in mango.

a) Approach grafting

Sprouted seeds are planted in nursery beds (of 1.0–1.5m width, 15–20 cm height and of convenient length) at a distance of 20–30 cm between seedlings. They are maintained for about one year in the beds. Irrigation, weeding and manuring may be carried out as and when required. During June-July months, seedlings having pencil thickness are uprooted and potted in coconut husk or polythene bags or earthen pots filled with potting mixture. They are kept under shade with regular watering for about a month so that the seedlings establish well in the container. Then, the rootstocks are ready for grafting. Grafting, nursing, separation etc. may be done, as detailed under approach grafting, in the previous chapter. The grafts are ready for planting or sales about two months of nursing in shade after the separation when the scions have putforth new growth.

b) Stone (epicotyl) grafting

This method is becoming popular now a days for the propagation of mango. In this case, the seeds are sown in nursery beds or polythene bags. Grafting is performed on 7-10 days old seedlings when the stem and leaves are still in purple-red colour.

For better success, pre-curing of scion is a must. Mature shoots of 4-6 months age are defoliated for about 10–12 cm length from the tip with their petiole intact to the shoots. After about 10-14 days, when the petioles fall down, the scions can be taken for grafting. Select scion-shoots with plumby and round tips for grafting. Never select sprouted scions for grafting.

Grafting may be performed by wedge method as described under stone grafting in the previous chapter. The maximum success will be obtained when grafting is done during July-September months, under high humid conditions. The scions may sprout in 4 to 8 weeks time.

If new seedlings arise from the base of the grafted seedling, they should be destroyed immediately.

If the grafting is done on seedlings grown in nursery beds, the grafts may be transplanted to polythene bags/pots, about 1½-2 months after the sprouting of the scion. Such transplanted grafts may be nursed under shade. Within 6-8 months after grafting, the grafts are ready for planting.

c) Soft wood grafting

This method is the latest one employed for the multiplication of mango. The method (wedge) of gtafting, precurlng of scion etc. are same as that in stone grafting. But, the grafting is done on a 1-1½ year old rootstock, when they put forth new growth. That is, the grafting is done on the purple coloured, soft or tender shoot of the rootstock.

This method can be practiced in the main field also, on 12-18 months old seedlings in rainy season.

d) Veneer grafting

The precured scions are grafted on 12-18 months old rootstocks as described in the previous chapter. This method is more popular in North India.

25:2.2. Jack and Sapota

The common method of vegetative propagation in jack and sapota is approach grafting. For jack (*Artocarpus heterophyllus*), the jack seedlings are used as the rootstock. In sapota (*Achras sapota*), rootstocks used are seedlings of Khirnee (*Manilkara hexandra*) or Mahua (*Madhuka latifolia*).

The seeds are sown in nursery beds very closely at a distance of. about 5 cm between seeds. After germination, seedlings of 8-10 cm height are transplanted in a secondary nursery at 30 cm x 30 cm spacing and maintained for about 1-1½ years to attain pencil thickness. Potting, nursing, grafting, separation, care of separated grafts etc. are same as that in mango.

25:2.3. Pineapple (Ananas comosus)

Pineapple produces three vegetative propagating units—suckers, slips and crowns. Suckers are the side shoots arising from the bottom of the plant. Slips are small shoots developing from the stalk (peduncle) of the fruit; and crown is the tuft of small leaves found on the top of the fruit Though all these materials can be used for propagation, the suckers are recommended for commercial propagation or planting because they produce fruits earlier (15-18 months after planting), followed by slips (20-22 months) and crowns (about 24 months).

For large scale planting, select and separate suckers of 500-1000g weight from high yielding varieties. Then dry them in open, under shade for about a week. Strip off the lower, old dried leaves and again keep them in shade for another week for drying. Afterwards dip the bottom of the suckers in 1% Bordeaux mixture and the suckers are ready for planting.

25:2.4. Guava (Psidium guajava)

Guava is vegetatively propagated by air layering and approach grafting.

Air layering: For layering, select pencil thick, healthy and dormant branches from the mother plant. About 30 cm. from the tip of the branch, remove a ring of bark of 2-3 cm long. In the centre of the girdled portion, make a knot with a twine. Then cover the girdled portion with a ball of layer mixture. (Sieved sand, soil, cowdung powder and saw dust or coir dust mixed in equal proportions and moistened is the usual layer mixture and can be just made in the form of a ball. The ball of mixture, with the optimum moisture content will break and scatter into pieces when dropped from about one metre height from the ground level. Moist moss or wood shavings or sand and saw dust or sand and coir dust can also be used as the rooting medium for layering.) After enclosing the girdled portion in the ball of rooting medium, the medium is covered with a small sheet of polythene film and tied firmly on both ends. The covering and tying should be so tight that moisture is not lost from the layer mixture. After 45-60 days of layering, roots would be seen through the polythene sheet. Then, the layer is ready for separation. Separation may be done gradually by deepening the cuts at 2–3 weeks intervals. Separated layers are carefully potted in polythene bags/earthen pots after removing the polythene covering without damaging the roots. When the potted layers produce new growth, they are ready for planting.

The best time for layering is February-March so that the layers will be ready for planting in June-July.

Approach grafting is also practised in guava. However, with respect to the cost of production and time taken, air layering is more easier and economical.

25: 2.5. *Papaya (Carica papaya)*

The most economical and commercial method of propagation of papaya is by seed. Using the seeds obtained from controlled pollination, the chances for variation among the seedlings can be reduced. Stool layering can also be practised as an asexual method of propagation in papaya. Recently, tissue culture techniques have been standardised, but not started on a commercial scale,

25:2.6. *Banana (Musa spp)*

Banana is propagated by means of suckers. 'Sword suckers' with narrow, small leaves and thick pseudostem are used for planting. Broad-leaved and slender stemmed suckers, known as 'water suckers' are to be rejected.

25:2.7. *Other fruit crops*

The common methods of propagation of some other important fruit crops are listed below:—

1	Citrus fruits:	
	Mandarin orange (*Citrus reticulata*)	— 'T' budding.
	Sweet orange (*C. sinensis*)	— 'T' budding
	Lemon (*C. limon*)	— Cuttings, air layering.
	Lime (*C. aurantifolia*)	— 'T' budding, air layering.
2)	Pomegranate (*Punica granatum*)	— Cuttings, air layering.
3)	Grapes (*Vitis vinifera*)	— Cuttings.
4)	Annonaceous fruits (*Annona* spp.)	— Seeds.
5)	Date palm (*Phoenix dactylifera*)	— Sucker
6)	Mangosteen (*Garcinia mangostana*)	— Seed, approach grafting.
7)	Roseapple (*Eugenia jambos*)	— Seed air layering.
8)	Avocado (*Persea americana*)	— Seed, budding, grafting.
9)	Aonla or gooseberry (*Phyllanthus emblica*)	— Seed, air layering
10)	Bread fruit (*Artocarpus altilis*)	— root-cuttings.
11)	Passion fruit (*Passiflora edulis*)	— Cuttings, seed.
12)	Cashew (*Anacardium occidentale*)	— Stone grafting, air layering, sesds.

25:3 Nursery management

Nursery and its management is an important topic in connection with propagation and multiplication of plants. Nursery management includes all aspects in connection with production of plants, right from the site selection to the distribution especially when it is a commercial one. Salient points in nursery management are briefly described below:

Site selection: The location selected for a nursery should be near to a perennial water source. The site should preferably be flat and there should not be any chances of water stagnation. The soil should be free of toxic elements and other adverse conditions. If the nursery in question is a commercial one, easy access to the nursery and transport conveniences should be there.

Water supply: Continuous water supply is essential for any kind of nursery. The water should not have high salt content.

Physical requirements: For easy, economic and quick multiplication of plants, they should be protected from high temperature, high evaporation, wind etc. For this, physical structures like overhead shade or pandals are to be provided. Glass house, mist chamber, hot beds, conservatory (a pandal-like structure on which climbers are grown for shade and keeping the atmosphere cool and humid—some times known as green house or lath house) etc. may be useful for propagation and caring of some plants. Conservatory may be the cheaper and convenient structure suited to our conditions. Store houses for implements, pots and other containers, chemicals, seed materials, office building etc. are also required for a commercial nursery.

Layout: In a commercial nursery, separate areas should be marked for growing mother plants of perennial crops (eg: progeny orchards of guava, sapota, mango etc.); seed production plots for annual crops (vegetables and ornamental plots); large shaded nursery area for plantation crops and spices (coconut, arecanut, coffee, pepper, cardamom etc.), conservatory or green house for multiplication through cuttings, nursing the separated grafts, layers etc. and for growing and multiplying shade-loving ornamental plants like cactii, succulents, ferns etc. Layout of all these should be done with economic use of the available space.

Containers: Depending upon the nature of plant and need, containers made of mud (earthen pots), plastics or polythene bags can be used for growing them. Polythene bags are cheaper than other containers. The size of the container varies with the nature of plant, duration of nursing etc.

Potting mixture: For propagation through cuttings or seeds, some rooting medium/potting mixture is required. An ideal potting mixture should be loose enough to permit the drainage of excess water, with good water holding capacity and fertility. It should provide adequate supply of nutrients for the growth of plants and should be free from pest and diseases. Loam (fertile top soil), sand and organic matter (dried cowdung) are the ingredients of the usual potting mixture. It is better to use sieved soil, sand and cowdung powder. For general purpose, a 1:1:1 mixture will be enough. For some crops specific potting mixtures are recommended, where the ratio of the ingredients will be different.

Potting: While filling potting mixture in pots, great care has to be taken to get good success. First of all, place some flat stones or asbestos pieces or small pieces of tiles above or side of the holes of the pots so that the holes for drainage are not plugged by potting mixture. Then, put one or two layers of rubbles or tile pieces (3-5 cm size), and over this, spread river sand for about 2-3 cm in thickness. This basement will provide enough drainage. Then fill the pot with the potting mixture leaving about 3-4 cm space on the top.

Plant protection: The protection of plants against pests and disease infestation is very important. Adequate care should be taken in this regard.

26. Ornamental gardening

26:1. Introduction:

We all like beautiful things and wish to keep our rooms, home, office and other surroundings in a beautiful way. Ornamental gardening is the art and science of developing a piece of ground by cultivation and maintenance of ornamental plants and other features, to provide a beautiful and pleasant environment for the work, play and relaxation of individuals or community. Thus, an ideal garden will be an out door living room just like an extension of the house. When we speak about a garden, it can be a home garden, school garden, public garden, or a childrens garden. When we study about gardens, we can see that there are different types of gardens based on some peculiar characteristics or designs. There are mainly three types or styles of gardens—formal, informal and free style gardens.

26:2. Formal and informal gardens:

The main characteristics of a formal garden or symmetric garden are symmetry and geometry. Symmetry means exact correspondence of parts on either side of a straight line or plane. That is, a part (a half portion of garden) exactly resembles the other part of the garden. Usually there is a focal point or a centre of attraction like fountain or statue or water pool or building. Around this central object, the different features like arches, paths, flower beds, trees, bushes etc. are arranged in a symmetrical fashion. Similarly, the different parts of the garden may have definite geometrical shapes such as a circle, triangle, square, rectangle, oval etc. The Brindavan gardens of Mysore is an example of a formal garden. To attain this symmetrical and geometrical features, the land has to be levelled. While constructing a formal garden, the natural topography would be changed. From the first look itself, we can understand that it is constructed artificially by giving exact size, shape and spacing between plants and other features.

The main characteristic of an informal garden or a natural garden is the natural out look as if it is created by the nature itself. The natural uneven topography, natural vegetations, rocky patches, streams or ponds etc. would be retained as such and beautified without destroying its naturality. And, it is difficult to distinguish between the man-made features or modifications of the garden and the natural features existed. Irregularity is another characteristic of an informal garden. The area of an informal garden would be very large, say 50 ha or more. National parks of many countries are examples for natural gardens.

26:3. Free style gardens:

Free style garden is a new concept in ornamental gardening, which combines harmoneously the good features of the formal and informal gardens. In free style gardens, no specific layout is defined. They are suited for home gardens, school gardens, public parks etc.

The main differences between a formal and informal garden are listed below

Formal garden	Informal garden
Area is limited	Area unlimited.
Even topography	Uneven topography
Geometric (regular) shape	Irregular shape
Symmetrical arrangement of features.	Assymetrical arrangement.
All features are introduced.	Existing natural features are also included.
Natural topography is changed.	Not changed.

Usually, in a free style garden, symmetry is maintained in the central part and towards the periphery or boundary, natural style is adopted. Both these parts are so harmoneously designed and arranged in such a way that we would not be able to identify the division between them. eg., Lal Bagh Gardens of Bangalore, the Ooty gardens.

Nowadays, the concept of 'garden' or 'gardening' is being replaced by 'Land scape architecture'. The term 'Landscape architect' is becoming popular and 'garden designer' is getting vanished. Or we can say, landscape gardening is the modern concept and ornamental gardening is traditional.

What is a landscape? The dictionary meaning of landscape is 'inland scenary' or more correctly the picture of inland scenary. Landscape gardening is the arrangement of trees, shrubs, climbers and various other plants together with the building; walks, drives, and other artificial and natural features for the use of human beings. Landscape architecture is the art of arranging land and landscape for human use, convenience and enjoyment. The profession of landscape architecture deals with the site development, building arrangement, grading, paving, plantings and play grounds and pools. It is related to individual home and the whole community. A landscape architect should be an artist. horticulturist and civil engineer.

26:4. Principles of gardening

As in the case of any other art and science, a good gardner should know the principles of gardening. A basic knowledge about the plants, soil, climate and their inter-relationships, cultivation of plants, their propagation, garden operations etc. are very essential in laying out and maintaining a good garden or landscape. The following are some principles of gardening.

Knowledge of plants: We should study each and every plant used in our garden as well as those around our place. The nature of their growth. affinity to shade or light etc. has to be studied. Similarly, by close watching we may be able to select suitable plants for our garden from our own locality. Some of the wild flowering or foliage plants, which flourish well in our locality can be suitably accommodated in our garden. If we go for the introduction of rare and expensive new plant species without knowing their adaptability under our conditions, sometimes, it may be a failure.

Soil: Loose, porous soil with high organic matter content and fertility is the ideal soil for gardens. It should have good drainage properties.

Climate: The selection of plants again depends on the climate and season. Temperature and light (both intensity and duration of sunshine) affect plant growth and flowering. In open spaces, sun-loving plants should be used and in shaded areas, shade-loving plants.

Watering: Water is essential for plant growth. Irrigation is an important operation in the garden except in rainy seasons. Water should be sprinkled on the soil. Irrigation may be given in the morning or evening. Avoid irrigation in the hot, sunny hours of the day. Soil should be sufficiently porous; there should not be water stagnation.

Planting: For most of the plants, rainy season is the best time for their establishment, provided that water stagnation is avoided. Similarly, if the plants are in dormant stage at the time of planting, they can tolerate the shocks and root-pruning better, and there is chance for better establishment. Planting may be done in the evening hours.

Maintenance: The following are some important aspects of garden maintenance.

1) Use the best seed and planting materials.
2) Dig the land deeply before planting.
3) Apply only good quality fertilizers.
4) Never over-water and over-manure a plant.
5) Soil may be forked well for aeration, when the plant is growing.
6) Remove the old and faded flowers from the plants; similarly, prune the dried and damaged plant parts.
7) Timely weeding may be carried out.
8) Give special and proper attention to potted plants, especially with respect to irrigation, potting, repotting etc.

Though the methods and principles of gardening can be learnt from books or journals. only through experience and keen interest in gardening, we will be able to design, develop and maintain a good garden.

26:5. Parts of a garden

For starting a garden, we have to prepare a layout first. To layout a good garden, a knowledge of different parts or features of a garden is essential. If we go to any garden, many of the following parts could be seen.

Lawn: Lawn is a piece of land or a large area of land with a fine grass-cover kept mown (trimmed) and smooth.

Carpet beds: These are formed by annual plants grown very closely in the form of alphabetic letters or in the form of political map of a nation or state etc.

Edges or edgings: These are closely planted bricks or concrete structures on either side of a path or flower beds to demarcate the boundary. Edges can also be made of small, branching type plants (Fig. 26.1).

Hedges: These are formed by growing foliage shrubs closely and kept levelled to a height of around 50 to 75 cm to divide the garden into different parts (Fig. 26.2).

Shrubbery: Group of shrubs of different colours and sizes are known as shrubbery. There are foliage shrubs and flowering shrubs.

Topiaries: These are structures with thick-growing shrubs, neatly trimmed in

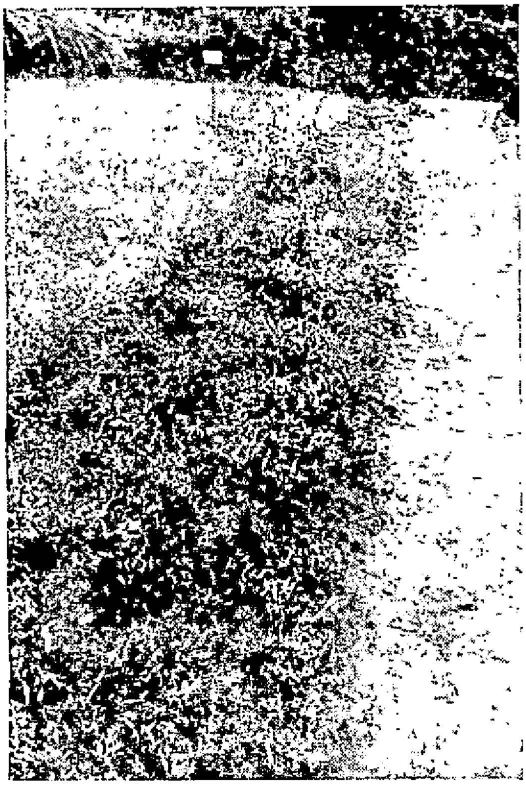

Fig. 26.1. An edge with *Alternanthera* sp.

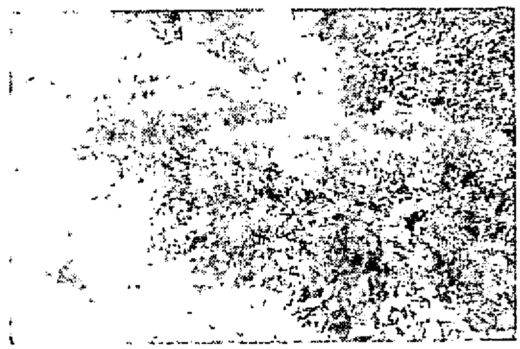

Fig. 26.2. A hedge with *Phyllanthus* sp.

the shape of animals, birds or in any other particular shape (Fig. 26.3).

Arches: Arches are usually seen at the entrance of a garden, or at the entrance of paths. These are made of wooden or metallic materials. Generally, flowering or foliage creepers are trailed on the arches.

Pergolas: Pergola is an extended arch all along a path. These are structures with closely planted pillars and roof, on which climbers are trailed.

Wall-type pergolas can also be seen in some places. In this case, creepers are trailed on closely planted pillars (or frame) in the form of a wall to act as a background. Climbers can be trailed on single pillars also.

Trophy: Trophy is the arragement of potted plants around a central object (flag post, statue etc.) in different tires or steps.

Arbours: Arbours (pandals) are structures with pillars and roof on which creepers are trailed. Sometimes, the side

Fig. 26.3. A topiary work

walls may be absent. Arbour is constructed on the side of garden, for relaxation of persons.

Conservatory: This is a shelter-house roofed and walled by creepers. The objective of conservatory is to ehxhibit and grow shade-loving and indoor plants, which cannot tolerate the open conditions. (Conservatory is often erroneously called as green house due to the green cover. True green house is actually a glass house).

Trees: Trees are planted either for shade, or to create a balance, or for the beauty of attractive flowers. In large gardens, trees are planted as avenue on either side of the road. Foliage and flowering trees can be seen in a garden.

Balloons: These are globe or oval shaped metallic structures trailed with creepers.

Sunken garden: These are formed by beautifying natural ponds or depressions. The slopy portions may be made into a number of terraces, and on these, ornamental plants may be grown.

Rockery or rock garden: These are artificial structures to imitate mountains, valleys etc. To get natural appearance along with the well shaped rocks and stones, some xerophytic plants, succulents etc. are also grown.

Water pools or water garden: A water pond beautified with water-plants, fountains, statues, fishes in water or with any other structures can be considered as a water garden. Sometimes bridges can also be seen over the water garden.

Annual flower beds: These are small plots of geometrical shape, grown with annual flowering plants of various colours.

Children's play area: In large gardens or public gardens, a portion may be designed as children's play area with various structures like see-saw, merry-go round, statues of animals etc.

Rosary or rosarium: This is a small plot of rose plants grown *in situ* or in pots. The different groups of roses are arranged in specific designs.

Statues, fountains, seats (benches etc.), stepping stones, ferney, orchidarium etc. are some other structures seen in a garden.

A lot of garden features can be listed out, but all these cannot be included in a garden. Depending upon the area, topography and the purpose of garden (school garden, home garden, garden in front of office etc.), we have to select the suitable features without losing the harmony of the garden.

26:6 Garden design

The main aim of the garden or landscape design is to create an attrative effect. Design means the manner in which objects or features are artificially arranged in an attractive way. The elements of design are *colour*, *texture* (usual effect of the surface qualities, eg., difference between the surfaces of pineapple and rose petal), *form* (shape and structure of objects like sphere, cube, pyramid) and *line* (the means by which form guides the eye).

26:6.1 Principles of garden design

The basic principles of landscape design are unity, balance, accent, focalization, scale, proportion, harmony and rhythm.

Unity: Unity refers to the grouping, arranging or placing the different parts so that they appear as a single unit. A good design should give a pleasant picture form several angles. Unity can be achieved by the use of plants similar in texture, form and colour. When paths, buildings and other areas are not logically related to the overall plan, unity is lost.

Balance: Balance means equilibrium. Balance can be achieved either through symmetrical equilibrium (symmetrical placement of objects around a central object) or through assymmetrical equilibrium (assymmetrical placement of objects utilising the lever principle). The equilibrium is obtained by the co-ordination of mass, distance and space. When we speak about balance, it is not the actual balance, but the visual equilibrium.

Accent: Accent provides emphasis. It can be obtained by specimen plants, use of water, lighting, variation in forms, contrasting colours etc.

Focalization: Focalization simply relates to the dominant point or the centre of attraction of a garden, which attracts and holds the attention of the viewer. eg., fountain, statue, arbour etc. of a formal garden, or the plant composition or attractive groupings of an informal garden.

Scale: It denotes the relative size or proportion of objects and plants. In a small garden, large leaved plants would be out of scale.

Proportion: Proportion means the pleasing and proper relationship of one part of a garden to another part and to the whole garden. If any part appears larger or smaller than the rest, it will not be attractive and pleasing.

Harmony: Harmony may be said as a sort of 'oneness' among the different parts of a garden. Different components of a garden should mearge into one another. In an attractive garden, the separate components lose their identity. eg., base planting of shrubs and herbaceous plants near the building makes the gradual merging of the building into the garden or the corner-planting of trees by the side of a building.

Rhythm: Rhythm in a garden design refers to the pattern of 'spatial' beats that our eye follows in any arrangement of objects. Rhythm directs and leads the eye through the design. In other words, rhythm is the repeatation of components to create a motion of our sight.

26:6.2 Some hints on garden design

The following may help to prepare a good garden design:

1) Base-planting of shrubs and herbaceous plants, or corner planting with trees to create harmony of building in the garden.
2) Big trees can be planted behind the buildings; the open and bare sky behind the building may look dull and unattractive.
3) The lawn may be constructed in the centre of the garden, or in a side getting good sight. Herbaceous border planting can be done on the boundaries of the lawn.
4) Boundaries of the garden can be planted with herbs or shrubs. Never plant tall growing trees in front of the garden; if so, they may obstruct the sight of the garden.
5) The garden should be attractive from every portion. Similarly, the whole garden should not be seen from the first sight itself.
6) The annual flowering plants may be planted in accordance with proper colour schemes selected for different seasons.

7) Roads and paths should be designed utilising the minimum space; and they should not be constructed in straight lines.

8) Never plant shrubs or construct flower beds in the centre of a lawn. If such plantings are done on the sides and corners, the lawn will look more spacious.

9) Better, not to plant any plants below the trunk of a tree. If planting has to be done, it should be loose and informal; crowd plantings may be avoided and planting may be done in a spreaded way.

10) Steps and terraces made should be as low as possible and wider; they should not be very narrow and high.

11) The bad views like cattle shed or compost pit etc. can be masked by constructing a wall-type pergola in front of them.

26:6.3 How to design a garden?

If we want to construct a building, based on the nature of site, necessities, capital available etc., we prepare a detailed plan. The construction will be according to the plan prepared. Similarly, the garden-construction also requires a previous planning because it will be very difficult, expensive and time-consuming to correct the mistakes made in a garden.

There are basically three phases or steps in the garden designing and construction—site analysis, preparation of the design or plan, and the execution of works or construction of the garden.

Site analysis: This refers to the detailed study of the location, where the garden is to be made. First of all, we should prepare detailed and complete plan of the site. The map should contain the topographical features showing the contours, natural features like trees, buildings, humps and depressions, rocks, water pools, streams etc. Such a plan drawn on a paper should be in a convenient scale like 1.0 centimetre = 1.0 metre. For easiness to draw the plan to a scale, graph paper can be used. We have to visit the site several times to learn its landscape character; the good views and bad views etc. should be taken into account.

Preparation of the garden design: Having completed the site analysis, drawing a design of the garden on the plan is the next step. The interests of persons, recreational needs, economic and time limits etc. must be taken into account while preparing a garden design. A home garden must have three parts—the front or the public space, the service space and the private outdoor living space. Like the different rooms in a house, these three parts should be designed to serve the specific purposes, but must be related to each other.

When we start to prepare a design, rough outlines of the various use areas are sketched on a tracing paper kept over the plan drawn at the time of site analysis. Then the detailed features like paths, walks, flower beds, lawn etc. etc. are drawn at appropriate locations. Then mark the locations for trees, shrubs etc. as a last phase. The existing features of the site to be retained in the garden, the features to be removed and new features to be introduced—all such modifications should be clearly indicated in the plan. Similarly, specify the type of plants to be used in the garden.

The designing should not be hasty; prepare the design with good thinking so that the final design is complete and satisfactory in all respects.

Execution of the work: Once we have finalised the design, arrange all the materials required for starting the construction. Then clean the site, and the boundaries, and the walks, paths etc. are laid out (marked) using ropes and pegs according to the design prepared. The best time for the layout and planting is April–May under Kerala conditions; just before the onset of monsoon season.

26:7. Garden maintenance

If the garden has to be beautiful and attractive, it should be maintained well. Our personal and regular attention is highly essential to maintain the garden in a good condition. The following are some important aspects in this regard.

1) Timely weeding, forking the soil, irrigation and manuring.
2) Regular training and pruning of herbs, topiaries, hedges etc. to keep them in good, attractive shapes.
3) Removal of old leaves, old flowers, dried and damaged twigs etc. of plants.
4) Planting of annual plants (especially in flower beds) in correct time, according to the scheme of planting prepared in advance.
5) Timely gap filling and other cultural operations.
6) Timely plant protection measures.
7) Timely potting, repotting and special care to plants grown in pots and other containers.

It is difficult to design and construct a good garden, and it is more difficult to maintain a garden most attractively.

26:8. Lawn

Lawn is an indispensable part of a good garden. Every good landscape garden invariably will have an attractive lawn. The lawn adds to the beauty of the garden. Like any other beautiful thing, it is very difficult to establish a good lawn and to maintain it well. The important aspects in the establishment and maintenance of a lawn are briefly described here.

26:8.1. Site selection

The area selected for establishing a lawn should be in open conditions, getting good sunlight. Most of the grasses will not grow well in shade. Lawns can be established in almost all soils having good fertility and drainage. High content of organic matter and good water holding capacity of soils are desirable. Slightly acidic soils (pH 5.5 to 6 0) are optimum for lawns. If the acidity is high, add lime @ 300g/m^2 at the time of land preparation.

26 8.2. Land preparation

The land may be made clean by scraping and weeding and dug to a depth of 30–45 cm in April—May, just before the onset of South-West monsoon. After three or four days, when the soil is dried, break the clods well and remove all weed stubbles with their roots and stones. This may be repeated three to four times till the soil is made free of all weeds, stones and prepared to a fine tilth. If the soil fertility is poor, add well dried and powdered cowdung @ 5 kg/m^2 and mix well with the soil. Then frequent irrigation may be given to make the soil compact for about two weeks. The germinating weeds may be uprooted and destroyed. Then the land has to be levelled. Since the stagnation of water in lawns damages the grass, provide a slight unnoticeable slope from the centre to the peripheries. The soil has to be pressed well using a roller or by beating hard on ground with some flat, heavy wooden material.

26:8.3. Lawn grasses

The following are some of the grasses suited for establishing a lawn.

Hariali grass or doob grass *(Cynodon dactylon)* is suited to most of the parts of India. There are many types of doob grass— erect and spreading. Spreading types are better for the lawn.

Blue grass or kikiyu grass (*Pennesitum clandestinum*) is suited to high ranges or hilly areas with low temperatures, and goose grass (*Stenotaphrum secandatum*) suited to shady areas.

25:8.4. Planting

Planting can be by means of seeds, turfing, turf–plastering, dibbling shoots or by planting cut grass.

Using seeds: The soil has to be forked to a depth of about 2 to 3 cm before sowing the seeds. The seed rate is 250 g/100m². Seed is mixed with some inert material like sand and, sown above the prepared land. Cover the seeds with a thin layer of soil and press well with a roller. Then irrigate with a rosecan. Seeds germinate in three to five weeks.

Turfing or sodding: Turf or sod is a piece of earth with a grass-cover. Turfs of about 20 cm x 20 cm sizes and 6-8 cm thickness are taken from places, where the grass is growing without weeds. Such turfs are paved closely on the prepared land after forking the surface, and the gaps are filled with soil. Then, the sods are pressed with a roller and irrigated with a rose can. This is the quickest method of establishing a lawn.

Turf-plastering: After the preparation of land, the grass is collected from a well established place. They are cut into small pieces, each with two to three nodes. The cut pieces are mixed with a slurry of cowdung and sand and is placed or applied on the prepared land. Then the land is covered with a layer of straw to prevent the evaporation for two or three days and irrigated daily.

Dibbling shoots: This method is almost similar to that of turf plastering. The off-shoots of grass collected are cut into small pieces, and scattered evenly over the prepared land. Then a mixture of sand and soil is evenly spread on it to a thickness of about one centimetre, and a light rolling is given followed by watering. The grass develops the roots and new shoots come out.

Turf-plastering and dibbling methods are successful in rainy seasons.

Planting cut grass: In this case, the slips of lawn grass are collected and they are planted very closely on the prepared land. Then it is lightly rolled and irrigated daily.

26.8.5. Aftercare

Once the lawn is established, requires regular care and maintenance. Otherwise the lawn becomes ugly and it spoils the beauty of the whole garden itself. The important operations in the maintenance of a lawn are mowing, rolling, irrigation, weeding, manuring and plant protection.

Mowing: The cutting and levelling of the grass periodically is known as mowing. To have good appearance, the lawn is to be mowed regularly at an interval of two to three weeks. In the early stages, grass-cutting swords can be used. When the grass has grown well, we could use a mower for this purpose. For vast areas, tractor-drawn mowers are used. The height of grass should not be more than five or six cm.

Rolling: During the time of land preparation, the soil is rolled to make it level and compact. When the lawn is established, rolling is done in order to bring the grass in contact with the soil and also to keep the ground level. It also helps to prevent the attack of white ants (termites) and to fill the air pockets created by earth worms. Rolling can be done twice or thrice in a month. In rainy season, or when the soil is too wet, it is not advisable to roll the lawn.

Irrigation: The lawn needs watering in summer season. Frequent and light irrigation is preferable than heavy watering at long intervals.

Weeding: All plants other than the lawn-grass are to be uprooted and removed frequently. Neglect in weeding may result the spread of weeds in the lawn. Never allow weeds to produce seeds.

Manuring: Yellowing of grass indicates nitrogen deficiency. Drenching the soil with 1 to 2% urea in water can cure the yellowing. This can be done every month.

It is advisable to fork the lawn once in a year. Then top dressing may be done with a mixture of powdered cowdung and sand in 1:1 ratio. Also, add a fertilizer mixture of ammonium sulphate. superphosphate and muriate of potash in the ratio 2:1:1 @ 50-75 g/m² area. Then roll the lawn well and irrigate.

Plant protection: Termite and earth worms may damage the lawn. Rolling can control them to some extent. If severe attack of termite is noticed dusting with 10% B.H.C. can be done. Indiscreminate use of pesticides in the lawn is not advisable.

26.8.6: Replanting

The beauty of the lawn is lost after about four to five years its establishment. Then replanting will be necessary after about five years.

26.9 Rockery

Rockery is the arrangement of cactii, ferns, succulents and other hardy plants along with rocks to imitate a mountain in a small area. It is usually created at a place unsuitable for growing other plants (rocky patches) or by the corner of the garden. A rockery can be accommodated in natural and formal gardens; in open space or in shaded places. We should not construct a rockery near the walls or at the base of a tree. The soil should have good drainage.

Rockeries are built as if they occur naturally. Rocks, boulders or irregular undressed stones etc. can be used in a rockery. Very beautiful rocks for the purpose can be collected from mountaineous regions or from rivers or from sea side. Sometimes artificial boulders of cement-concrete and cut stones are also planted in the rockery. Rocks bigger than 30 cm size are better. The stones used should be of different sizes and shapes.

Once we have selected the site and collected the rocks, we can start constructing the rockery. First of all, mark out the area with lime powder. Dig the place to a depth of 10-30 cm at various places irregularly and escavate the soil. Irregularity is the main feature of a rockery. In the escavated places, place rocks of different shapes and sizes. The crevices are then filled with potting mixture or good earth and the rocks are partially covered. Arrange another layer of rocks around this, and irregular tiny peaks and depressions are also prepared.

The slope of peaks should not be too deep. The area can be filled with gravel, broken bricks, stones etc. The rocks and stones should not be over-crowded. One or two streams or a water pool constructed at the base of rockery may improve its appearance.

Some hardy plants like succulents, cactii, shrubs etc. can be planted irregularly. Annuals like dianthus, petunia, gomphrena, vinca, zinnia etc.; shrubs like drasaena, croton, lantana etc; creepers like philodendron, pothos etc; cactii and succulents like sansevieria, pedelanthus, agave, chlorophytum, opuntia, euphorbia, bryophyllum etc; and ferns are the most appropriate to get a narural appearance. We may select any of the locally available plants for the purpose.

Weeding, irrigation in summer season, thinning out of the overcrowded plants, application of organic manure, removal of dead leaves and twigs and such other operations are to be carried out whenever needed. Regular care and management of rockery is a must to keep it attractive.

27. Ornamental plants

27:1. Introduction

Ornamental plants are an indispensable part of any garden. A large number and type of plants are used for beautification. Proper selection of plants for specific purposes and their suitability or adaptability to the climate and soil are of utmost importance. Some of the common ornamental plants and their general characteristics and uses are described in this chapter.

The ornamental plants can be grouped as trees, shrubs, creepers and climbers, bulbs, cactii and succulents, ferns, hedge and edge plants, orchids, annuals etc.

27:2. Trees

The cultivation of trees for their beauty or aesthetic or recreational value is termed *arboriculture*. They are perennial plants attaining more than four meters in height. Trees can be planted in a garden either as single, or in groups in a line on the sides of road as avenue. There are foliage and flowering trees.

Foliage trees:

In foliage trees, the aesthetic value is for their leaf or canopy. Foliage plants will be evergreen in nature. eg: *Polyalthia longifolia, P. longifolia pendula, Araucaria* spp., *Caesalpinia coriaria, Azadirachta indica, Thuja* spp., *Casuarina equisetifolia, Cupressus* spp , *Cycas* spp., *Eucalyptus* spp., *Ficus* spp., etc.

Flowering trees:

Flowering trees are planted for the beauty of their flowers. While selecting flowering trees, the colour of their flowers, season of flowering etc. have to be taken into account. eg: *Plumeria alba, P. rubra, P. hybrida, Bauhinia* spp., *Butea frondosa, Callistemon lanceolatus, Cassia fistula, Delonix regia, Jacaranda mimosaefolia, Michelia champaka, Sareca indica, Spathodea campanulata* etc.

27:3 Shrubs

Shrubs are important in any garden. They are easy to grow. They are perennial in nature and attain a height of 0.5 to 4.0 metres. Shrubs can be planted in a garden either as a shrubbery (on a long strip of land, where taller shrubs are grown in back, medium ones in middle and the dwarf ones in the front), or in small groups of a few plants or through the border/boundary. There are foliage and flowering shrubs.

Foliage shrubs:

The common foliage shrubs are *Acalypha, Polyscia, Codiaeum variegatum, Dracaena. Pandanus, Psuederanthemum, Aphelandra, Euphorbia cotinifolia* etc.

Flowering shrubs:

Some of the shrubs may produce flowers throughout the year but some others are seasonal in nature. Plants like *Hibiscus, Rhododendron, Bauhinia, Calliandra haematocephala, Cameilia japonica, Crossandra, Hamelia patens, Gardenia, Hydrangea hortensis, Ixora, Lantana camera, Mussaenda, Euphorbia pulcherrima, Nerium oleander, Pentas lanceolata* etc, are good flowering shrubs.

27.4. Creepers and climbers:

Creepers trail along the ground and climbers grow on supports. A large number of beautiful climbers can be used in a garden for arches, pergolas or for growing on bare walls/compound walls, fences, trellies, arbours etc. In this case also, there are foliage and flowering types. Plants like *Asparagus plumosus, Scindapsus, Vernonia elaegnifolia, Hedera helix, Ficus pumila* etc. are foliage climbers. Some of the common flowering climbers are *Ipomoea, Jasminum, Clitorea ternatea, Gloriosa, Aristolochia grandiflora, Thunbergia grandiflora, Pyrostegia venusta, Quisqualis indica, Allamanda cathartica, Antigonon leptopus, Bougainvillea, Clerodendron thomsonae, Jacquemontia pentantha, Lonicera japonica* etc.

27 5. Bulbous plants

In the context of ornamental horticulture, bulbous plants include all the bulb forming and tuber forming plants, where the underground structures like bulb, corm, rhizome, tuber etc. are used for their propagation. Such plants have a vegetative (growth) phase, reproductive (flowering) phase and a dormant phase. After flowering, when the shoot portion dries off, the underground bulb/tuber undergoes a dormant period. Then the tubers/bulbs are uprooted and stored in a dark, cool, airy place and planted in the next saason. Bulbous plants are used in flower beds, shrubbery, herbaceous border, pots etc. in a garden. The common bulbous plants are *Amaryllis* spp., *Dahlia* spp., *Gladiolus* spp., *Hedychium* spp., *Polianthes tuberosa, Canna* spp., etc.

27:6. Cactii and succulents

Cactii and succulents are an important group of plants of a garden. They require less care and attention and lesser space. Due to this, cactii and succulents are becoming very popular in home gardens especially in cities.

Cactii are a group of plants with definite size and shape and are mostly xerophytic in nature. They have thick and fleshy stem; leaves are mostly absent, sometimes rudimentary scales or very small leaves may be present but they fall off soon. Cactii have spines of various sizes and shapes depending on the species. Examples of cactii are various species of *Opuntia, Astrophytum, Borzicactus, Cereus, Echinocactus, Epiphyllum, Ferocactus, Notocactus, Rebutia* etc.

Succulents are also adapted to desert conditions. Their stem and leaves are very juicy and contain about 95% water. Succulents are grown in a garden for their particular shape or attractive foliage or showy flower. They are suited to rockeries. Some of the common succulents are *Agave* spp., *Cissus* spp., *Echevaria* spp., *Euphorbia* spp., *Kalanchoe (Bryophyllum)* spp., *Pedilanthus* spp , *Portulaca* spp., *Sedum* spp., etc.

27:7. Hedge and edge plants

Hedges are required in a garden to demarcate the garden from roads, or into different parts. They are grown very closely in a row and trained on sides and at top to keep them in shape. Plants like *Phyllanthus, Lawsonia, Casuarina Durauta, Thuja, Inga, Malvaviscus* etc. can be grown for making topiaries also.

Edges are constructed by the sides of paths, flower beds etc. In this case, plants are grown very closely and trimmed to a height of 15-20 cm above ground. *Alternanthera, Aerva sanguinea, Pilea mucosa, Portulaca, Coleus,* etc. can be used as edge plants.

27:8. Indoor plants

Many ornamental plants are shade loving in nature. They can be used for decorating the rooms, verandas or can be grown in green houses. Most of the indoor plants or house plants are grown in pots or in other suitable containers or in hanging pots. In rooms, the plants may be kept near windows to get enough light for their growth.

Plants like *Aglaonema* spp., *Alocasia* spp., *Anthurium* spp., *Begonia* spp., *Billbergia* spp., *Caladium* spp., *Chlorophytum* spp., *Cordyline* spp., *Costus speciosus*, *Dieffenbachia* spp., *Dracaena* spp., *Ficus* spp., *Gynura sarmentosa*, *Haliconia* spp., *Maranta* spp., *Peperomia* spp., *Philodendron* spp., *Sansevieria* spp., *Xanthosoma lindenii* etc. can be used as indoor plants.

Some shade loving plants are suited for hanging pots. *Episcia* spp., *Pilea* spp., *Zebrina pendulaa*, *Tradescantia* spp., *Sedum* spp., *Kalanchoe* spp. etc. come under this group.

27:9 Annual flowering plants

Annual flowering plants are important in any garden. A large number of annual plants with a wide range of colours are available. They can be grown in flower beds or in pots. They have short duration. Annual flowering plants are easy to cultivate and can be grown in almost all seasons. However, winter and summer seasons are better.

The common annual flowering plants are *Gerbera jamesonii*, *Tagetes* spp., *Gomphrena globosa*, *Celosia cristata*, *Impatiens balsamina*, *Zinnia* spp., *Catharanthus roseus*, *Cosmos bipinnatus*, *Petunia hybrida*, *Helianthus annus*, *Salvia splendens*, *Cleome spinosa*, *Amaranthus* spp., *Calendula officinalis*, *Chrysanthemum* spp., *Tropaeolum (Nasturtium)* spp. etc.

Annuals require an open site with good sunlight for their growth and profuse flowering. Usually seeds are used for propagation, though cuttings or slips can also be used in some species. The seeds are sown in shallow pans or in nursery beds containing a 1:1:1 potting mixture and watered daily. Light watering is enough; water stagnation or excess moisture may cause damping off of the seedlings. Seedlings with 4–6 leaves are used for transplanting.

The land is prepared by digging three to four times to a depth of 30-45 cm. The weed stubbles are removed, clods are broken and the soil is mixed with well dried cowdung powder. Depending on the growth habit of the species, the seedlings are transplanted at 15-30 cm distance, shaded for 4-7 days, and irrigated daily.

Weeding, irrigation, hoeing, plant protection measures etc. may be conducted as and when required. In addition to the organic manure, small quantities of fertilizers can also be applied to boost up growth of plants.

Removing the stem tip (tipping), when the plants are 15–20 cm high, helps to develop side branches. Sometimes selected thinning of flower buds (pinching) is also practised to get bigger flowers, especially when the plants are grown for exhibition purposes.

28. Commercial flowers

28:1. Introduction

Commercial flowers are those, which are cultivated on a large scale for their market either for cut flowers or for extraction of aromatic oils or concentrates. Rose, jasmine, chrysanthemum, crossandra, gladiolus, tuberose etc. are some of the important commercial flowers. They are widely cultivated in Tamil Nadu and Karnataka states. In Kerala, these flowers are not cultivated on a commercial basis.

28:2. Rose

Rose is one of the important commercial flower crops grown in Karnataka and Tamil Nadu. However, rose is not a commercial crop in Kerala, but popular as an ornamental plant of the home gardens. Rose can be grown on a variety of soils having a pH range of 5.3 to 5.5 with good drainage and fertility. Cool dry climate is favourable for rose culture. The area selected should be open with plenty of sunlight and have protection against wind.

Rose cultivars are classified as Hybrid Teas, Floribundas, Polyanthas, Miniatures, Ramblers and climbers etc. Some of the popular cultivars recommended for commercial cultivation are Amerioan Heritage, American Home, Queen Elezabeth, Super Star, Christian Dior, King's Ransom, Sweet Heart, Baccara etc.

Rose is propagated mainly by 'T' budding, patch budding, air layering, or rooted cuttings. Budding is the most popular method. Wild rose, used as rootstock, is propagated by cuttings.

Wild rose cuttings of pencil thickness and 15-20 cm length are planted in polythene bags. When they grow for about six months, they produce vigorous side shoots. 'T' budding is performed on these shoots with buds of the desired cultivars. However, patch budding is more easier and can be done directly on the rootstock itself about 10 cm above the ground level, 1-1½ months after planting when they produce small sprouts of 4-6 cm long. Within about 45-60 days of budding, the union is completed and buds start sprouting. Patch budding is practised in the high range regions like Wayanad, Ooty, Coorg etc. But, the success or 'take' of patch budding in plains is not satisfactory.

Land preparation involves weeding and digging for 3-4 times. All clods are broken and weed stubbles are removed. Then pits of 45 cm x 45 cm x 45 cm size are taken at 0.75 m to 1.0 m apart. The pits are filled with a mixture of the top soil and well dried cowdung powder. The months of June to October is the ideal time for planting.

The cultural operations include weeding, watering, desuckering, pruning, manuring etc. In summer months, irrigate the plants at an interval of 7-10 days. Desuckering involves the removal of all the rootstock sprouts arising from the lower and upper portion of the bud union. Retain or allow to grow only the growth of the scion-bud.

Pruning includes the removal of all the dead, weak, criss-cross and diseased branches,—known as 'clean up'. There are light, moderate and hard prunings depending upon the amount of shoots removed. Light pruning involves cutting back the shoots 2-3 buds from the tip after the clean up. In the case of moderate pruning, the strong and healthy branches of the previous year's growth are cut back to half length after the clean up. Hard pruning consists of keeping only three or four canes of the last year and cutting back to about 20 cm from the base, approximately above 3-4 eyes from the base. The objective of pruning is to maintain the plant in a healthy, short-stature and to get more flowers. The moderate or hard pruning is usually done once in a year (October to December months); the light pruning can be done periodically, say, once in a month or so.

Manuring is a must for rose for producing maximum flowers. After the annual pruning, about 2-3 kg of farm yard manure should be applied in basins taken around each plant. Similarly, fertilizer application is also needed. N, P_2O_5 and K_2O @ 5g: 5g: 7.5g/plant (or 50g of rose mixture) may be applied just after pruning and irrigate well. About 45 days after pruning a similar dose of fertilizers may be given. Slight quantities of fertilizer application at 1½–2 months interval helps to get good yields.

Termites, cock chaffer beetles, redmites, aphids, scales etc. are the major pests of rose. The common diseases are die back, powdery mildew and black spot.

About 8-10 tonnes of flowers can be obttained per hectare. The [economic life span of a budling is about 10 years. The yield, economic life span etc. depends on the cultivar also. Flowers are used for cut-flower industry and for extraction of rose water and rose oil.

28:3. Jasmine

Jasmine is an important commercial crop grown in Karnataka and Tamil Nadu. The flowers are used for the preparation of garlands. The essential oil and concentrate extracted from jasmine flowers have great export potential.

It can be cultivated on a wide range of soils. Drainage is a must.

Kakada, Gundumallige, Co-1 mullai (Vasantha mallige). Jaji mallige etc. are the important cultivars of *Jasminum auriculatum* (Mulla). *J. grandiflorum* (Pichi) is also cultivated commercially. Flowers of Co–1 and Jaji mullai contain high content of essential oil (0.24 to 0.42%).

Kakada is propagated by terminal cuttings and suckers; other cultivars are propagated by layering or cuttings.

Pits of 0.45 cm x 0.45 cm x 0.45 cm size are taken at 1.5 m x 1.5 m spacing, after land preparation. Planting is done in monsoon season.

Cultural operations consists of weeding, irrigation, manuring, pruning etc. Irrigate the plants once in a week in the summer months. Fertilizers may be applied @ 120g N, 240g P_2O_5 and 240g K_2O in two equal splits in January and July. Farm yard manure @ 20 kg/plant is also required. Prune the plants in December to a height of 40 to 60 cm from ground level to keep them into bushes.

For garland preparation, flower buds are picked; and for oil extraction, fully opened flowers in the early morning. Average yield of 8,000-10,000 kg of flowers/ha is obtained from fourth year onwards. The economic life span of jasmine is 10–15 years.

Scales, mites, mealy bugs and leaf eating catterpillars are the usual pests of Jasmine. Diseases are Cercospora leaf spot, Fusarium wilt, powdery mildew etc.

28:4. Chrysanthemum

Chrysanthemum is another important commercial flower grown in Tamil Nadu and Karnataka. Flowers are used for cut flower purposes, oil extraction and in the preparation of pyrethrum dust.

It grows in all types of loamy soils with good drainage. Chrysanthemum is a cool season crop. Main season of cultivation is June to November.

Yellow, white and pink flowered cultivars are available. Green Goddes, Green Sensation, Mahatma Gandhi, Prime Rose etc. are some Indian cultivars.

The plants can be propagated through cuttings, suckers or seeds.

After weeding and digging, furrows are taken at 30 cm distance. Apply the basal dose of manures and fertilizers and plant the suckers at 20 cm spacing. Farm yard manure @ 20 tonnes/ha is needed. Fertilizers @ 120 kg N, 154 kg P_2O_5 and 100 kg K_2O are required per hectare of land. Apply 1/3rd of N, full P_2O_5 and K_2O as basal at the time of planting. The remaining N is applied in two equal splits at the time of pinching and one month after pinching. (When plants are 15-20 cm high, the terminal buds are pinched off to induce the development of more branches). Weeding and irrigation (once in 4 days) are also given.

Usually, the plants start yielding flowers in 3½ months of planting and continues for 45 days. Average yield is 10-15 tonnes/ha.

28:5. Tube rose

Tube rose is grown for the cut flowers to use in the preparation of garlands and boquetes and for essential oil extraction.

Porous, well drained soil and a cool dry climate are favourable for tuberose culture. April-May is the time of planting. Single, double, semidouble and variegated varieties are available; but single whorled varieties are popular.

Bulbs are used for planting. Spacing is 30 cm x 20 cm as in the case of chrysanthemum. About 800-900 kg of tubers are required per hectare. Apply farm yard manure @ 30 t/ha. Fertilizers to get 100 kg of N, 50 kg P_2O_5 and 50 kg K_2O/ha are also needed. Half dose of N and full P_2O_5 and K_2O are applied as basal. Remaining N is applied as top dressing, 4 5 days after planting. Irrigation and weeding are also needed.

After the harvest, flower-stalks are headed back and the field is manured and irrigated to take the ratoon crop. About 3-4 ratoon crops can be taken.

Flowering takes place by 3-3½ months after planting. Average yield is 8 tonnes of flowers per/ha.

28:6. Orchids

Among the commercial flowers, orchids are getting considerable importance nowadays. Orchids belong to the family Orchidaceae and there are about 24,000 species and thousands of hybrids among them. Orchid flowers are famous for their beauty, due to their variability in colour and size, variety of fragrance and the long life of flowers. Attractive blooms of orchids are getting importance in cut-flower industry. In Kerala too, there are certain nursery men who grow and export orchids on a commercial scale.

A large number of orchids are naturally seen in our forests. Over 200 species of orchids are reported from the forests of Western Ghats. Orchids require a high humid atmosphere for their satisfactory growth. Ample air circulation, optimum ranges of light and temperature etc. are the other requirements. Orchids suited to warm or hot conditions (night temperature 18.3°C and above) can be successfully grown in Kerala.

The natural habitat of many of the orchids is forests. Hence, the atmospheric conditions of a forest—protection from direct, severe sunlight and wind, high humidity of atmosphere, air circulation etc.—are the most ideal for orchid culture. An orchid house is essentially required to grow the orchids. A flat roof lath house is sufficient for this purpose. The roof is to be covered with split bamboos or wooden battens of 5 cm width, placed at a distance of 2 cm between them. The sides may be covered with coir mats for enough air circulation. Around the walls, frames can be fitted for hanging orchids. The height of the roof from ground level should be 3.5 to 4.0 m. it is better to spread sand or porous gravel or any such other materials on ground to keep the atmosphere humid. Similarly, a small pond or water pool in the centre also helps to keep the required humidity in the lath house. Indoor and foliage plants can also be kept on the ground to maintain the humidity. It will be advisable to spray water occasionally in the orchid house to keep the house cool and moist but over-watering should be avoided. Nutrients are usually supplied through foliar spray.

Orchids such as *Cattleya, Dendrobium, Oncidium, Vanda, Cymbidium, Rhyncostylis, Arundinia* etc. which are suited to warm conditions can be successfully cultivated in a lath house as described above.

Orchids can be generally grouped into two—*epiphytic* (which grow up on trees and have their roots exposed to air) and *terrestrial* (which grow on the ground). Epiphytic orchids can be grown on pieces of wood, charcoal, bricks, or coconut husk in a orchid house and the terrestrial ones can be grown in pots filled with special potting mixture of orchids, ie., well decayed leaf mould (1 part) + charcoal powder (1 part) + loam ($\frac{1}{4}$ part).

Propagation of orchids is mainly done by micro propagation. The seeds are germinated and seedlings grown in culture media under aseptic conditions of controlled atmosphere. Vegetative propagation is also possible by means of offsets (*Dendrobium Epidendrum*), air layering (*Vanda*), cutting (*Arachnis, Renanthera*) division of new growth (*Cattleya, Dendrobium*) division of psuedo bulbs (*Cymbidium*) etc. Commercial multiplication of hybrids are mainly done through meristem culture in tissue culture laboratories.

ENTOMOLOGY

29. The world of insects

29:1 Introduction

The science of *entomology* is a branch of zoology which deals exclusively with the study of insects. The word 'entomology' is derived from two Greek words—*'Entoma'* (insects) and *'Logos'* (to study). Insects influence human life in many ways. Both beneficial and harmful insects are present around us. However, harmful insects always outnumber the beneficial ones. The struggle for existance between man and insects has no end. They cause great losses to his crop by way of direct attack and also by spreading diseases. Insects also attack livestocks and even human beings and spread a number of livestock and human diseases. The study of insects in relation to agriculture is known as Agricultural entomology. Forest entomology, Veterinary entomology, Medical entomology etc. are other applied entomological sciences.

29:2 Scope of entomology

The importance of insects in human life is great, since they influence almost all activities of man. Agricultural entomology, Forest entomoloy, Veterinary entomology etc. are equally important in this respect.

The red palm weevil—which destroys coconut palms by way of feeding the internal parts of the trunk; the *Anopheles* mosquito—which spreads malaria in human beings; the blood sucking lice and fleas of domestic animals; the pulse beetle—which damages the stored pulses; the banana aphid—which spreads bunchy top disease in banana etc. are some important examples for the harmful or destructive activities of insects. However, some other insects are useful to human beings. Silk worm, honey bee and lac insect are productive, and their products are useful to mankind. A large number of insects help in the pollination of crops. There are some natural insect-parasites and predators which help to control the harmful insects, and hence, such insects are important in the biological control of insect pests.

A fundamental study of the insects includes the following sections of entomology.

Insect Morphology— Study of the form and structure of different insects.

Insect Taxonomy— Study of classification of insects.

Insect Physiology— Study of functions of organs and parts of insects.

Insect Anatomy— Study of the internal system of insects.

Insect Ecology— Study of insects in relation to their environment and to other organisms which influence their life histories.

The applied branches of entomology mainly deals with the methods of insect control and management. It also includes the use of pesticides,toxicological studies of pesticides, their residual effects on crops, human life, and on the balance of nature etc.

29:3 Harmful, productive and beneficial insects

Based on the relationship of insects with man, we may classify the insects as harmful, productive and beneficial.

Harmful insects

The harmful insects cause damages to crops and other plants, spoil the stored food, and spread diseases in human beings and animals.

Pests of crops, plants and forest trees: Insects damage the plants by way of feeding on various parts, oviposition, and by spreading the disease organisms.

Pests of stored products: Insects cause considerable damages to the stored seeds and food products like rice, wheat, pulses etc. Certain insects like cockroaches spoil the food by contaminating with their excretions.

Insects inimical to man and animals: Such insects spread diseases in man and animals, or inject venoms, or feed on the blood, or cause other irritations.

Productive insects

Productive insects are those, which directly or indirectly produce some useful or commercial materials. Productive insects are, hence, beneficial also. The productive insects can be grouped as follows

- *Whose secretory products are useful* eg: silk worm (silk), honey bee (bee wax), lac insect (shellac) etc.
- *Whose bodies are useful, since it contains the useful materials* eg: Cochineal insect (dye), blister beetle (cantharidine) etc.
- *those, who collect and store plant products.* eg: honey bee which gives honey using the nector collected from plants.
- *those, which give useful products from the plant galls caused by them.* eg: tannic acids, inks, and dyes obtained from certain insect-galls.
- *those, which form the food* for fishes, birds, certain animals, human beings etc.

Beneficial or helpful insects

These insects do not give us anything directly, but are useful in many ways. For instance, insect pollinators aid in pollination and give good yields from crops. Parasitic/predatory insects of harmful insects are employed in the biological control of crop pests. Certain insects feed on and completely destroy some weeds, and therefore, they are effective in the biological control of weeds. Some other insects act as good scavengers of our surroundings.

29:4 General characters of insects

The major characteristics of an insect are the presence of a chitinous exoskeleton and presence of three pairs of legs. Besides, the body can be easily recognised into three conspicuous parts–the head, the thorax and the abdomen.

The body of an insect has a chitinous exoskeleton or body–wall. The exoskeleton is nearly cylindrical in shape and consists of ring-like parts or segments. The head of the insect is made up of six segments. The structures found on head are a pair of compound eyes, a pair of antennae (sensory organs) and mouth parts. The thorax consists of three segments—the prothorax in front, the meso thorax in the middle, and the metathorax in the hind part. A pair of legs can be seen on all these three segments. Similarly, two pairs of wings are also attached on thorax—one on the mesothorax and the other on the metathorax. The thorax is the most important part of an insect with respect to its movement.

The abdomen consists basically of 11 segments. Sometimes, pro-legs can be seen on the abdominal segments, especially on larvae. Other appendages seen on the abdomen are a pair of cercii on the 10th segment, ovipositor for depositing eggs (in bees, wasps, and ants, the ovipositor is modified as a stinging organ), anus and anal filaments, and spiracles or the external openings to the respiratory system. The major functions of the abdomen are digestion, respiration, excretion, and reproduction.

29:5 Mode of feeding and mouth parts

The appendages borne on the head capsule around the mouth are collectively called mouth parts. In a typical insect, the mouth parts basically consist of four parts—labrum, mandibles, maxillae, and labium.

Labrum — This is the flap-like upper lip.

Mandibles — These are a pair of chewing jaws.

Maxillae — These are the second pair of jaws which help to touch, smell, taste, hold, and cut the food tissues.

Labium — This is the lower lip which helps to hold the food. It is also sensory in nature.

The mouth parts described above are suited to chewing, and commonly known as chewing type of mouth parts. Such chewing mouth parts are seen in grass hopper, cockroach etc. Chewing type is the most primitive and widely seen type of mouth parts. There are many other modified types also, suited to various purposes.

Types of mouth parts

We have seen the typical type of mouth parts of an insect suited for chewing purposes. However, all these parts may not be present as such in several insects. There would be certain modifications to suit various needs. Based on the purpose it serve there are two basic types of mouth parts—the mandibulate or chewing type and the haustellate or sucking type. We shall see each of them briefly.

Mandibulate or chewing type

Those insects which feed on solid food materials by masticatory process have the mandibulate mouth parts. eg: catterpillars, grass hoppers, beetles etc.

Haustellate or suctorial type

This type of mouth parts are seen in those insects which feed on liquid diet. eg: bugs, mosquitoes, aphids, jassids etc. There are modifications in the suctorial type of mouth parts. They are–

Siphoning type: The sucking organ consists of an elongate hollow tube kept rolled up and concealed vertically in the head capsule when not feeding. eg: butterflies, moths etc.

Piercing and sucking type: In this case, the insect makes an injury by piercing into the cell wall with its mandibular stylets, and then sucks the liquid cell sap using the maxillary stylets. The mouth parts consist of a long, foldable, and curved stylet. eg: plant bugs, mosquitoes.

Spongi type: In this case, the mouth parts are modified into a swollen, flattened and sponging type organ, which is moulded to any surface on which the insect is feeding. eg: flies.

Chewing and lapping type: This consists of a combination of the mandibulate and haustellate types as seen in honey bees.

Rasping and sucking type: Here, the insect injures the epidermis first by lasceration or scratching, and then feeds on the exuding sap This is an intermediary type between the mandibulate and haust-ellate type. eg: thrips.

23:6 Insect classification

About 80 percent of the known species of the animal kingdom consists of insects. To study such a large number, it is essential to classify them into distinct groups. The systematic grouping of insects, based on their external and internal characteristics, metamorphosis etc., is termed insect classification or taxonomy.

The whole Animal Kingdom is divided into certain major groups called *Phyla* (*Phylum*-singular) and all insects and certain related animals belong to the Phylum Arthropoda. The Phylum Arthropoda is divided into four sub groups known as *Class* and all the insects come under the class-Hexapoda or Insecta. The class Insecta is divided into two *Sub-classes* (Apterygota and Pterigota) and the sub-classes into *Orders*. Under each Order, there are other distinct groups known as *Families*. Each family consists of a number of *genera* and each genus contains one or more *species*. So, the species is considered as the basic unit or the ultimate end of the classification. Species is a genetically distinct, reproductively isolated population which is evolved or evolving.

When we speak about a particular insect, in scientific parlance, its genus and species names are indicated, and hence, this type of naming is called *binomial nomenclature*. The binomial nomenclature was introduced by Linnaeus and the system is accepted internationally in plant and animal taxonomy. The genus and species names are to be denoted in Latin forms. For example, the scientific name of cockroach is accepted as *Periplanata americana*. This means that the cockroach comes under the genus, *Periplanata* and its species name is *americana*. Sometimes, the individuals of a particular species may vary for some specific characters, and they are grouped into *sub-species*. In such cases, sub species names are also given.

The general classification of insects is given below:

Kingdom — Animal Kingdom
Phylum — Arthropoda
Class — Hexapoda (Insecta)
Sub-class — Apterigota (wingless insects)

1) Order Collembola (spring tails)
2) Order Protura (proturans)
3) Order Thysanura (Silver fish, bristle tails)
4) Order Diplura

Sub-class — Pterigota (winged insects)

5) Order Ephemeroptera (May flies)
6) Order Odonata (Dragon flies, Damsel flies)
7) Order Plecoptera (Stone flies)
8) Order Dictyoptera (Cockroaches, mantids)
9) Order Grylloblatodea
10) Order Orthoptera (grasshoppers, crickets)

11) Order Phasmida (leaf insects, stick insects)
12) Order Dermaptera (ear wigs)
13) Order Embioptera (web spinners)
14) Order Isoptera (termites. white ants)
15) Order Zoraptera (bark beetles)
16) Order Psocoptera (book lice)
17) Order Mallophaga (bird lice or biting lice)
18) Order Siphunculata (sucking lice)
19) Order Hemiptera (plant bugs—leaf hoppers, aphids, scale insects etc.)
20) Order Thysanoptera (thrips)
21) Order Neuroptera (Aphid-lions, ant-lions)
22) Order Mecoptera (scorpion flies)
23) Order Trichoptera (caddis-flies)
24) Order Lepidoptera (Moths and butterflies)
25) Order Diptera (two-winged flies)
26) Order Siphonaptera (fleas)
27) Order Hymenoptera (bees, wasps, ants etc)
28) Order Coleoptera (beetles, weevils)
29) Order Strepsiptera (stylopids).

As described earlier, each of the above Order may further be divided into various families, and the families include a number of specific individuals or species.

29:7 Metamorphosis

Insects lay eggs for reproduction. The young ones of the insects (larvae) which are coming out of the eggs on hatching differ from the adult in many respects. During its post- embryonic development, most of the insects undergo marked changes in its form to develop into an adult. The changes in form, which occur during the post embryonic development, is usually termed metamorphosis. Metamorphosis is usually accompanied by growth, differentiation and reproduction. Growth is taking place in the larval stage; differentiation in the pupal stage; and reproduction in the adult stage.

The larvae which are coming out of the egg will have a very hard body covering. This hampers the growth of the larvae; and therefore, to continue the growth, it has to shed its outer skin. This shedding process is known as *ecdysis* or *moulting*. The developmental stages of an insect between two successive moults is termed *instars*. The number of moults vary with insects. After attaining adulthood, no moulting would take place. At the time of moulting the insects would be in a non-feeding state, and specialised hypodermal cells produce the moulting fluids. This fluid helps in loosening the outer skin, and subsequently, a new skin is developed. In usual cases, three to six mouitings take place. However, it may reach to even twenty three as in May flies. During metamorphosis, the insects undergo changes in their form and feeding habits. The changes occur both internally and externally. The internal changes are very complicated and not visible to naked eyes. However, the external metamorphosis in insects are highly conspicuous and stages are well defined. Based on the way in which the changes take place, there could be different types of metamorphosis.

Development without metamorphosis (Ametabolous)

There are some insects in which the young ones coming out of the eggs are exactly similar in form to the adult. In such cases, there occurs little changes in form between the subsequent instars, except the development of sexual organs. eg: Order Thysanura (silver fish) and Order Collembola.

Gradual metamorphosis (Paurometabolous)

In this type of metamorphosis, the young ones resemble the adult in general body form, food habits, and occupy the same habitats. However, they differ from adults as they lack wings and external reproductive organs. The wings appear externally during the later instars.
eg: Grass hopper, Aphids etc.

Incomplete metamorphosis (Hemimetabolous)

Here, the young ones undergo more pronounced changes during their development, when compared to gradual metamorphosis. Usually, the adults and young ones differ in their food habits and habitats. Usually, the immature stages of the insects are spent in water, as the nymphs possess tracheal gills. They undergo a series of moults, and at last insects with fully developed wings which are suited to an aerial life are formed. eg: May flies, Dragon flies etc.

Complete metamorphosis (Holometabolous):

It is a complex form of metemorphosis which encomposses four developmental stages, namely, *eggs, larvae pupae*, and *adults*. The larvae which are coming out of the eggs are entirely different from the adults. The larval stage is a growing stage in which it undergoes a series of moults keeping the general form as such. Larvae of different orders are known by different names; larvae of beetles are known as *grubs* and butterflies and moths as *caterpillars*; and those of flies, bees, and wasps as *maggots*. The larvae when fully mature cease to feed and transform into the pupal stages. It is the non feeding inactive stage in the development of insects. The pupal stage is a distinctive feature of insects with complete metamorphosis. After a lapse of several days and months the adult insect emerges from the pupal stage with fully developed wings and other appendages. eg: Orders like Neuroptera, Lepidoptera (Butterflies and moths) Coleoptera (beetles), Diptera (flies), Hymenoptera (ants).

Hypermetamorphosis:

It is a modified form of complete metamorphosis, in which there is the presence of two markedly different larval stages. This is mainly noticed in the case of some blister beetles and in some families of Hymenoptera and Neuroptera.

29:8. Balance of life in nature

Every living organism is capable of reproduction, and gives birth to several offsprings for the maintenance of its species. The ability of reproduction in insects is astonishing. We may just take the case of an insect laying about 200 eggs and completing its life cycle in one month. If all the eggs come to maturity after one month, there would be 200 adult insects. Assuming that half of them (100) are females, they produce 20,000 eggs. If the same process of reproduction continues, after one year, the whole earth would be covered by the insects to a height of about 24 m. It is a matter to ponder over, what happens if all the insect species and other living organisms multiply like this without any hindrance. However, this does not happen in nature. It does not mean that the organisms abstain from reproduction; but a lions' share of the offsprings are destroyed at various stages of their development by some natural forces. In other words, the proportion of each and every organism on the earth is always kept in a balance. That is to say, in any environment, *undisturbed by human beings*, there is a broad pattern of equilibrium among the different species of plants and animals so that no species would be allowed to increase extraordinarily to the detriment of another. This phenomenon is called balance of life in nature or *population balance*.

Factors of population balance

Biotic potential and environmental resistance are the factors controlling the balance of life in nature. Biotic potential is the highest inherent capacity of an organism to reproduce under ideally optimum conditions. When a particular species multiplies like this, the various unfavourable climatic conditions (temperature, relative humidity, light, wind etc.), scarcity of food, natural enemies (predators, parasites, disease causing organisms, or germs) etc. play an important role in destroying the excessively produced progenies to keep the population balance.

If the rate of reproduction and rate of destruction (death) are equal, the balance is maintained. In organisms, where multiplication rate is very higher, death rate will also to be higher. For instance, in cotton ball worm (*Earis fabia*), the destruction is about 99.99%. In certain species, where the reproduction rate is too low, almost all the progenies may survive.

When the reproduction rate overcomes the destruction rate, *'population explosion'* will occur; and if death rate exceeds the reproduction rate, it may result in the complete destruction of the species.

29:9. Adaptations of insects

Many of the insects have got specific adaptations or devices to tide over the adverse conditions or have natural resistance. Such adaptations can be classified as morphological adaptations, behaviouristic adaptations, construction of protective structures, selection of safety niches etc.

Morphological adaptations: There are several types of morphological adaptations in insects to tide over the factors of natural resistance. Some insects have thick exoskeleton or scales on their body to resist unfavourable temperatures, humidity etc.; some have bristles, spines, hairs etc; and certain others can produce venomous liquids for their protection. Very minute insects may escape from large predators by their smaller size. Protective resemblence of insects with their surrounding (mimicry) as seen in stick insects, leaf butterfly, bark insects etc. enable them to escape from their enemies. We could note a large variety of morophological adaptations like these in insects.

Behaviouristic adaptations: Adaptation is achieved in some species through their particular behaviour. Certain insects threaten the predators (though they have no weapons), so that the predator is frightened. Others adopt dodging attitudes as feigning death. Some caterpillars, lady bird beetles etc. produce a type of offensive liquid, when the enemy approaches them.

Construction of protective structures: In some insects, the protective structures provide them the adaptation. eg: galleries of termites, hives of honey bees and wasps, underground nests of ants etc.

Selection of niches: Jumping or flying capacity of some insects provide them the means of adaptation and to escape from danger. Some species like locusts, migrate from unfavourable places to favourable places.

29:10. Insect collection

Collection and preservation of insects are a hobby for many people. However, it has got many other purposes, rather than simply a hobby. Usually, insects are collected due to their attractive colour and nature. A good collection of insects acts as a ready reference to understand the elements of insect life in a particular locality. It helps to understand their relation with the nature, plants and animals of the locality. A good insect collection could also contribute a lot in the classification of insects.

29:10.1. Insect collection devices

The major devices used for insect collection are a hand net, a killing bottle, specimen tubes, alcohol, glycerine, labels, setting boards, and a store box.

Insect net: Hand nets for collecting insects are available. Usually, nets made of cloth which are fitted on to a circular frame and handle are used. The cloth bag may be about 45–50 cm deep for collecting bigger insects, and it should be shallow and thick when used for collecting aquatic insects. A convenient hand net can be made by using the circular frame of a badminton racket.

Aspirator: An aspirator is used for collecting smaller insects like flies, aphids etc. The apparatus consists of a glias tube fitted with a two holed stopper. Two pieces of metal or plastic tubing are fitted to the stoppers. To the longer of the metal tubes, attached a rubber tube of about 50-60 cm length fitted at the ends a cloth piece. The longer tube is directed against the insects and by the sucking action the insects are collected into the bottle.

Killing bottle: Bottles made of thick glass are used as killing bottles. For killing the insects, chemicals like potassium cyanide, sodium cyanide and benzene are used. The chemical is placed in the bottom of the bottle and covered by a filter or blotting paper. The chemicals used in the killing bottle are extremely poisonous, especially cyanide. So the bottle should not be opened, except to put in or take out specimens. Insects like beetles and butterflies should not be kept in the same bottle, as it may damage the fragile specimens. Insects should be removed from the bottle as soon as they are killed; otherwise, they may be discoloured due to the action of the chemicals used.

Separator: Small insects can be collected by means of a separator or Berlese funnel. It usually has a sieve, for holding the litter or trash, which fits in to a funnel. As the litter dries, the insects move downward through the sieves and drop through the funnel, which opens into a killing bottle.

Sifters: Small insects can be first sifted on a cloth back ground, and then, they can be picked up by using an aspirator or wet camel hair brush.

Light traps: They are common devices used in surveys and other studies to find out the distribution and number of certain insects in a locality.

Baits: Baits of different materials are used to trap insects.

29:10.2 Preservation of insects

Soft bodies insects are usually preserved in 80 per cent alcohol or 4 per cent formaldehyde solution. Hard bodied insects may be mounted on pins, and if they are too small to be pinned, mount on card points or slides. Insects are usually put in relaxing jars before pinning. This avoid their breakage and damage while pinning. The jar contains wet sand or saw dust covered by cardboard pieces. Insects are put in this jar for two or three days to get them sufficiently relaxed.

Insect pinning: Insects are pinned by using specialised pins which are resistant to rusting. Depending upon the type of the insects, the part which is to be pinned varies. For instance, grass hoppers are pinned through the right side of the pronotum; bugs through the right side of the scutellum; beetles through the right elytron about the middle of the body; butterflies and moths pinned between the base of the fore wings; and bees and wasps through the thorax, slightly to the right of the midline.

Usually, insects are mounted about 2.5 cm above the pin point. The labels attached to the pins should also be uniform and kept at the same heights.

Spreading boards: Spreading boards are used in the case of insects, the wings of which are to be spread in the mounted condition. The boards are usually made of soft wood to facilitate easy pinning. The wings of inssects are kept in position, by pinning strips of paper across the wings

Insect boxes: Usually, the collected insects are kept in boxes, the bottom of which are lined with cork or such soft materials. Before storing in the boxes, the specimens are to be properly labelled. The label should give at least the following details—the host of the insect, the collecting date, locality of collection, name or inilials of the collector etc. Labels should be made of stiff paper of uniform size. The insect boxes are to be kept in a dry place with observations now and then. Keep the boxes clean as well as free of predatory insects which might have crept into the store box. Repellants like napthalene balls are used to drive away the common pests.

29:10.3. Rearing of insects

Rearing of insects is practised to get specimens in good condition. It is usually done in a natural condition as far as possible. Immature stages of insects are collected and kept in cages made of wire gauze along with their food materials. If the insect is one which pupates in soil, some loose soil is also put in to the cage. Insects attacking dried grains and such other food stuffs can be reared by enclosing the infested material in a good vial. Gall flies and such other parasitic insects can be reared like this and studied.

30. Bee keeping

30.1. Introduction

Honey bees form one of the most important group of productive insects. They give us honey, a valuable and nutritious article of diet having medicinal properties. Besides, the 'bee wax' obtained as a by-product from the bee-hives have got several commercial uses. Honey bees also help the mankind by way of assisting in the pollination of several crops. The role of honey bees in the pollination of cardamom is a well known fact. Realising the importance of honey bees, man started to domesticate them from time immemorial, and there are mentions of honey in the Bible and the *Puranas*. Nowadays, bee rearing has acclaimed the status of a commercial enterprise. The growing of honey bees on a commercial basis is known as bee-keeping or apiculture.

30:2. Kinds of honey bees

Honey bees belong to the family Apidae of the order Hymenoptera. Mainly, four species of honey bees are found in India. They are the large rock bee (*Apis dorsata*), the medium sized Indian honey bee (*Apis cerana indica)*, the little bee (*Apis florea*), and the Dammer bee (*Melipona irridipennis*). All these species are social insects living in colonies. The division of labour and other social instincts are also there among all the members of the colony. Of the four mentioned above, *Apis cerana indica* is the domesticated species grown extensively in India. We may see the general characters of these four species in brief.

Apis dorsata (rock bee): They are the biggest type of honey bees and are good honey gatherers. Rock bees make large single combs in open areas under overhanging rocks, branches of large trees, sides of buildings etc. Though they produce about 50-100 kg honey/year/colony, they are not domesticated due to many undesiable characters. They are of low temperament and ferocious in nature. Besides, they make single combs, which make the extraction of honey very difficult. They are also migratory in nature.

Apis cerana indica (Indian honey bee): This is the domesticated species in India. They are smaller in size than the rock bees, and found both in forests and plains. They mainly colonise in hollows of trees, cracks and crevices in walls, burrows in grounds etc. They make many parallel combs, usually seven to ten in number. They are not migratory in habits, and can be easily domesticated in artificial hives. The annual yield of honey is about 2-5 kg per colony.

Apis florea (little bee): This is the smallest of the three species of the genus *Apis* which constructs single combs on twigs, bushes, caves of buildings etc. They yield very small quantities of honey, but is very sweet and possess medicinal properties.

Melipona irridipennis, (Dammer bee): They differ from *Apis* bees in many aspects. They make small single combs and do not develop stings. They are very poor honey gatherers. and produce only about 100-200 ml honey/colony/year.

30:3 The bee colony

The honey bees are social insects and they live in colonies varying in strength from 20,000-30,000. This population consists of three categories of bees—the worker, the drone, and the queen.

Worker: The worker-bee is an imperfectly developed female and is incapable of reproduction. It is smaller in size than the queen or the drone. The workers are selfless members of the colony. They perform various duties in the colony like gathering of honey and pollen, constructing combs, rearing brood, defending colony from enemies, attending on the queens and the like. Usually, the adult workers go for honey gathering, and young workres look after the domestic affairs of the colony.

Drone: The drones are the functional male bees and are bigger and darker than the workers. They are sluggish in habit and remain idle in the bee-hive for most part of the day. Their only function is to mate the queen during her nuptial flight.

Queen: The queen is the functional female of the colony, and usually, only one queen is found in a colony. They are two or three times bigger than the workers. The only function attributed to the queen is that of reproduction and maintaining the colony strong.

30:4 Bee hives

The rearing of honey bees for getting honey and wax is termed bee keeping or apiculture. Usually, they are reared in artificial hives for the above purpose. Different types of hives like pot hive, book hive, house hive, nucleus hive, Newtons hive etc. are commonly used for keeping honey bees. Of these types, Newton's hive designed by Fr. Newton is the most popular hive in South India. The important parts of this hive are the floor board, brood chamber, wooden frames, super chamber and a roof with an opening guarded by wire gauge.

The keeping of honey bees in artificial hives has many advantages compared to natural shelters. One advantage is is that it protects the combs, and thereby, save considerable time, energy, and honey stored by the bees. In primitive methods, the honey combs are fully destroyed for extracting honey, and along with that, a considerable number of young and adult bees are also killed. This indescriminate killing of bees is completely eliminated in the artificial hive. Frequent extraction of honey is also possible in the artificial hives. It also ensures good protection to honey bees from inclement weather and natural enemies.

Newton's beehive: All parts are made of wood. It essentially consists of a floor board, a brood chamber containing the brood frames, a super chamber containing the super frames, and a roof. The hive is to be fixed over a termite proof stand of about one metre height and in a shady place. Also, provide oil bands on the stand or water troughs under them to protect from ants.

30:5 Important accessories needed for the honey industry

Dummy division board: It is used to confine bees to a limited space during lean season.

Comb foundation sheets: They are made of wax and are acting as support to construct comb cells by bees during honey flow season.

Swarm trap: It is used to trap the bees during swarming.

Queen gate: It is provided to prevent the queen from escaping out of the hive.

Smoker: Smoker is used to create smoke which helps in controlling bees, while collecting honey and catching new colonies.

Honey extractor. This equipment is used to extract honey from the combs. It consists of a drum containing a rack or box inside to hold the frames. The box can be rotated with the help of a gear system, and honey is thrown out from the combs by the centrifugal action.

30:6 Management of an apiary

The success or failure of bee keeping depends on the care taken by the owner in directing the desirable instincts of bees to his advantage and suppressing the undesirable characters. The important factors concerned with the bee keeping are as follows.

Selection of site

While selecting a site for starting an apiary, tha following points are to be kept in mind. An apiary should be located in a place where there is availability of plenty of nectar and pollen. It should be in a shady place well protected from direct wind and rains. Clean and fresh water should be available in the nearby areas and the site should be well drained. Provisions should also be there to protect the hive from termites and black ants.

Precautions to avoid sting of bees

The factors that irritate bees and make them sting are many. Inclement weather, rough handling, instinct to protect the young ones, entry of enimies, smell of the stings, excitement, absence of queen etc. are some of them. With care and attention given to the above factors, one can handle the bees with confidence. Some precautions like wearing heavy cloths or gunny bags and directing smoke can be resorted to handle bees—while collecting honey and during other operations—to avoid stinging by bees.

Care of colonies during breeding season

With the availability of enough pasturage during honey flow season, the activities in the colony will increase considerably and there is an increased rate of egg laying by queen. So, additiional space has to be provided for the increased population by supplying clean, combs or comb foundation sheets.

Swarm control

According to the need of the apiarist, new colonies are to be allowed, or are to be curbed. Swarming lead to depletion in strength of the colonies, and control of swarming can be achieved by various methods. Most important method is the destruction of the special queen cells—as the colonies will not swarm, unless a new queen is produced.

Uniting

When the colonies become weak or queenless or having bad traits, uniting is resorted. Direct uniting or newspaper methods are usually practiced.

Queen rearing

This is often followed to produce good pedegree queens, and whenever new queens are required. For this, the brood combs from the desirable colony are distributed in two or three newly made small hives. Then, a few cells in these combs containing the just hatched larvae are enlarged by cutting the adjacent cells. Queens are reared in these cells. This will lead to the emergence of a new queen in each hive.

Care during lean season

During lean months, availability of nectar and pollen will be very less. Due to this inadequacy of food, the strength of the colony goes down. In this condition, bees are to be confined to a small area in the hive, and are to be fed artificially by providing honey or sugar syrup.

30:7 Enemies of honey bees

Wax moth: The larvae of this moth live in tunnels which are made through the honey combs. They penetrate the wax layers, and thereby, dislodge them. In severe forms of attack, the combs will be fully covered by silken webs and faecal materials of larvae. In such cases the bees may desert the colony. By maintaining the hive in a clean and hygenic condition, the wax moth damage can be avoided.

Ants: The black ants and the red ants attack weak colonies and take away honey, pollen etc.

Wasps, Birds: Both wasp and birds are bee eaters. They catch bees from the hives as well as from outside.

Diseases of honey bees: Diseases caused by mites, viruses, bacteria, fungi, protozoa etc. are attacking the bees. Of these, Acarine disease caused by a parasitic mite *(Acarapis woodi)* and American foulbrood disease caused by a bacteria (*Bacillus larvae*) are important. Suitable precautionary measures should be taken against these diseases.

30.8. Properties and uses of honey

Honey may be defined as an aromatic, viscid, sweet fluid obtained by the modification of nectar of flowers by the honey bees. It contains about 20% moisture, 65—80% sugars, and several minerals and vitamins. It also contains certain enzymes and acids: The amount of moisture in honey has great influence on its keeping quality and granulation. It normally varies with the source of nectar. Excess moisture, if present, can be removed by artificial ripening—by keeping at 60°C in water bath for 30 minutes.

The worker bees collect nectar from the flowers and keep it in their honey stomach, till their return to the hive. The nectar is pre-digested in the stomach and mixed with the enzyme invertase—which splits the sucrose of the nectar to dextrose and levulose. The resultant fluid is then regurgitated into the honey cells. The moisture content in the fluid is lessened by taking it again and macerating it in their mouths and regurgitating back into the honey cells The winging action of the bees also help to reduce the moisture. All these processes of reducing the moisture content of the honey is called *natural ripening*. After this ripening, the honey cells are sealed with wax. In contrast to the ripe honey in the sealed cells, the honey in the unsealed cell is called unripe or green honey.

Honey is used in a variety of ways. it is an important item in several religious rites. It is a rich energy giving food; and along with milk, form a complete food. Honey is given to new born babies as a first food, since it provides ready energy. Honey can also be used with coffee, tea, or milk in place of sugar. It is a laxative and blood purifier and a curative for sore, ulcers in tongues etc. It is good for stomach and intestinal ulcers. Honey is alkaline in nature and is a good stomachic. It is an essential ingredient of many Ayurvedic and Unani medicines. Honey may also be used to make alcoholic drinks, skin and beauty lotions etc.

From the bee-hives, we get the honey as the main product. We may also get a by-product—the bee wax—without much effort. It is produced from old combs, cappings collected after honey extraction, and combs affected by wax moth.

Bee wax is a yellowish solid, insoluble in water, having an aroma reasembling that of honey. Chemically, it is a mixture of cerotic acid and myricyle palmitate. It becomes plastic, when heated; and brittle, when cooled. Bee wax is used for the manufacture of a variety of items, especially cosmetics like beauty lotions, creams, lipsticks, ointments and pomades. It is also used in the manufacture of boot, floor, and furniture polishes, paints and varnishes, inks, electrical insulating apparatus and candles.

31. Pest Management

31:1. Introduction

The word 'pest', in a broad sense, includes insects; invertebrate organisms such as nematodes, mites, slugs, and snails; vertebrate animals such as rats, squirrels,birds and jackals; disease causing organisms such as fungi, bacteria and viruses; and weeds, that cause significant and economic damage to standing crops, stored products and animals. However, the term 'pest' is usually used for those living organisms having defenite mouth parts which affect crop or livestock.

Insects had appeared on earth, very long before the descent of man. They depend upon the same plant and animal sources on which man depends for his food, shelter, clothing, and other needs. The struggle between man and insects had begun long before the dawn of civilization. It is still continuing, and will continue till human race endures on earth. For getting their requirements, insects cause injury to plants directly or indirectly, and nature of the damage caused by them is mainly dependant upon their feeding habits. In this chapter, we shall see the various control and management measures to be employed, so as to keep the pests at bay.

31:2. Pest control

The factors which are capable of making life hard for pests, that will kill, repel, or intefere with its feeding, mating, reproduction, or dispersal can be considered as methods of pest control, in it broadest application. In nature, the various factors like climate, topographic factors, and natural enemies of the insects keep the insect population at bay. This is called natural control, and here, the operations are not influenced by man. But, sometimes, the insect population which has survived natural control, stil, would be capable of causing sufficient damage to crops. Under such circumstances man has to think of some means to control them. The applied or artificial methods of insect control can be grouped as cultural, mechanical, physical, biological and chemical methods.

Depending upon whether these measures are applied as a preventive step before the actual occurrence of the pest or as a curative step to eliminate the insects after they had started attacking the crops, the control measures may be grouped into prophylactic or preventive methods and curative or direct methods.

31:2.1. Prophylactic or preventive methods

These methods are effective, especially in the case of certain pests which are known to occur in any area, year after year or season after season. eg: Stem borer of rice, Brown plant hopper of rice etc. These methods include the following:

Field or plant sanitation: Field sanitation measures such as regular removal of weeds, grasses, pest affected plants, or plant parts etc. help to eliminate the source of infestation of pest. In the case of rice, keeping the field bunds free of weeds help to reduce the attack of leaf and grass hoppers. Similarly, the removal and burning of infected twigs of coffee and citrus helps to reduce the attack of shot hole borer.

Cultural methods: The deep ploughing of the rice field after the harvest, would eliminate the breeding of stem borer moths in the sprouts from the stubbles. The use of pest free, healthy, seeds and seed materials may minimise the possible infestation of seed borne insects such as sugarcane scales, ginger scales, banana weevil and sweet potato weevil. Certain crop cultivars escape the attack of pests, as they come to maturity before the pests begin to cause much damage.

Growing pest resistant or tolerant cultivars: Growing of resistant or tolerant cultivar is one of the most effective and economical method of pest control. Pest resistant/tolerant cultivars are now available in almost all field crops.

Other prophylactic measures: There are several other prophylactic measures also worth mentioning here. These include treatment of seeds and planting materials with pesticides before planting; swabbing of tree trunks and branches with pesticides, especially to ward off the attack of borers; periodical drying of harvested produce to prevent infestation by pests of stored products, adjusting the time of sowing etc.

31:2.2.Direct or curative methods

Curative measures are employed to destroy a pest or check its further multiplication after it has already appeared on a crop. These measures can be grouped into cultural methods, mechanical methods, physical methods, legal methods, biological methods, and chemical methods.

Cultural methods: Cultural methods include ordinary farm practices which are employed, in such a way that the insect pests are either eliminated or prevented from multiplying their population. These practices are designed to hit at some weak points in the seasonal history or environmental or host adaptation of the insects. Cultural methods are the cheapest of all measures and include practices like crop rotation, mixed cropping, trap cropping, and tillage operations such as deep ploughing and flooding the field.

Mechanical methods: Here, the insect population is directly hit by adopting mechanical devices or manual operations. These include handpicking of egg masses, larvae or nymphs, and sluggish adults; hooking out adult rhinoceros beetle from the crown of cocount palms; passing a rope or thorny twig across rice crop to dislodge the case worms over standing water, which is then drained out and collected at the mouth of the field; digging trenches in the field to prevent the migration of army worms in groundnut; covering bittergourd fruits with polythene bags to prevent the attack of fruit files fixing tin bands around coconut trunk to prevent the attack of rats; setting light traps to attract adult moths and beetles etc.

Physical methods: These include artificial heating or cooling of stored products to kill the insect pests; steam sterilisation of soil to kill soil borne insects and nematodes; use of high frequency radio waves to kill grain weevils and flour bettles; sterilisation of male insects using chemicals or gamma radiations etc.

Legal methods: These are aimed at preventing the introduction of new insects/diseases/weeds etc. from foreign countries, preventing the spread of already established insects/diseases/weeds etc. within the country, and forcing the farmers to take up effective control measures against established insects, diseases, or weeds etc.

These are achieved, mainly by enforcing certain laws. In Kerala, there exist restriction to purchase and transport coconut seedlings from root (wilt) affected districts to other districts. Plant quarantine laws also prohibit import of planting materials, without clearance certificates.

Biological methods: The successful control of a pest species by means of another living organism, encouraged and disseminated by man, is called biological control. Such a programme involves the introduction, encouragement, multiplication, and dissemination of natural enemies by man with his own efforts. The natural enemies of insects include some of the insects themselves—both parasitic and predatory, disease causing viruses, bacteria, fungi, protozoa, parasitic nematodes, and predatory vertebrates. In Kerala, black headed caterpillar of coconut is successfully controlled by releasing parasitic natural enemies like *Bracon brevicornis* and *Trichospilus pupivora*. Efforts are also under way to control the mealy bug of coffee by releasing predatory lady bird beetles.

Chemical methods: Sometimes, owing to many reasons, the preventive plant hygeinic measures, cultural and other curative measures etc., will not be effective in bringing down the pest population to a balanced level. so that economic losses are avoided. Under such situations, chemical agents are resorted to—both as preventive or curative measure—to minimise the pest damage. These chemicals are called *pesticides*. Today, a large number of pesticides in different formulations, having different mode of action are available in the market.

31:3 Integrated methods of pest control

It is not always possible to have an effective control of pests by the use of pesticides alone. Neither, the adoption of cultural, physical, biological, or mechanical measures alone would bring down the pest problem significantly below the injury levels. Sometimes, there may be fresh outbreaks of pests induced by pesticide application, mainly due to the destruction of natural enemies of pests. Very often, the role played by the natural enemies in controlling the pest population is totally ignored. The beneficial insects like pollinators are also killed by the indiscriminate use of chemicals, besides leading to the pollution of the eco-system. The prolonged use of chemicals may result in the development of resistant biotypes of pests. The residues left over in the crop produce and soil often cause health hazards to man and animals. The dependance on chemical control has to be reduced and rationalized, because of the many similar hazards related with it. Thus, pest control gave way to pest management or rather integrated pest management.

An integrated pest management is a system in which we take into consideration the biotic potential of the pest, the environment in which they live, and all the compatible methods to maintain the pest population below the economic injury level. The methods employed should be augmentative with the objective of pest control, with little or no harm to the eco-system. This system is not just a super imposition of one method over another. It should be drawn out taking into consideration the nature of the crop, pest, environmental features etc. and giving utmost importance to the ecosystem. The main principles to be followed include the encouragement of the existing mortality factors and the introduction of additional mortality factors into the ecosystem without much disturbance to it.

In any pest management system, our first aim should be to preserve maximum natural control. Parasites, predators, and pathogens contribute to natural control when pests are endemic. The absence of natural enemies may happen only where man has interfered in the balance of nature. Preservation of natural enemies can be supplemented with the introduction of biological control agents whereever possible.

In recent years, growing pest resistant cultivars of crop and search for more such cultivars have evoked much response among farmers and scientisis. Growing resistant or tolerant cultivars are, of course, a major part of the integrated system of pest management.

Another method is by limiting or reducing the source of pest inoculum and pest multiplication. Adjusting time of planting, crop rotation, destruction of crop residues infested with the pest, clean cultivation, destruction of alternate hosts etc. help in reducing the pest inoculum. It is a known fact that introduction of ducks in paddy fields check the spread of certain pests to a considerable extent.

Pest multiplication in fields also has to be limited. This is mainly achieved by limiting favourability of the crop for large scale egg laying and consequent high population of the pest. Insects require nutritious food, especially amino acids, for their multiplication. Giving too much nitrogenous fertilizers in single doses result in the concentration of free amino-acids. So, methods which prevent large concentration of amino acids in plants have to be an integral part of the pest management. For instance, split doses of fertilizers and application of urea with neem cake will help in the reduction of pest population.

Chemical methods are to be adopted in the most judicious manner. It may be the most effective method of saving a crop severely infested by large pest population. Extreme care should be taken to use pesticides, only to supplement the natural methods of control. The general principles to be observed while adopting chemical methods are:

1) Need based application

2) Use of selective insecticides

2) Adopt selective method of application eg. Seed treatment, row application, seedling root dip etc.

4) Use pesticides which are harmless to natural enemies.

5) Avoid broad spectrum pesticides.

6) Avoid excess doses of pesticides.

Another area of interest in an integrated pest management is the third generation pesticides such as juvenile hormones, Chitin synthesis inhibitors, attractants, repellants, antifeedants, pheromones, microbial pesticides, chemosterilants etc. Wherever possible, these materials may also be attempted to.

In nutshell, the use of various natural, cultural, physical, mechanical, biological, chemical, and other modern methods in an integrated compatible manner, so as to bring down the pest population below the economic injury level with as little disturbance to the ecosystem as possible, is integrated pest management.

32. Pesticides

32:1. Introduction

All the chemicals which are used to poison and control the pests are called pesticides in a broad sense. Chemicals which control insects by chemical action are called insecticides. Similarly, chemical substances used to control fungi, weeds, nematodes, mites, rodents and molluscs are referred as fungicides, weedicides (herbicides), nematicides, miticides (acaricides), rodenticides and mollusicides, respectively. In this chapter on pesticides, more emphasis is given to insecticides, since herbicides, fungicides, nematicides etc. are discussed elsewhere. An insecticide can be defined as a substance or a mixture of substances intended for killing, repelling, or otherwise preventing insects from attacking crops and livestocks.

32:2. Insecticide formulations

The basic insecticide material or toxicant may not be in a state to be applied directly on crops. So, it is essential that they are formulated in suitable ways for different methods of application. The term *formulation* is used to denote the processing of a pesticide compound by any method which improves its properties of storage, handling, application, effectiveness, or safety. The commonly available insecticide formulations are dusts, wettable powders, solutions, emulsifiable liquids, insecticide aerosols, fumigants and poison baits. Sometimes, the same insecticide is available in different formulations. The suitable formulation has to be selected depending upon the crop, soil conditions, nature of insect attack, environmental conditions, and availability of equipments for application. Common formulations, usually used are briefly discussed below.

Dusts: A dust formulation consists of the toxicant (active ingredient) and an inert carrier or diluent in dust form. It is prepared, either by mixing with or by impregnation, on a suitably finely divided carrier. The toxicant in a dust formulation ranges from 0.65 to 10%. The particle size should be less than 100 microns. The carriers are usually an organic flour or a pulverized mineral such as sulpher, lime, gypsm, talc, and clay. eg., BHC 5% dust, BHC 10% dust etc.

Granules: In a granular formulation, the particle is composed of a base which may be an inert material or vegetable carrier impregnated or fused with the toxicant. The size of the granules varies from 0.25 mm to 2.5 mm. Granules, usually contain 2 to 10% concentration of the toxicant eg., carbofuran 3G, phorate 10G. Granular pesticides are commonly used for the control of soil inhabiting insects and nematodes. Granules of systemic insecticides are used for making the plant poisonous to sucking insects. This is achieved by applying to the soil or applying into the crown of plants. eg., banana, sorghum, maize etc.

Wettable powder: This is a powdered formulation which yields a stable suspension when diluted with water. It is formulated by blending the toxicant with a diluent and dispersing or spreading agents eg., BHC 50 WP.

Emulsifiable concentrates: A large number of pesticides are formulated in this form. An emulsifiable concentrate contains the toxicant, a solvent for the toxicant, and an emulsifying agent. It is a clear solution and gives an emulsion when diluted with water. eg., Quinalphos 25 EC. When sprayed, the solvent evaporates quickly, leaving a deposit of toxicant, from which water also evaporates. Emulsions are not stable and tend to separate into component parts. Therefore, the mixture is to be agitated from time to time.

Concentrated insecticide liquids: The toxicant at highly concentrated level is dissolved in non-volatile solvents. This is formulated, mainly to be applied from higher altitudes in extremely fine droplets, especially through aerial spraying using helicopters. The concentrated insecticide liquid is, therefore, non-volatile and have high viscosity and high specific gravity.

Fumigants: A chemical compound which is toxic and volatile at ordinary temperature is known as a fumigant. Fumigants are usually in liquid form and sometimes as tablets kept in air tight containers. Actually, they are mixtures of two or more gases. Areas not easily acceptable to other chemicals can be easily reached by the fumigant due to penetration and dispersal effect of the gas. eg., aluminium phosphide, DDVP, ethylene di bromide etc.

32:3. Classification of insecticides

A large number of insecticides are used for the control of insect pests of crops, livestock, and stored products. While studying individual insecticides, it is quite common to classify them into certain groups so as to have a more easier and meaningful study. Insecticides are usually classified in three ways, viz., based on their mode of entry, mode of action, and the chemical nature of the toxicant (active ingrediant).

32:3.1. Classification based on mode of entry

Based on the mode of entry of pesticides into the pest-body, they are classified into four groups.

Stomach poisons: This kind of poisons when ingested by the insects act on their digestive system and bring about the kill. This type of poisoning is mainly limited to chewing insects. eg., BHC.

Systemic insecticides: A systemic insecticide is capable of moving through the vascular system of plants and poison insects that feed on the plants. In other words, a systemic insecticide is a chemical compound that controls an insect pest remote from the point of application. For instance, a soil applied systemic insecticide can control the insects feeding on the leaves or stem of the plant growing in that soil. The compounds when applied are absorbed by the plants, get translocated within it, providing protection and eradication of already established pest menace. Mainly, sucking insects are controlled by the application of these insecticides. eg., phosphamidon, dimethoate, phorate, carbofuran etc.

Contact poison: A contact insecticide controls the pests by means of getting contact with the pest body. The poison on contact with the wax layer of insect body gets absorbed on the surface of the cuticle. It also penetrates the pest body through vulnerable sites like sutures, membranes, base of setae and tracheal system. A contact poison may be directly applied on the pest species or the plant surfaces coming into contact with the pest. These are effective against externally feeding insect pests. eg., carbaryl, methyl parathion, quinalphos etc.

Fumigants: Fumigants enter the insect body in the gaseous form through the tracheal system and kill them. All kinds of insects, irrespective of their feeding habits, can be controlled by fumigants. These are effective against storage pests and concealed pests like red palm weevil, eg., Aluminium phosphide, DDVP etc.

There is one difficulty in following this classification. Many of the insecticides now available in the market enter into pest body in more than one way. This is obvious from the following examples.

Systemic and contact—eg. dimethoate, monocrotophos.

Systemic, contact and fumigant—eg. phorate.

Contact and stomach—eg., DDT, endosulphan.

Contact, stomach and fumigant—eg., BHC, DDVP.

So, nowadays, these terms are mainly used to describe the modes of entry and general nature of the insecticides rather than to classify them.

32: 3.2. Classification based on mode of action:

Based on the mode of action, insecticides are classified as physical poisons, protoplasmic poisons, respiratory poisons, or nerve poisons.

Physical poison: The Insecticide chemicals which bring about the control of insects by exerting a physical effect are physical poisons. Heavy oils, tar oils etc, cause the kill of the insects by asphyxiation, ie., by exclusion of air. Inert dusts cause loss of body moisture due to their abrasiveness as in aluminium oxide; or absorb moisture from the body due to their hygroscopic nature as in charcoal, thus bringing about their kill.

Protoplasmic poison: Protoplasmic poisons kill the insects by precipitation of protein, especially through the destruction of cellular protoplasm of midgut epithelium. Fluorine compounds, arsenic compounds, etc. are examples of this group.

Respiratory poison: These poisons block the cellular respiration by combining with enzymes like cytochrome oxidase and other oxidases containing iron, and thus inhibiting their catalytic action. eg., hydrogen cyanide, methyl bromide etc.

Nerve poison: Nerve poisons function by blocking acetyle choline esterase in insects and warm blooded animals, thus causing the death of the pest species. eg., Organophosphorous insecticides, carbamates, organochlorines etc.

32:3.3. Classification of pesticides based on chemical nature

This system of classification is the most important one and is used widely. Here, the chemical characteristics and relationships are made use of. insecticides are broadly grouped into *inorganic* and *organic* compounds based on their chemical nature. Inorganic compounds include arsenic compounds, fluorine compounds, sulphur and lime sulphur, barium carbonate, thallium sulphate, zinc phosphide etc

Organic compounds are again grouped into hydrocarbon oils, insecticides of animal and plant orgin, synthetic organic compounds, and other miscellaneous organic compounds.

Hydrocarbon oils—eg; petroleum oils (mineral oils), tar oils etc.

Animal origin— eg; Nereistoxin.

Plant origin—eg; Pyrethroids, Nicotinoids, Rotenoids, Azadirachtins etc.

Synthetic organic compounds—eg, dinitrophenols, thiocyanates, organochlorines, organophosphorus compounds, carbamates, organic sulphur compounds, etc.

Other miscellaneous organics—eg: fixed oils and soaps.

32.4 Important insecticides

A short description of the commonly used groups of insecticides is given in this section.

32:4.1. Insecticides of plant origin:

Nicotinoids: Nicotinoids are well known for their insecticidal properties. Nicotine (2 to 14%) is found in the leaves of *Nicotiana tabacum* (tobacco) and *N. rustica*. Nicotine is the most important alkaloid in tobacco contributing to about 97 percent of the twelve alkaloids present. It is a highly toxic nerve poison, and do not leave any harmful residual effect. Nicotine sulphate, containing 40 percent alkaloids, can be safely used for the control of sucking insects like aphids and thrips. Tobacco in water and soap is very commonly used for the control of aphids, thrips etc , especially in vegetable crops.

The preparation of tobacco decoction is as follows: Take 500 g of tobacco wastes (refuses, leaves, or stem), chop into pieces, and steep it in 4.5 litres of water for 24 hours. Then it is squeezed well and the decoction is taken. In another vessel, take 120 g of sliced ordinary bar soap, and dissolve it in sufficient quantity of water. The soap solution is then added to the tobacco decoction, and the resultant solution is stirred well. The stock solution thus obtained is diluted with water 6-7 times, and then sprayed on crops.

Pyrethroids: Pyrethroids are powerful contact insecticides having quick '*knock down*' effect. The chief source of pyrethroids are *Chrysanthemum cinerariaefolium*. Compounds such as piperonyl butoxide are used with pyrethroids as synergists. Pyrocon E 2/22 (1 part of pyrethrin + 10 parts of piperonyl butoxide) is recommended for the control of coconut red palm weevil.

Azadirachtin: It is observed that an alkaloid found in neem trees (*Azadirachta indica)* has insecticidal properties. The alkaloid azadirachtin acts as a good antifeedant, repellant, or deterrent against a number of insects such as locusts, grass hoppers, and other chewing insects, especially of the order Lepidoptera. Since it is harmless to animals and man, it is suitable in vegetable crops. For spraying on crops, a neem-kernal suspension is usually recommended. The preparation is as given below:

Take mature dried neem kernals, and grind into a coarse powder. The effective concentration of the suspension recommended is 0.1-0.3 per cent. For preparing a 0.2 percent concentration, 2 gm of the powered neem seed is required per litre of water. The required quantity of the coarse powder is put in a small muslin cloth-bag, and dipped in the required quantity of water for about 12 hours. Thereafter, squeeze the cloth bag repeatedly, after dipping in the solution, until the outflowing liquid turns light brownish. This can be directly sprayed on crops.

39:4.2. Synthetic organic insecticides

Synthetic organic compounds are the most commonly used insecticides in the field. The use of these chemicals became popular only recently. Until 1939, only inorganic compounds were used. The discovery of insecticidal properties of DDT in 1939 revolutionized the pest control operations. Since then, more and more compounds are being added to the list, and they are described, usually, under certain broad groups such as organo chlorines, carbamates, organo-phosphates etc. We shall see the important groups under these categories, and major insecticides among them.

Organo chlorine compounds

Organo chlorine compounds, basically contain carbon, hydrogen, and chlorine, and in certain cases, oxygen and sulphur too.

DDT (Dichloro diphenyl trichloro-ethane): D D T was first synthesized by Othnar Zeidler, a German Chemist in 1874. However, its insecticidal properties were discovered only in 1939 by Paul Muller. D. D. T. is a contact and stomach poison with long residual effect. It is effective in controlling a wide range of insects affecting crops, stored products and animals. It is usually formulated as 10 percent dust and 50 per cent WP, and marketed under various trade names.

The indiscriminate use of DDT has posed several problems. It has many undesirable side effects, due to the stable chemical nature and high lipid solubility. Killing of non-target organisms such as natural enemies and thereby disrupting the ecosystem is one among these. DDT passes through the food chains of organisms, resulting in the killing of non-target organisms such as fishes, birds, wild animals etc. D D T is absorbed by the body lipids, and it is even detected in the milk of human beings. D. D. T. poisoning suppresses the formation of egg shells in birds. Another hazard is development of insect biotypes resistant to DDT toxicity, due to its continuous use. Because of these hazards to ecosystem and human health, DDT is banned totally in several countries. In India, its use is being discouraged in the field of agriculture and not recommended at all for food crops.

B H C (Benzene hexa chloride): The correct chemical name of the material is Hexa Chloro Cyclohexane and is also abbreviated as HCH: The active ingredient is a mixture of a number of isomers of which gamma isomer is the lethal component. BHC contains 10–18% of gamma isomer. BHC is a contact and stomach poison with fumigant properties also.

BHC is effective against a number of insect pests such as caterpillars, beetles, bugs, grass hoppers, locusts etc. It is a good soil insecticide, and commonly used to control termites and ants. BHC is phytotoxic to some plants, especially cucurbitaceous vegetables. It is commercially formulated as 5% WP, 10% dust, and 5% dust, and available in several trade names. The recommended dosage for spraying is 0.2%. Dust application is to be done at 2.0 kg ai/ha. Waiting period is 15–20 days.

Lindane: Lindane is a purified form of HCH which contains 90-100% of gamma HCH. This is suitable for the control of pests of vegetables, since this does not taint the products unlike ordinary BHC.

Cyclodiene compounds

These are highly chlorinated cyclic hydrocarbons which includes chlordane, heptachlor, aldrin, dieldrin, endrin, endosulphan etc.

Endosulphan: It is a contact and stomach poison which is slightly fumigant.

It is effective against a number of sucking and chewing insects. This is usually recommended for the control of tea mosquito in cashew. It is less toxic to honey bees. However, it is highly toxic to fishes.

Commercial formulations—Thiodan 35 EC; Hildan 35 EC; Starsulphan 35 EC; Corosulphan 35 EC; Premier Endosulphan 35 EC; Hexasulphan 35 EC; Endocel 35 EC; Hexasulphan 4% DP; Parrysulphan 4% DP; Thiotex 4% DP.

Dosage — 0.05% ai./ha (spray)
— 2 kg ai./ha (dust)

Organophosphorus compounds

A good number of presently used insecticides come under this group. A few important insecticides of this group are described here.

Dichlorvos (DDVP): It is a contact insecticide with fumigant action. It is having a quick knock down action. The toxicity lasts for only 24 hours, and does not leave any residues. Therefore, it is safer to be applied on vegetables.

Commercial formulations — Vapona 76% EC; Nuvan 100% EC; Marvex super 100% EC.

Dosage — 0.05% ai (spray)
Waiting period — 1 day

Phosphamidon: A systemic insecticide with slight contact action, and effective against many sucking, chewing and mining insects. It is a very common insecticide used by farmers.

Commercial formulations — Dimecron 86% EC

Dosage — 0.05% ai. (spray)
Waiting period — 8–10 days.

Quinalphos: A broad spectrum contact insecticide with knock down action. It is effective against sucking and biting pests of rice, pollu beetle of pepper, ginger stem borer, cardamom thrips etc. It is also effective against mealy bugs and scale insects.

Commercial formulations — Ekalux 25% EC; Quinalphos 25% EC; Quinalphos 5% G; Quinalphos 1.5 % DP.

Dosage — 0.025%-0.05% ai. (spray)
1.5 kg ai./ha (granules)

Waiting period — One week

Mercaptothion: It is a safe insecticide with contact action for controlling pests of vegetables, fruits, stored pests, and pests of poultry and cattle.

Commercial formulations — Malathion 25% WP; Malathion 50% EC; Malamar 50% EC; Cythion 50% EC; Malasandoz 50% EC; Star Mal 50% EC; Cythion 5% DP.

Dosage — 0.1% ai. (spray)
0.5 kg ai./ha (dust)

Waiting period — 3–5 days.

Methyl parathion: It is a general insecticide with contact action. It is having rapid knock down action; and used against many sucking and biting insects. It is harmful against natural enemies.

Commercial formulations — Metacid 50% EC; Paramar M 50% EC; Paramet M 50% EC; Parataf 50% EC; Metacid 2% DP; Parataf 2% DP; Ekatox 2% DP.

Dosage — 0.05% ai. (spray)
0.5 kg ai./ha (dust)

Waiting period — 7 to 10 days.

Dimethoate: A systemic insecticide with contact action. It has got miticidal properties too.

Commercial formulations — Rogor 30% EC; Dimor 30% EC; Tara 909 30% EC; Corothioate 30% EC.

Dosage — 0.03-00.5% ai. (spray)

Waiting period — 7 days

Monocrotophos: It is a systemic and persistant insecticide with long residual action. It has got ovicidal effect as well. It is used to control many sucking pests of rice including brown plant hopper.

Commercial formulations — Nuvacron 40% EC; Monocrotophos 40 % EC; Monocil 40% EC; Corophos 36% EC; Monophos 40% EC.

Dosage — 0.05% ai. (spray)

Waiting period — 3-5 weeks.

Phorate: It is a systemic insecticide cum nematicide, formulated only in granular form, suitable for pest control in rice and banana.

Commercial formulations—Thimet 10% G; Phorate 10% G.

Dosage — 1.5 kg ai./ha.
(Soil application)

Waiting period — 3 weeks to 3 months

Carbamates

These compounds are derivatives of carbamic acid and dithio carbamic acid. Carbaryl and carbofuran are important among these.

Carbaryl: It is a contact insecticide with slight systemic action, effective against a wide range of insect pests. Usually formulated as 5% DP, 10% DP, 50% WP, and 85% WP. A micronised formulation Sevin 85% S is also available.

Dosage — 0.15-0.20% ai. (spray)
2 kg ai./ha (dust)

Carbofuran: It is a systemic insecticide and nematicide, effective against sucking and soil insects. It is widely used for the pest control in rice and banana.

Commercial formulations — Furadan 3 G; Hexafuran 3 G.

Dosage — 0 5 to 0.75 kg ai./ha
(Soil application)

Waiting period — 20-30 days.

32:5. Handling pesticides

Pesticides are highly toxic materials. and extreme care should be taken while handling them. If not handled properly, it may prove dangerous to human beings and domestic animals. The following precautions should be observed while handling them.

1) Pesticides should be stored in their original containers only, and kept in separate locked cupboards out of reach of children.
2) The instructions found on the labels should be carefully read and strictly adhered to, while handling them.
3) Spray solutions should be prepared in open places, and bare hands should never be used for mixing the chemical with water.
4) Empty containers after use should be destroyed or buried.
5) The chances of inhaling of pesticides should be avoided. Smoking, chewing, eating, or drinking while mixing or applying the chemicals should be avoided.
6) Spilling of insecticides on skin or clothing should be avoided as far as possible. If happened accidentally, thorough washing with soap and water should be done.

7) It is preferable to use protective clothing and devices, while handling pesticides to avoid exposure to sprays and drifts.

8) Spraying and dusting should never be conducted against wind. These operations should be done in calm and cool weather.

9) After handling pesticides, hands, face and body should be thoroughly washed and clothing changed.

10) Washing of equipments and containers connected with the use of pesticides in or near wells, ponds, or streams, should be avoided.

11) Persons engaged in spraying or dusting pesticides should undergo regular medical check up.

12) If any poisoning is suspected due to pesticides, the nearest physician should be consulted immediately.

As already pointed out, pesticides being toxic to human being and animals, extreme care should be taken in their handling and application. There is no doubt that the indiscriminate use of pesticides leads to pollution of the ecosystem. Besides, the insecticides are more harmful to the beneficial insects and natural enemies than to the harmful insects. This often lead to killing of non-target insects. In the absence of the natural enemies that had been exercising a partial control over the pests in the area, the pests may rapidly return to economic injury level. This condition due to the disturbance in the pest-natural enemy balance is called *pest resurgence*.

The pesticides indiscriminately used enter into the biological chain, get subjected to biological magnification, and ultimately reach human beings. Recently, the presence of DDT and BHC in exceeding permissible limits has been detected in many vegetables sold in Indian markets, and even in the breast milk of human beings. A good number of insect species have developed resistance to some of the commonly used insecticides like DDT. According to United Nations Environment Programme, every year about 10,000 people die in the world by pesticide poisoning, and the health of another 4,00,000 is permanently impaired.

32:6. Preparation of spray solution:

It is a must that the insecticides should be applied at the recommended concentration. There are some formulae, which can be used to find out the quantity of insecticide required to be dissolved in one litre of water to get the specified strength, and also to find out the concentration of the spray solution, when a known quantity of the commercial formulation is added to a known quantity of water.

When we know the recommended dosage of an insecticide in terms of the concentration of active ingredient in the final spray solution and the strength of commercial formulation in percentage, the following formula can be used to find out the quantity of commercial formulation in g or ml to be dissolved in one litre of water.

$$\text{Quantity of commercial formulation in g or ml, to be dissolved in one litre of water, to get the desired strength} = \frac{1000 \times \text{Dosage given as percentage of ai. in the final spray solution.}}{\text{Strength in percentage of the commercial formulation.}}$$

eg., The recommended dosage of quinalphos against pepper pollu beetle is 0.025% spray. One commercial formulation of quinalphos, available in the market is Ekalux 25 EC. The quantity of Ekalux 25 EC, to be dissolved in one litre of water, so as to spray it at a final strength of 0.025% of quinalphos is,

$$= 1000 \times \frac{0.025}{100} \times \frac{100}{25} = 1000 \times \frac{.025}{25} = 1 \text{ ml}$$

If a particular area requires 500 litres of spray fluid at this rate we need 500 x 1 ml = 500 ml of Ekalux 25 EC.

When we have added a known quantity of commercial formulation to a known quantity of water, the following formula can be used to find out the strength of finished spray solution in terms of percentage of ai.

$$\text{Strength of finished spray solution in \% of ai.} = \frac{\text{Quantity of commercial formulation used in litre or kg} \times \text{Strength of commercial formulation in \%.}}{\text{Quantity of finished spray solution}}$$

eg., If 500 ml of Ekalux 25 EC is added to 500 litres of water, the strength of quinalphos in the spray solution is

$$= \frac{0.5 \times 25}{500} \text{ or } \left\{\frac{500 \times 25}{500{,}000}\right\} = 0.025\%$$

33. Plant parasitic nematodes

33:1. Introduction

. The group of animals which come under the Phylum Nematoda are known as nematodes. Several other names are also used for nematodes such as thread worms, eel worms, round worms etc. These names indicate that they are wormy in nature. They are found everywhere, and great diversity exist among them. Some are free living in soil or water; while majority of them are parasites of animals or plants. The group of nematodes which parasitize plants are known as phytonematodes, plant parasitic nematodes or simply plant nematodes (Fig. 33.1). The plant nematodes are particularly important to us on a crop production point of view. In this chapter, the main focus is on plant parasitic nematodes and their control, especially under Kerala conditions.

The plant nematodes are very small, usually microscopic, of about 0.02 to 1.00 mm in length. Every parts of plants such as roots, stems, leaves, buds, flowers, seeds etc, are liable to be attacked by one or other nematodes. However, most of the nematodes are seen in soil, attacking the under ground parts of plants. Some of the nematodes are endoparasites which enter into the roots of plants and feed from within. The mouth of the plant parasitic nematode is modified as a stylet. It is the stylet which aids the nematode to penetrate into the plant tissues and suck sap from them. Nematodes may be classified on the basis of parasitic or feeding habits and plant parts attacked.

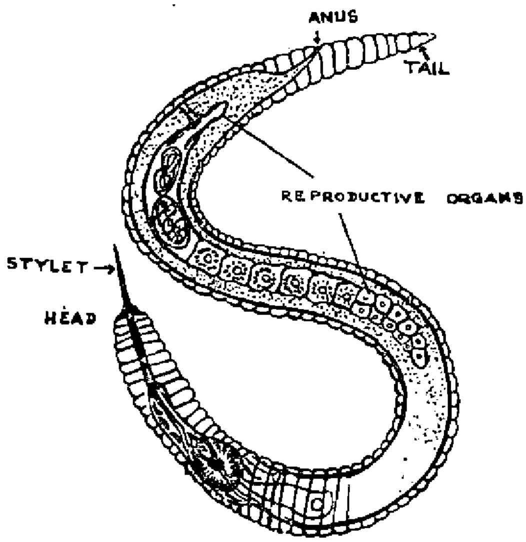

Fig. ypical plant nematode

33:2. Symptoms and damages caused

The plant parasitic nematodes are obligate parasites. While feeding the plant tissues, they inject several digestive enzymes into the plant cells which alter the plant metabolism. They act as primary pathogens in such cases. They drain the plants of the cell sap, destroy the plant cells, and disrupt the transporting system in plants. This leads to stunted growth, distortion of leaves and stems, development of galls, abortion of flowers etc.

Sometimes, nematodes attack the plants in combination with other soil plant pathogens like bacteria or fungi, leading to multiple disease symptoms. The primary injury on plant tissues, caused by the namatode attack, acts as entry point for other pathogenic fungi and bacteria resulting in serious complex diseases. Some of the nematodes like root knot nematodes are responsible for poor seed germination and seedling damage. The altered metabolism of the plants due to the nematode attack make the plants more vulnerable to the attack of secondary pathogens. Some of the plant nematodes are found to act as vectors of serious soil borne virus diseases.

The visible symptoms of nematode attack are not well defined, and it may be confused with the symptoms produced by other pathogens. They are often of generalised type and unspecific which gives the impression that the plants are suffering from shortage of nutrients and water. Some of the common symptoms produced by nematode attack on plants are stunted growth, chlorosis, leaf curl, browning of leaves, galls on stem and leaves, leaf drop, root rot, root lesions, root knots, proliferation of roots, swelling on root tips, shallow and reduced root system etc. Since many of these symptoms are also produced by other pathogens, laboratory examination of the diseased parts and soil is highly essential to make sure of the association of nematodes in nematode induced plant diseases.

33:3. Common plant nematodes

The common nematode parasites found in association with crops are described below

Root knot nematode (Meloidogyne spp.)

These are internal parasites. They are the most common plant parasitic nematode widely distributed in India. They are found to attack crops like vegetables, pulses, tubers, coffee, cocoa, groundnut, tea, black pepper etc. As a result of attack, knot like galls are produced on the roots of plants. The affected plants will be stunted in growth and wilt during day time even if sufficient moisture is present in the soil. An important species causing serious damage under this group is *Meloidogyne incognita* which affects brinjal, chillies, tomato, cotton, carrot, bhindi, pulses, pepper etc.

Cyst nematode

The dead mature females of this nematode transform into a cyst. The cyst contains the eggs which are released only when favourable conditions are present. This cyst forming nature help these nematodes to tide over adverse conditions, and make them very resistant to control measures. Majority of nematodes under this group are host specific. eg: *Heterodera rostochinensis* (Golden nematode of potato), and *Heterodera oryzicola* (Rice cyst nematode).

Burrowing nematode

They are internal parasites which feed on the root tissue from within. They completely damage the feeder root tissues, and lead to the complete destruction of root system resulting stunted plant growth. eg: *Radopholus similis*—which affects crops like tea, banana, coffee, pepper, cardamom, citrus, coconut, etc.

Root lesion nematode

These group affect a number of crops such as vegetables, coffee, cotton, rice, pineapple, spices, etc. They are similar to burrowing nematodes and cause lesions by entering into the roots. Their life cycle is completed inside the roots and come out only when the roots are fully decayed and unfit for feeding. The wounds made by these nematodes facilitate the entry of other pathogens like fungi and bacteria.

The combined attack by the nematodes and the pathogens, causes complex plant diseases like root rot and wilting. eg: *Pratylenchus* spp.

Reniform nematodes (*Rotylenchulus* spp.)

The adult females of these species are kidney shaped and hence named as reniform nematodes. They are semi endoparasites, burying only their anterior portion into the host tissue. These nematodes are found to attack chillies, tomato, bhindi (okra), brinjal, cotton, castor, papaya, pulses etc. Due to their attack, the root system is reduced considerably.

Rice root nematode (*Hirschmanniella oryzae*)

This nematode infects rice roots and make them hollow. The feeding adversely affect the absorption of water and nutrients, production of tillers, and finally grain weight. Besides rice, this nematode is also parasitic on other monocot crops like bajra, sugarcane and wet land weeds.

33:4. Control of nematodes

The control of nematodes is a must for successful crop production. The complete eradication of nematodes from a particular area is difficult, and as such control measures are usually aimed at keeping the nematode population as low a level as possible to get profitable yields. Different methods of control are resorted to; which include cultural methods, biological methods, physical methods and chemical methods.

33:4.1. Cultural control

Though not as effective as chemical methods, if adopted for a number of years, they are found to bring about significant results. The main aim of cultural methods is to keep the field with minimum nematode population load. The common measures include the following.

Crop rotation: Host specific nematodes can be controlled by following suitable rotations. Non-host crops are to be grown in rotation with host crops for different intervals.

Fallowing, Ploughing, Flooding etc. Summer fallowing with periodical ploughing and flooding are found to bring about good control of some nematodes like root knot nematodes. The nematodes are very sensitive to heat and they may not be able to tide over the high temperature prevalent in hot summer months.

Trap cropping: Here, the nematodes are first allowed to attack and grow in a susceptible and less remunerative crop; and then, the crop is destroyed along with nematodes before they complete their life cycle and multiply further. Such crops grown are called 'trap crops' and the method is trap cropping.

Soil amendments: Applying organic amendments such as green manures (green leaves), cattle manure, oil cakes, saw dust, paddy husk etc. are found to reduce the nematode population. They aid in the build up of the natural enemies of nematode parasites and release some products in soil which are toxic to nematodes.

Resistant cultivars: A number of resistant cultivars have been evolved against specific nematodes. For example, cotton cultivars like Auburn 56, Stoneville wilt etc. are resistant to Root knot nematodes.

33:4.2 Biological control

The control of plant parasitic nematodes utilizing the natural enemies is termed biological control. These can be done either by innoculating or by creating a favourable condition for their rapid multiplication. The natural enemies include bacteria, fungi, protozoa and viruses.

33:4.3. Physical control:

Hot water treatment of the planting materials and the steam sterilization of soil are two important physical methods which are commonly practised. The temperature and time of exposure of the materials should be controlled, and they differ for different nematodes and type of planting materials. eg: Dipping banana suckers attacked by *Radopholus similis* for 20 mts., in hot water of 55°C.

33.4.4. Chemical control:

Chemical control measures are adopted where the economic value of crops is higher and the environmental conditions are favourable. The chemicals used for the control of nematodes are known as nematicides. Mainly, two formulations of chemicals are used as nematicides, viz., fumigants and granular nematicides.

Fumigants: Fumigants spread through the soil in a vapour form and kill the nematodes present in the soil. They are most effective in warm, well drained soils of tropics. eg: methyl bromide, ethylene dibromide etc.

Granular nematicides: They are non-volatile unlike fumigants. They are used both in temperate and tropical conditions. Granular nematicides should be mixed well with soil to get optimum effect as they are contact or systemic in action. They are absorbed by roots due to their high water solubility; and kill internal parasites and external feeders. eg: Carbofuran, aldicarb, phorate etc.

The chemical control of nematodes is yet to become popular in India. The reasons attributed to this are the prohibitive cost of the nematicides and difficulties in their application. Nematicides should be used only when the nematode parasite can not be controlled by other means and the possible damage done by it is very severe. However, in the case of certain high value crops like pepper, banana etc., the chemical control of nematicides is commonly resorted to and is popular. The best possible approach that can be followed is an integrated one, combining the different methods like crop rotation, seed treatment, growing resistant cultivars etc., supported by minimum quantity of nematicide application.

PLANT PATHOLOGY

34. Plant pathology and its improtance in agriculture

34:1 Introduction

Ever since man started agriculture, the plant diseases have been taking their toll of crops. Plant diseases are important because of the losses caused by them. The losses are caused both in yield and quality of the produces. The losses may occur in the field, in the store, or at any time between the sowing and consumption of the produce. Nearly one fifth of the total production is lost due to the attack of pests and diseases annually.

Plant pathology is that branch of agricultural science which deals with the diseases of plants. It may be defined as the study of the nature, causes, and prevention of plant diseases. The term pathology is derived from two Greek words—*pathos*, meaning suffering and *logos*, meaning discourse.

34:2 Importance of plant diseases

In the history of mankind, plant diseases have been connected with a number of important events. The classic example is the Late blight of potato which brought the science of plant pathology into limelight. In 1845, Late blight disease completely destroyed the potato crop in Ireland, which was the staple food of the people of that country. This led to a famine due to which the population of 80 lakhs was reduced to 60 lakhs. A large number of people died of hunger, and many became diseased due to physical weakness. The famine led to migration of people in large numbers to other countries including North America. Many social and political changes were brought about in the affected countries. In England, free trade was permitted and food grains were allowed to be imported from abroad. The country strengthened its naval force to protect the shipping. People who had migrated, settled in other countries, and helped in the development of nations like United States of America.

Wheat rust is another example of plant disease which had forced farmers in many countries to change their cropping pattern. As a result, the people had to change their food habits.

Coffee rust which appeared in 1867, drastically reduced the yield, and very badly affected the economy of Sri Lanka—the largest producer of coffee in the world during that time. The economic crisis forced the planters to cut down coffee and to take up tea planting. This resulted in the decrease of coffee consumption in England. Export of tea, however, revived the economy of Sri Lanka to some extent, and at the same time, the consumption of tea increased in England. Coffee rust was not prevalent in South America during that time. With the decline of coffee cultivation in Sri Lanka, its cultivation in Brazil increased rapidly, and today, Brazil produces the maximum coffee in the world.

Another example for the ravages caused by plant diseases to mankind is the Ergot of rye. Due to the consumption of ergot along with the flour, several people became diseased and died. This is referred to as 'St. Antony's Fire' in the history. The grazing animals in rye fields, when ingested ergot, got poisoned and many were killed. The ingestion of ergot caused abortion in pregnant animals.

During the second world war (1943), Bengal faced a famine due to the *Helminthosporium* leaf spot of rice, and this took a heavy toll of human lives. Bunchy top disease of Banana, which was introduced to Kerala from Sri Lanka during 1940, causes an annual loss of 10-12 crores of rupees in Kerala alone. The root (wilt) disease of coconut brings about an anuual loss of about 300 million nuts in Kerala.

34:3 History and development of plant pathology

Like all natural sciences, plant pathology had its begining in the dawn of human civilization. There were references in *Vedas* (1500 BC) to plant diseases and the methods of control. The Old Testament also have references to blasting, mildew, and insect pests of crops. As back as 700 BC, the Romans used to celebrate a festival *'Robigalia'* to ward off rusts. *'Vruksha Ayurveda'*, written by Surapal in ancient India, is the first book in which plant diseases have been described. Theophrastes, who lived between 370 and 286 BC, was the first botanist to observe and write about the diseases of trees, cereals, and legumes. He was not aware that diseases were caused by microorganisms, and the general belief was that microorganisms associated with the diseased or decaying plants arise spontaneously from plants or environment. There was no development for the science of plant pathology during 300 AD to 1300 AD, like all the other sciences, and this period is called the Middle Ages or Dark Ages. The period between 14th to 16th century AD is referred to as the Renaissance period.

Land marks in the history of plant Pathology are listed below:

1675— Anton Von Leeuwenhock invented microscope. He described bacteria seen with his microscope in 1683.

1729— Antonio Micheli published *Nova Plantarum Genera*. He cultured fungi on pieces of watermelon for the first time.

1753— Linnaeus, who introduced 'binomial nomenclature' and is often called the father of botany, published *Species Plantarum*.

1755— Tillet published a paper on bunt of wheat and demonstrated experimentally that bunt of wheat is contageous.

1807 – Prevost observed the germination of spores of wheat bunt and put forward the idea that the organism penetrated the young wheat plants, and was the actual causal agent of the disease. This provided the first proof for the role of micro-organisms in the causation of disease.

1831—1888 Anton de Bary contributed much to the development of mycology and plant pathology. He studied the life cycles of several fungi and the subtle mechanism of parasitism and saprophytism. He discovered heterocism in *Puccinia graminis tritici*, the causal organism of black rust of wheat. He also proved that the late blight of potato is caused by *Phytophthora infestans*.

1858— J. H. Kuhn published the first book on plant pathology, 'The diseases of cultivated crops, their causes and their control.'

1860— Louis Pasteur disproved spontaneous generation theory, which held that micro organisms could arise spontaneously from inanimate or non living matter. He furnished evidences that micro organisms arise only from pre-existing living entities, and also proved that fermentation is a biological phenomenon.

1876— Robert Koch established germ theory in relation to diseases of men and animals. He put forward certain rules or criteria that should be satisfied before identifying an organism to be the cause of a particular disease. These are called 'Koch's postulates.'

1882— Millardet discovered Bordeaux mixture.

34:4 Terminology

Some of the common terms used in plant pathology and their descriptions are given below.

Disease: Disease can be defined as a physiological disorder or structural abnormality that is harmful to the plant, or to any of its parts, or products, or that reduces their economic value. In simple words, disease is a harmful deviation from the normal functioning of the physiological processes.

Host: An organism that harbours or supports the activities of a parasite is called host.

Infection: It is the establishment of a pathogen inside the host following penetration, in which a parasitic relationship is established between the two organisms.

Inoculum: It is the infectious material which causes disease, and it is that portion of the individual pathogen that is brought into contact with the host.

Parasite: Any organism or virus existing in an intimate association with another living organism, from which it derives an essential part of the materials for its existence, is called parasite.

Pathogen: Any organism or virus capable of causing disease in a particular host or a range of hosts is called pathogen.

Resistance: It is the inherent ability of a plant to prevent or restrict the establishment and subsequent activities of a potential pathogen.

Saprophyte: An organism capable of securing nutrients from dead organic tissues or from available inorganic materials is called saprophyte.

Susceptibility: It is the inability of a plant to resist the effect of a pathogen or any other damaging factor.

Symptoms: The external or internal alterations or reactions as a result of a disease are called symptoms.

34:5 Classification of plant diseases

A perusal of the various plant diseases would reveal certain peculiarities. Many of them are similar in one way or other. The similarity may be with respect to the disease causing organisms, or the host plants, or on the mode of spread—which means, we could group the diseases based on several parameters. Such a grouping is extremely important in order to have a meaningful study of the disease, and it would also help us to correlate the occurrance of one with the other.

Classification of plant diseases can be based on several criteria.

Classification based on the host plants affected

Based on this criterion, diseases can

be classified as diseases of rice, diseases of coconut, diseases of mango, diseases of sugarcane and so on. The classification such as diseases of cereals, diseases of oilseeds, diseases of fruits etc. are also adopted.

Classification based on the parts of host plants affected

If we adopt this criterion, plant diseases may be root diseases, foliar diseases, fruit diseases, vascular diseases, stem diseases etc.

Classification based on the symptoms produced on the host plants

Accordingly, there are blast diseases, rust diseases, smut diseases, damping off, wilt, blight, anthracnose, mosaic etc.

Classification based on the causal organisms or factors

Plant diseases are classified into non-parasitic and parasitic diseases, based on the major causal factors. These groups can be further classified based on the actual causal agents

Non-parasitic diseases: These diseases are caused by abiotic (non-living) factors and include:-

a) Low temperature injury.
   eg: Freezing injury on many crops.
b) High temperature.
   eg: Heat canker of flax.
c) Unfavourable oxygen.
   eg: Black heart of potato.
d) Unfavourable soil moisture.
   eg: Flooding injury.
e) Injurious atmosphere.
   eg: Black tip of mango.
f) Lightning injury.
g) Mineral excesses.
   eg: Internal bark necrosis of red delicious apple.
h) Mineral deficiency.
   eg: *Khaira* disease of rice.

Parasitic diseases: These are caused by biotic (living) agents and include:-

a) Bacterial diseases.
   eg: Bacterial leaf blight of paddy, Bacterial wilt of ginger.
b) Fungal diseases.
   eg: Blast of paddy, Quick wilt of pepper, Bud rot of coconut.
c) Diseases caused by nematodes.
   eg: Root knot disease of brinjal.
d) Diseases caused by phanerogamic parasites.
   eg: *Striga* of jowar, *Loranthes* on trees etc.
e) Viral and mycoplasma diseases.
   Viral diseases.
   eg: Bunchy top of banana, Yellow vein mosaic of bhindi.
   Mycoplasma diseases.
   eg: Little leaf of brinjal.

Classification based on the nature of occurrence and severity of infection

Based on this, diseases can be endemic, epidemic, sporadic and pendemic diseases.

Endemic disease: When a disease is more or less constantly occurring in a moderate to severe form and is confined to a particular region, then it is called an endemic disease.

eg. *Udbatta* disease of rice in Wayanad.

Epidemic disease: When a disease occurs periodically but widely in a destructive form, it is called an epidemic or epiphytotic disease. The pathogen may be constantly present in that locality, but the environmental factors favourable for the disease development occurs only periodically. eg. Blast of rice.

Sporadic disease: The diseases which occur at very irregular intervals and locations, and in relatively fewer instances are called sporadic diseases.

eg. False smut of rice.

Pandemic disease: These diseases occur all over the world causing heavy damage. eg. Late blight of potato.

35. Disease causing organisms

35:1 Introduction

For each disease, there is a cause behind it. It may be biotic (living) or abiotic (non-living). The symptoms produced may differ based on the host, parts affected and causal agents. To understand a disease, a detailed study of symptoms thus becomes necessary. A knowledge on the causal organisms, survival, their dissemination, mechanism of disease development etc. are also important. In this chapter, an introduction to the major disease causing organisms common symptoms of diseases, survival and dissemination of plant pathogens, infection, forecasting of plant diseases, assessment of plant diseases, and the methods of collection and despatch of diseased specimens for identification are covered.

35:2 Disease causing organisms

The important biotic agents causing plant diseases are fungi, bacteria, viruses, mycoplasma, algae, actinomycetes, nematodes, and phanerogamic parasites. Among these, fungi, bacteria, and viruses are the causes behind most of the plant diseases.

Fungi

The fungi are responsible for majority of the plant diseases. Fungi lack chlorophyll and their body consist of microscopic threads of filaments called hyphae. The hyphae grow on or within the substratum, from which it absorb food thereby causing diseases. They reproduce mainly by spores. Some are pathogenic to man and animals too.

Bacteria

Bacteria are microscopic unicellular organisms belonging to the primitive group of plants, Schizomyceteae. There are five important genera of them—*Agrobacterium, Corynebacterium, Erwinia, Pseudomonas* and *Xanthomonas*—causing diseases in plants. Bacteria are less important when compared to fungi and viruses as causal organisms of plant diseases

Viruses

Viruses are submicroscopic obligate intracellular parasites. They are made of nucleoprotein and lack enzyme system. Viral diseases of plants are mainly transmitted through insects. Vegetative propagating parts also play a role in the spread of the diseases.

Before attempting to control a plant disease, a thorough knowledge of the cause of the disease, the life cycle of the causal organism, collateral hosts if any, environmental factors favourable for the disease development, mode of spread, nature of loss caused by the disease etc. are very essential. The first step is the identification of the causal organism/factor. In the case of biotic agents of plant diseases, there are certain methods to establish the real causal organism. These methods were put forward by Robert Koch and are called *'Koch's postulates'*. They are:

1) A specific organism must always be associated with a disease.
2) The organism must be isolated in pure culture, and identified.

3) The organism must produce disease in a healthy susceptible host when inoculated.

4) The organism must be isolated from the artificially inoculated host, multiplied again in pure culture, and its identity be established.

35:3. Symptoms of plant diseases

Symptoms are helpful in the diagnosis of diseases; but the true nature of the disease cannot always be understood from the symptoms alone. Similar symptoms may be produced by many unrelated factors. A general yellowing of the plant may be due to the infection by fungi, or virus, or due to the deficiency of certain minerals. Symptoms are only the means to understand that the plant is suffering from some disorder caused by an infectious or non infectious agent or factor.

Symptoms of plant diseases may appear on leaves, twigs, stem, roots, flowers, fruits etc., in different ways. Based on the nature of tissue changes involved, the symptoms of plant diseases can be grouped into four--viz., *hyperplasia*, *hypoplasia*, *hypertrophy* and *necrosis*. The enlargement of tissues as a result of excessive production of cells is known as *hyperplasia*. A reduction of tissues which results in underdevelopment as in dwarfing because of subnormal cell multiplication is called *hypoplasia*. The excessive growth of tissues as a result of enlargement of individual cells is *hypertrophy* and the term *necrosis* is applied when there is destruction or death of plant tissues.

The general symptoms of plant diseases are given below.

Yellowing or chlorosis: The leaves and other plant parts become pale green or yellow due to the underdevelopment or destruction of chlorophyll. The grades of discolouration may vary depending upon the intensity of the disease. eg. Yellow dwarf disease of rice.

Mosaic: Mosaic symptoms are generally associated with virus diseases, and there will be uneven development of chlorophyll, resulting in alternate light green patches with dark green areas. Mosaic symptoms may appear on leaf lamina, leaf sheath, stem, flower, and even on fruits wherever chlorophyll is present. eg. Cowpea mosaic.

Reduction in leaf size: The leaf size get reduced, and ultimately leads to 'little leaf' symptoms as in 'little leaf' of brinjal.

Stunting or dwarfing: This is a characteristic symptom of virus or mycoplasma disease. The plants become stunted due to the reduction or underdevelopment, resulting in the shortening of internodal length. eg. Grassy shoot of sugarcane, Grassy stunt of rice etc.

Galls and tumors: These symptoms are produced due to the overgrowth and enlargement of affected tissues. The overgrowth may be due to the increase in size of the individual cells (hypertrophy) or excessive multiplication of cells (hyperplasia). eg. Club root of crucifers, Root galls formed by root knot nematodes.

Blistering, puckering and leaf curl: Here, blistering and puckering of leaves followed by leaf curling are the symptoms. These symptoms are common to both fungal and viral infection. eg. Blister blight of tea, Peach leaf curl, Leaf curl of tomato etc.

Witche's broom: The abnormal and excessive developmet of axillary buds stimulated by infection lead to such symptoms. eg. Potato witche's broom, Witche's broom diseases of millets etc.

Phyllody: In phyllody, the floral parts get transformed into green leaf like structures as in phyllody of sesame and cucurbits.

Damping off: This disease generally appear in patches in the nurseries. The tissues at the collar region rot and as a result, the seedlings collapse and die. In the case of pre-emergence damping off, the seedlings get killed before they came above the soil surface. eg. 'Damping off' of vegetable seedlings.

Rots: Rotting of plant parts such as fruits, bulbs, tubers, rhizomes, roots etc. may be caused by infection by fungi or bacteria. When there is no oozing of liquid associated with the infected tissues it is called *dry rot*. eg. Dry rot of groundnut. Here, the affected portion shrinks and dries up ultimately producing a powdery mass. When there is oozing of liquid or softness of tissues, it is called *wet rot*. eg. Soft rot of ginger, Fruit rot of citrus, apple etc.

Wilt: The leaves and other green succulent parts loose their turgidity, become flaccid and droop, thereby resulting in the death of the plants. eg. *Fusarium* wilt of cotton, Bacterial wilt of solanaceous vegetables.

Cankers: Cankers cause localized death of cortical tissues of stem, leaves and fruits. The symptoms appear as malformed necrotic lesions in the cortical tissues eg. Citrus canker.

Anthracnose: The term anthracnose is used to denote a plant disease having characteristic limited black lesions, usually sunken, caused by certain fungi. eg. Anthracnose of beans, chillies, grapes, mango etc.

Scab: It is a symptom having hyperplastic, roughened or crust like lesions. eg. Apple scab, Potato scab, Citrus scab etc.

Spots: The death of tissues (necrotic) in a limited area, usually appearing on leaves, stem, twigs, flowers, and fruits, are known as spots. eg. Brown leaf spot of rice, Grey leaf spot of coconut etc.

Blight: If the necrotic area is not limited and extended to large area, then it is known as blight. eg. Leaf blight of turmeric, Bacterial leaf blight of rice etc.

Die back: In die back, the twigs or young branches start drying from tip downwards. eg. Die back of mango.

Rust: Rusty appearance of symptoms, just like iron rust, on plant parts is known as rusts. This is again classified according to the colour of rusted area such as Black stem rust of wheat, White rust of amaranths, Red rust of pepper etc.

Smut: The plant parts, especially floral parts, converted into black powdery mass is known as smut. eg. Loose smut of wheat, Grain smut of jowar, Whip smut of sugarcane etc.

Mildew: Powdery or cottony growth on green parts of the plants, young twigs and leaves are termed mildews. Mainly, there are two types of mildews—*downy mildew* and *powdery mildew*. Downy mildew generally appear on the lower surface of the leaves in high humid conditions; whereas powdery mildew appear on the upper surface of the leaves in low humid conditions. eg. Downy mildew of grapes and millets; Powdery mildew of cucurbits, rubber, rose etc.

35:4. Survival and dissemination of plant pathogens

35:4.1. Survival

The overwintering or oversummering of the plant pathogen in adverse conditions is generally termed as survival. It may occur in soil, seed, vegetative parts, plant debris and on collateral host in the absence of a susceptible host plant in the field. In fungi, the survival structures are chlamydospores, sclerotia, thick walled hyphae, rhizomorphs and spores like oospores, ascospores etc. When the adverse conditions are over, these structures germinate giving rise to new infection. For instance, *Pythium* and *Phytophthora* survive as thick walled mycelia and oospores; *Erysiphe* and *Mycosphaerella* as ascospores; and *Rhizoctonia* as sclerotia.

35:4.2. Dissemination

The transport of disease initiating propagules from the point of production to the host plant is generally termed dissemination. Wind, water, soil, seed, vegetative propagating materials, animals, insects and man help to disseminate diseases. A few of them are disseminated by contact also.

Wind: The spores or conidia of fungal pathogens produced on the surface of aerial plant parts and seeds of phaneroganic parasites are effectively disseminated through wind. Wind also carries some plant pathogenic bacteria to short distances. eg. Wheat rust, Rice blast etc.

Water: Running water and flood may carry inoculum present in or near the soil. The bacterial leaf blight of paddy is spread in the field through irrigation water. Wind splashed rain also play a role in the dispersal of plant pathogens like *Phytophthora* attacking crops like pepper, arecanut, coconut etc.

Soil: Fungal pathogens can spread to short distances in the soil due to the active growth of hyphae or hyphal strands. eg. *Fomes noxius* attacking coffee (brown root disease).

Seed: The dissemination of plant pathogen which survives in the seed takes place along with the germination of seed eg. Grain smut of cereals and many mosaic diseases.

Vegetative propagating parts: Vegetative parts used for propagation such as suckers, rhizomes, tubers, cuttings, scions etc. also aid in the dissemination of pathogens surviving in them. eg. *Katte* disease of cardamom, Bunchy top disease of banana, Tapioca mosaic etc.

Animals: Insects mites, and nematodes also aid in the dissemination of plant pathogens. For instance, bees and wasps transmit the bacterial diseases such as 'fire blight' of apple and pear. The *Katte* disease of cardamom, 'bunchy top' disease of banana, mosaic disease of cucurbits etc. are spread in the field by insects. Such disease carrying insects are usually termed as vectors. In certain cases, the plant pathogens multiply within the insects, and some may survive in them in the absence of a plant host

Man: Knowingly or unknowingly, man also disseminates diseases. This usually occur through the transport of infected plant parts such as seed, nursery stock, timber products etc. from one place to other place.

By contact: Some diseases may spread in the field on contact by implements, or by touch of infected plants. eg. Tobacco mosaic virus.

35:5. Infection

There is a sequence of events by which the pathogen-host relationship is established. The viable propagule of the pathogen must arrive on the susceptible parts of the host by any means discussed under dissemination. Then, the propagule germinates and penetrates into the host tissue either by softening the epidermal tissues of the host, or by mechanical force, or through the natural openings like stoma and lenticels. After the penetration, the pathogen establishes in the host tissue till the external symptoms are expressed. The period from germination of propagules to the expression of external symptoms is generally termed as *incubation period.* The first viable symptoms indicate the establishment of pathogenic relationship, and is considered to mark the beginning of the disease. Penetration, establishment and expression of symptoms are the steps in disease development.

35·6. Plant disease forecasting

Plant disease forecasting is a method used in advanced countries to give warning for taking up early steps to protect the crops against the diseases. It enables the farmers to be conscious and to keep ready all their resources to combat the disease. Forecasting involves all the activity in notifying the growers of a community that conditions are sufficiently favourable for certain diseases, and that application of prophylactic measures will result in effective management of the disease. It gives the growers an opportunity to revise their plans in order to avoid or reduce losses. Forecasting the incidence of a plant disease is usually done taking into consideration the environmental factors like weather parameters favourable for the plant diseases, viable inoculam loaded in the atmosphere and the susceptible host in the field. If these three factors are well known, then forecasting of a disease is more reliable.

Netherlands pioneered the development of forecasting and spray warning services for the control of 'late blight' disease of potato. Analysing the combined effect of various weather parameters on the incidence of 'late blight' disease, they have laid down certain rules known as 'Dutch rules'. The appearance of 'late blight' disease was observed to depend on these rules. When all the conditions prescribed under these rules are observed to occur, control measures are immediately recommended. In nutshell, forecasting is mainly based on the weather parameters congenial for a particular disease, viable inoculam in the atmosphere and susceptible host in the field.

As forecasting and warning system involves considerable expenditure, they should be economically justifiable. Forecasting is feasible in the following cases.

1) For destructive diseases of important cash or food crops.
2) For diseases which can be reliably predicted early enough for effective and economical control measures.
3) For diseases against which economic control measures are available.

35:7. Assessment of plant diseases

Quantitative assessment of plant diseases is necessary to judge the relative importance of diseases, so that attention can be directed towards the most harmful crop diseases. The measurement of losses due to plant diseases is helpful in convincing the farmers about the economics of control measures, taking into consideration the benefit/cost ratio, and also to avoid indiscriminate use of plant protection chemicals. The strategy for the assessment of crop losses due to diseases involves the following two steps.

1) Measurement of disease incidence and severity, and its correlation with loss in yield.
2) Assessment of the disease by field surveys by making use of the method of assessment developed in the first step.

The tactics of disease measurement vary according to the nature of the disease and the crop. Field keys and disease indices to assess the severity have been developed for most of the important crop diseases.

35:8. Collection and despatch of diseased specimens for identification

Very often, we can not identify a plant disease by merely seeing the symptoms in the field. We may require some laboratory studies to arrive at definite conclusions. Or sometimes, we may have to seek the opinion of experts. For such purposes, the diseased specimens have to be taken to the plant pathology laboratory, or sent to experts for further studies. The diseased specimens should be properly collected from the field and despatched neatly so as to reach the laboratory without any damage. Along with the specimens, basic informations such as the name of the crop, locality, symptoms observed in the field etc. should be furnished. The procedure for collecting the diseased specimens vary with the crops. The procedures are briefly discussed here.

Field crops and vegetables

Diseased but alive plants showing typical symptoms should be selected for collecting specimens. Small plants can be collected as such including the root system. A healthy plant should also be collected for comparison. Labels written with lead pencil should be tied separately for healthy and diseased plants. Then, they should be wrapped loosely using news paper or brown wrapping paper. Care should be taken to enclose the specimen in a container which will not crush or break during transit by post.

Fruit crops

The leaves, stem, or other affected portions which are diseased but still alive must be collected. The leaves should be pressed in a single layer between the folds of a newspaper, and after drying, packed properly in a box. The affected stem or root portions should be wrapped separately with brown wrapping paper.

Fleshy fruits, vegetables, bulbs, tubers etc.

The specimens collected should show early stage of infection. Completely rotten specimens should always be avoided. Specimens are collected and wrapped separately with an old piece of cloth, and then with newspaper sheet. The container selected for enclosing them should not break or crush during transit.

36. Principles and methods of plant disease control

36:1. Introduction

Plant diseases are a great threat in the cultivation of crops. Diseases should be controlled. In the control of plant diseases, our primary aim is to prevent the incidence or reduce the severity of diseases, so as to minimise the economic losses. Several methods are available for the control of diseases. These methods are based on certain specific principles. To achieve a satisfactory control, more than one of the control measures, singly or in combination, have to be adopted. However, before choosing the method, a knowledge of the causal agents, stage, susceptibility of the host, environmental conditions, and the cultural practices adopted for the crops etc. are essential.

36:2. Principles of plant disease control

The principles of plant disease control can be grouped into prophylaxis and cure or therapy.

36:2.1. Prophylaxis

Prophylaxis includes all the measures adopted to protect the plant against the disease. The various preventive or prophylactic measures can be described under avoidance, exclusion, eradication, protection and immunization.

Avoidance: The principle behind this measure is to avoid contact between the host and the pathogen, or to avoid the coincidance of susceptible stages of the crop with the favourable conditions for the growth of the pathogen.

Exclusion: The principle is to prevent the entry of pathogen to new areas where it does not exist. This include measures such as seed certification, plant quarantine etc.

Eradication: The principle here is to remove or destroy the pathogen at the source, or from the plant, or plant parts in which it has already established. The primary aim of eradication measures is to break the infection chain.

Protection: Protection aims at protecting the plant, plant parts, or seeds from the infection by pathogens through the use of chemicals, or by other agents.

Immunization: This is aimed at enhancing the resistance of plants by treating with chemicals, or by evolving new varieties [by hybridization, or by any other suitable method. The growing of resistant varieties is the best and economic method of plant disease control.

36:2.2. Cure/therapy

The principle used here is to reduce the severity of diseases in the infected plants. Chemicals or other agents are used to reduce the infection, and there by to cure the plants. Therapy is very difficult to be practiced in plants and successful only in a few cases. Cure is achieved mainly by the use of systemic fungicides and antibiotics (therapeutants).

36:3. Methods of plant disease control

Plant diseases can be controlled by

various methods such as physical, cultural, chemical and biological measures

Physical methods

These include measures such as removal and destruction of infected plant or plant parts, making trenches to prevent the spread of soil borne pathogens, flooding the field to provide unfavourable anaerobic conditions to pathogen etc.

Cultural methods

Crop rotation, mixed cropping, adjusting the date of sowing/planting, field sanitation, removal of alternate and collateral hosts etc. come under cultural method of plant disease control.

Chemical methods

The control of plant diseases by the use of various chemicals in different way is referred to as chemical methods of control.

Biological methods

Biological method of plant disease control is defined as any condition under which or practice whereby survival or activity of a pathogen is reduced, through the agency of any other living organisms (except man himself), with the result that there is a reduction in the incidence of the disease caused by the pathogen. A living agent other than man himself is employed or made use of in the biological control. The use of *Trichoderma viride* against Rice sheath blight pathogen (*Rhizoctonia solani*) is an example of biological control.

Application of organic amendments to soil is a widely accepted practice against many soil borne diseases. By doing so, the population of antagonistic microflora in the soil is enhanced, which bring about a reduction in the disease incidence. For instance, the application of oil cakes like neem cake to soil is beneficial in reducing the incidence of soft rot of ginger.

36:4. Fungicides

The word 'fungicide' was orginated from two Latin words, *Fungus* and *Caedo* (to kill), which means fungus killer. Chemical substances which have the ability to prevent the damage caused by fungi to growing crops and their products are called fungicides. Chemicals which inhibit the fungal growth temporarily are known as *fungistats* and the phenomenon of temporarily inhibiting the growth is called *fungistasis*. Some chemicals like Bordeaux mixture inhibit only spore production without affecting the growth of vegetative hyphae. They are called *antisporulants*. Fungicides can be classified in many ways; based on their chemical nature, mode of action and general use.

Based on the chemical nature

Based on the chemical nature, fungicides are classified into two broad groups, viz. inorganic and organic. Inorganic fungicides include copper preparations, elemental sulphur, nickel chloride and mercuric chloride. However, almost all the modern fungicides belong to the group organic fungicides Organic fungicides include organomercurials, organosulphur compounds (Dithiocarbamates), heterocyclic nitrogen compounds, chlorinated nitrobenzenes, quinones, nitrophenols, organophosphorous compounds, organotin compounds, antibiotics, systemic fungicides and mineral oils.

Based on the mode of action against fungi

Accordingly, a fungicide may be a protectant or therapeutant. Fungicides can also be classified into systemic or non systemic based on this criterion.

Protectants and therapeutants: Fungicides which are effective, only if applied prior to infection are called protectants.

These cannot cure an already present infection. Majority of the fungicides available in the market are protectants. However, the fungicides coming under the group therapeutants are capable of eradicating fungi after the infection. and thereby curing the plants. eg. Carboxin

Systemic and non-systemic fungicides: Systemic fungicides act by entering into the system of plants. When applied to any part of the plant, they get absorbed and translocated in the fluid system of plants to other parts and render the whole plant toxic to fungi. eg. Carboxin. However, nonsystemic fungicides do not enter into the system of plants, but act from outside. eg. Bordeaux mixture.

Based on the general use

Based on the general use, fungicides are classified as seed protectants, soil fungicides, foliage and blossom protectants, fruit protectants, eradicants, tree wound dressing fungicides and antibiotics.

Seed protectants: Seed protectants are used for treating the seed prior to sowing, so that the germinating seeds and the young seedlings are protected from the harmful fungi. Organomercurial compounds are generally used as seed protectants.

Soil fungicides (pre-planting): These are used to treat the soil before sowing to kill the soil borne pathogens. A certain period of time should elapse between the treatment and sowing or planting. eg. Vapam, Formaldehyde.

Soil fungicides (for growing plants): These are used for the application in the soil for protecting the growing plants from the attack of harmful soil fungi. eg. Captan, Thiram, Brassicol.

Foliage and blossom protectants: Fungicides like Captan, Zineb, Bordeaux mixture etc. are applied on the foliage and blossom of plants to protect them from fungal infection.

Fruit protectants: Fungicides of this group are used for treating the fruits to protect them from infection in the field, or during transit and storage.

Eradicants: Eradicants eradicate fungi and cure the diseased plants. For instance, lime sulphur is used as an eradicant on fruit crops like apple.

Tree wound dressing fungicides: These are used to protect the cut ends of branches after pruning and also the wounds formed on the trunk and branches of trees from the infection. eg. Bordeaux paste.

Antibiotics: These are substances produced by certain micro organisms which are toxic to other micro organisms at very low concentrations. eg. Aureofungin Streptocyclin.

36:5 Important fungicides and antibiotics

Now, we shall study certain important group of fungicides and antibiotics.

36:5.1. Inorganic fungicides

Sulphur fungicides

Elemental sulphur has been in use as fungicide for a long time and even today it is one of the best for the control of powdery mildew diseases. Sulphur also acts as an acaricide. However, sulphur fungicides when used on cucurbits in warmer climates may cause severe burning.

Inorganic sulphur fungicides can be grouped as elemental sulphur and lime sulphur. Elemental sulphur is used in two formulations—dust and wettable powder. Lime sulpur is generally used against diseases of fruit crops as a dormant spray.

The fungicidal efficacy of sulphur dust depends upon the fineness of particles. Particles having a diameter of 47—75 μm are preferrable. For dusting, 15 – 20 kg of sulphur dust is required per hectare.

Cosan, Esso wettable sulphur, Thiovit 80 WP and Microsul 80% W are the commercial formulations of wettable sulphur available in the market. They are to be applied at a concentration of 0.2 – 0.5%.

Copper fungicides

Copper fungicides are widely used against the diseases of fruit crops, vegetables and flowering plants. These are also commonly used in plantation crops like pepper, coffee, rubber, arecanut, cardamom etc.

Copper fungicides can be classified as copper sulphate, copper carbonate, copper oxychloride and cuprous oxide prepartions. Copper sulphate preparations include Bordeaux mixture, Bordeaux paste, Burgandy mixture and Cheshunt compound. Copper sulphate and lime are dissolved separately in 50 litres of water. Pour copper sulphate solution to lime solution, or mix simultaneously these two solutions by pouring into a third container, while agitating thoroughly. The mixture thus prepared should be tested for free copper before use. Free copper in Bordeaux mixture can be phytotoxic. To test its presence, a few drops of 10 per cent potassium ferrocyanide solution are added to a small quanity of prepared Bordeaux mixture. If a reddish brown precipitation is formed, it indicates the presence of free copper. If potassium ferrocyanide is not available, a clean iron knife can be used by dipping it for some time in the mixture; and observe for reddish brown deposit of copper on it. If reddish brown deposit of copper is found, more lime should be added. The containers used for the preparation of Bordeaux mixture should be such that it do not react with free copper. Copper, wooden, plastic or, earthern vessels can be used.

Copper fungicides

- Copper sulphate preparations
  - Bordeaux mixture
  - Bordeaux paste
  - Burgandy mixture
  - Cheshunt compound
- Copper carbonate preparations
  - Chaubattia paste
- Copper oxychloride preparations
- Cuprous oxide preparations

Bordeaux mixture: Bordeaux mixture was discovered by Millardet in 1882 and was first used against downy mildew disease of grapes. Later, it was used for the control of 'late blight' of potato, and it became very popular.

Bordeaux mixture of one percent concentration is generally used. In order to prepare 100 litres of one per cent Bordeaux mixture, one kg of copper sulphate and one kg of powdered hydrated

Bordeaux mixture should always be sprayed fresh. On standing, it loses its fungicidal property. However, it can be stored for a few days by adding sugar or jaggery at the rate of one gramme per litre of the solution. The merits of Bordeaux mixture lie in its natural adhesiveness or tenacity, relative cheapness, and safeness to handle. Morever, Bordeaux mixture is suitable for the control of a wide range of diseases.

However, certain demerits are also there. Bordeaux mixture is phytotoxic to certain crops, particularly cucurbits. In certain cases, it tends to delay ripening. The botherations in preparation is another demerit. The corroding action on the metallic containers and the spraying equipment is another problem.

Bordeaux paste: Bordeaux paste is used to apply at the cut ends after pruning and at the collar region of crops like pepper, citrus etc. to prevent fungal attack. It is primarily a wound dressing fungicide as used for the control of stem bleeding disease of coconut. It is prepared in the same way as that of Bordeaux mixture. However, the quantity of water is reduced to one tenth, ie. 1 kg copper sulphate + 1 kg lime in 10 litres of water.

Burgandy mixture: It is prepared in the same way as that of Bordeaux mixture except that sodium carbonate is used in place of lime. This preparation was developed at the time when good quality lime was not easily available. Nowadays Burgandy mixture is not commonly used.

Cheshunt compound: Cheshunt compound contains 2 parts of copper sulphate and 11 parts of ammonium carbonate. These two compounds are well powdered, thoroughly mixed and then the dry mixture is stored in an airtight coloured glass container for 24 hours before use. Then it is dissolved in water at the rate of 3g per litre. Cheshunt compound is generally used to drench the nursery beds against 'damping off' diseases. It is also effective against 'soft rot' disease of ginger.

Chaubattia paste: It is used as a wound dressing fungicide in apple, pear, peach, rose etc. Chaubattia paste is prepared by mixing 800 g of copper carbonate and 800 g of red lead in one litre of lanolin or raw linseed oil.

Copper oxychloride preparations: Nowadays, several copper oxychloride preparations are available in the market Though they are not so effective as Bordeaux mixture, in view of the convenience, frequently used in place of Bordeaux mixture. Copper oxychloride preparations are generally available as wettabie powders, and marketed in the trade names as Blitox 50 W, Cupramar 50 W, Blue copper 50 W, Starcop 50 W, Fytolan 50 W etc. These are recommended against many diseases at 0.3-0.4 per cent spray.

Mercury

Inorganic mercury fungicides are mainly used for seed treatment and soil drenching. Because of their extreme toxicity and high persistance they are not recommended for spraying on the foliage. Mercuric chloride is the only inorganic form of mercury fungicide being used.

Nickel

Nickel chloride is the only nickel preparation used in plant disease control. Nickel chloride is found to be specific against the 'blister blight' disease of tea and recommended at a concentration of 0.2-0.5 percent for spraying.

36:5.2 Organic fungicides

Organo mercurials

These are compounds of mercury with organic materials. Since they are highly poisonous and require heavy precautions, they are used only for seed treatment especially against externally seed borne diseases. These are also used for soil drenching. MEMC (Methoxy ethyl mercury chloride), EMMC (Ethoxy methyl mercury chloride), and PMA (Phenyl mercury acetate) are the commonly used compounds under this group. A formultion EMC (Ethyl mercury chloride) + PMA (Phenyl mercury acetate) is also sometimes used. Important commercial preparations of these compounds are given below:

MEMC — Agallol-3, Agallol-6, Emisan-6, Hexasan-6, Tafasan-6, Ceresan wet.

EMMC — Aretan-3, Aretan-6

PMA — Ceresan dry, Hexasan, Tillex

EMC+PMA — Agrosan GN

For wet seed treatment, MEMC and EMMC are recommended at 0.05-0.1% concentration of the formulated product. For dry seed treatment PMA and Agrosan GN are recommended at 2.5 g/kg of seed.

Organo phosphorus compounds

Two compounds of this group are famous and widely used.

Ediphenphos. It is highly effective against rice blast disease. Two commercial formulations are Hinosan 50% EC and H-Phos 50% EC, and are recommended at 500 ml in 500 ml of water/ha.

Kitazin: This organo phosphorus compound has got good systemic action. It is mainly recommended against rice blast. Kitazin—P 48% EC is the widely used commercial formulation of Kitazin which is recommended at 500 ml/500l/ha.

Dithiocarbamates

These are derivatives of certain organic acids with dithio carbamic acid which contains sulphur. Most important among them are noted below.

Thiram: It is a good fungicide against many foliar diseases. It can be used for soil and seed treatment.

Commercial formulations—Thiride 75 WP Hexathir-75WP.

Dosage —0 2 to 0.3% of the formulated product.

Zineb: Zineb is used to control a large number of diseases affecting foliage and fruit.

Commercial formulations — Dithane-Z-78, Sandos zineb, Zineb-75, Hexathane-75 W

Dosage — 0.2 to 0.4%

Maneb: Maneb is not available in India as a pure product. A combined product of 78% Maneb and 2% zinc ion by the name *'Mancozeb'* is available. The product is being marketed in India under the trade name Dipthane M-45. This is recommended for foliar sprays and also for seed treatment. The dosage recommended is 0.2 to 0.4% of the product.

Heterocyclic nitrogen compounds

Two compounds, viz., Captan and Captafol are commonly used.

Captan: it is mainly used for seed treatment and also as a post harvest treatment for the preservation of fruits. Common formulations available in the market are Captan 75 WP and Hexacap 75 WP. For foliar spray, it is to be applied at a concentration of 0.1 to 0.2%. The dosage for seed treatment is 1 5g/kg of seed.

Captafol: It is widely recommended against many foliar diseases of rice and other crops. It is effective against sheath blight of rice, sigatoka disease of banana, pepper pollu disease etc, and available as Difolatan 80% WP, or Foltaf 80% WP in the market. It is recommended at 0.1 to 0.3% of the formulated product.

Nitrophenols

Among these, the fungicide dinocap is most important.

Dinocap. It is a good fungicide for foliar spraying against powdery mildew, and proved to be an excellant substitute for sulphur. This particular fungicide, therefore, can be safely used in crops which are sulphur shy or sulphur-sensitive. Usually recommended against the control of powdery mildew diseases in cucurbits and roses. Dinocap is mainly marketed as Karathane 48 EC, and it is to be applied at a concentration of 0.05%.

Systemic fungicides

A systemic fungicide is defined as a systemic fungitoxic compound that controls a fungal pathogen away from the point of application and that can be detected or identified. These compounds when applied are absorbed by the plant, get translocated within it, providing protection and eradication of already established infection. Thus by using a systemic fungicide, it is possible to control the diseases affecting inaccessible parts of plants like roots. There is no possibility of missing any plant parts or new growths, as in the case of non-systemic fungicides. Certain commonly used systemic fungicides are described here.

Benzimidazole compounds

Carbendazim and benomyl are the most widely used fungicides of this group.

Carbendazim: This systemic fungicide is effective against many rice diseases such as blast, sheath blight and sheath rot. It has got a wide spectrum of activity. It is also recommended against powdery mildew diseases in ornamental plants. Carbendazim is available in the market as Bavistin 50 WP or B-stin. The dosage recommenned is 500g/500 l/ha.

Benomyl: It is an excellant systemic fungicide which shows good eradicant and protectant activities. Benomyl has got mite ovicidal action also. It is marketed as Benlate 50 WP. The dosage recommended is 1-2 g of the formulated product per litre of water.

Oxathins

Carboxin and oxycarboxin are the compounds of this group. Carboxin is the widely used one.

Carboxin: This fungicide is effective for seed treatment purposes and for foliar application against rice diseases such as sheath blight, sheath rot etc. Carboxin is available in the market as Vitavax 80% WP and Vitavax 75%. The recommended dosage is 500 g of the formulated product per hectare.

36:5.3. *Antibiotics*

Antibiotics are substances produced by certain micro organisms which are toxic to other micro organisms at very low concentrations. These are systemic in nature. Antibiotics fall into two categories viz. antifungal materials and antibacterial materials. A few examples are given here.

Antifungal materials: These are effective against fungal diseases. Aureofungin is a common antibiotic which is recommended against blast and brown leaf spot diseases of rice. it is available as Aureofunginsol and to be applied at a concentration of 50 g/ha.

Antibacterial materials: These are recommended against bacterial diseases affecting many crops. eg. Agrimycin-100 Plantomycin, Paushamycin, Streptocyclin etc.

36:6. Characteristics of a good fungicide

A good fungicide should fulfil the following characteristics.

1) High field performance.
2) Low phytotoxicity.
3) Stability in sotrage.
4) Stability after dilution to spray strength.
5) Low toxicity to human beings and cattle.

36:7. Formulation of fungicides

Commercial fungicides are formulated in various ways. Most commonly available formulations are noted below.

Dusts: These formulations are in powder form and usually contain particles of 47-75 μm diameter, and are used as dry dusts. eg. Sulphur dust.

Wettable and water dispersable powders: Most of the fungicides are prepared in these forms and are used as spray materials. eg. Difolatan 80 WP, Blitox 50 WP, Captaf 75 W etc.

Emulsifiable concentrates (EC): These are liquids in which the active ingrediant is dissolved in a solvent. The fungicide and the solvent will not mix thoroughly with water. So an emulsifying material is included. As a result, when the formulation is mixed with water, we get an emulsion. Very few fungicides are available in this form, whereas most of the insecticides are marketed in this formulation. eg. Hinosan 50 EC, Kitazin 48 EC.

Solutions: Solutions are formulations in which the active ingredient or a combination of active ingredients and solvent are dissolved in water. eg. Cuman L.

Granules: Granular formulations of fungicides are also rare. Granular fungicides are meant for soil application. The percentage of active ingrediant is usually low. eg. Captaf 5% G, Kitazin-17 G.

36:8. Methods of application of fungicide

Fungicides are applied in many ways. Spraying is the most commonly adopted method. Others are seed treatment, soil treatment, dusting and pasting.

Seed treatment

The purpose of seed treatment by chemicals is to destroy the pathogens present on them, and also for protecting the germinating seeds from the attack of certain soil borne pathogens. Seed treatments are of different types and it is done by various methods. More details on seed treatment can be had from the section on seed treatment in chapter 14– seed production and handling in this book.

Soil treament

Soil treatment with fungicide is aimed at protecting the crop from the soil borne pathogen. Fungicides are applied to the soil in various ways such as soil drenching, broadcasting and fumigation.

Soil drenching: Fungicidal solution or suspension is applied to the soil in sufficient quantity to wet 10-15 cm depth of the soil. This method is followed for controlling damping off, root rots, or infection at the ground level. eg. Cheshunt compound, organomercurials etc.

Broadcasting: In this method, non-volatile granular fungicides mixed with soil or fertilizers are broadcast uniformly on the soil surface. eg. Captafol and Kitazin granules.

Fumigation: The chemicals used for this purpose are usually volatile, and on coming in contact with soil moisture, release a gas which diffuse in the soil and kill the soil borne pathogens. eg. Methyl bromide.

Spraying

Spraying is the most commonly adopted method of fungicide application. Spraying of fungicide is done on foliage, stem and fruits. Wettable powders are commonly used for sprays. Based on the amount of liquid in which the plant protection material is applied in unit area, the sprays can be grouped as high volume, low volume and ultra low volume sprays. High volume sprays require more than 500 litres or more spray fluid per hectare. Low volume sprays require 5-400 litres per hectare, whereas ultra low volume sprays require less than 5 litres of spray liquid per hectare.

Dusting

Dusts are applied to leaves, fruits and stem of plants as an alternative to spraying. Generally, dusting is practised in calm weather, and a better protective action is obtained, if the dust is applied when the plant is wet with dew. Dusting is particularly advantageous when water is scarce and in difficult terrains.

There are certain advantages and disadvantages both in the case of spraying and dusting. Spraying gives a better coverage of foliage and longer residual effect of the chemical used. The spraying operation is comparatively easier for the operator and the materials required are less costly in per hectare basis. On the other hand, in the case of dusting, the equipment is lighter and cheaper and can be used under adverse ground conditions. Dusting requires no water, and therefore, has less operational difficulties. Besides, the materials meant for dusting are in ready to use form.

Fungicide pastes and paints

These are used at the cut ends after pruning and also for tree wound dressing.

36:9 Storage and handling of fungicides

The following precautions should be taken during storage and handling of fungicides:

1 Fungicides should be stored in a separate room away from the reach of children. As far as possible, they should be stored separately from other agrochemicals.

2 The manufacturer's instructions should be carefully read before use.

3 Preparation of spray solution should be done in open air.

4 All the spills of spray fluid on the body should be washed with soap and water. In case of splashing of any fungicide material into eyes, immediate washing with clean water is essential; and consult a doctor, if necessary.

5 The empty containers and packages should be burnt or buried. They should not be used for any other purpose.

6 Spraying or dusting should not be done against the direction of the wind. Dusting should be done when the atmosphere is calm, preferably, in morning or evening hours.

7 Protective clothing should be worn, while applying fungicides.

8 The operator should wash his body Thoroughly with soap and water after the application of fungicides.

9 Individuals should not be entrusted with the task of applying plant protection chemicals for more than four hours a day. Otherwise, it may hamper their health.

10 It is desirable to know the first aid measures and the use of antidotes, at least of those fungicides which are being used most frequently.

36:10 Compatibility of fungicides and other agrochemicals

In the plant protection schedule, very often, it becomes necessary to combine the application of different agrochemicals such as fungicides, insecticides, herbicides and fertilizers, due to several considerations. In doing so, we can save on the cost of labour and time too.

Though the combined application is advantageous, it may create a few problems, if one is not careful. Pesticides and fertilizers being chemicals, tend to react with each other, and in this process, may form compounds which have no pesticidal value. For instance, the fungicide Captan can be mixed with many other fungicides, insecticides as well as fertilizers. However, this is not done when the materials are alkaline in reaction; because under alkaline conditions, Captan gets decomposed, thereby losing its fungicidal properties. Sometimes, materials can be mixed for immediate application but not for using after a cartain time interval. It is therefore, very essential to know the interactions between these materials, before they are mixed. Sometimes, mixing of agro-chemicals may result in an increase in the fungitoxicity of certain fungicides. This phenomenon is called *synergism*.

37. Plant protection equipments

37:1. Introduction

Plant protection chemicals are formulated in different ways such as dusts, wettable powders, emulsifiable concentrates granules etc. Various types of equipments are needed for the application or these formulations. Depending on the nature of crop also, the type of plant protection equipment differs. For instance, there are differences in the type of sprayers suitable for spraying field crops and tree crops. The important plant protection equipmbnts used in agriculture are described below.

37:2 Dusters

In ordinary situations, dusting operation can be done with a very simple equipment. Dust filled in a small cloth bag will serve the purpose, if only a small area is to be applied. However, when large area is to be covered, other improved dusters are to be used. Two types of dusters are commonly used by farmers. They are hand operated rotary duster and motorized knapsack sprayer cum duster.

Hand rotary duster

When compared to sprayers, dusters are very simple in design and also in operation. Hand operated duster (Fig.37.1) is a very simple equipment with only a few mechanical components. The essential components are a hopper with agitator which carries the dust, a fan to produce air current—which is the propulsion force to carry the dust, a feed mechanism to control the flow of dust—usually a rotating brush is provided for this purpose, and a nozzle—which is a flexible tube

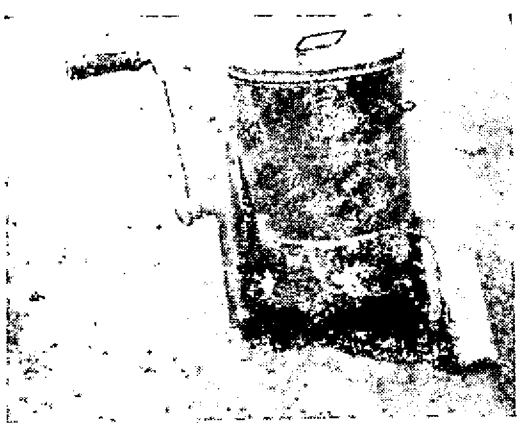

Fig. 37.1 Hand operated rotary duster

Rotary dusters function properly, only if the dust used is of good quality. With a rotary duster, an area of 1–2 hectares can be covered in 8 hours.

Motorized dusters

Power driven knapsack sprayers (Fig. 37.2) are designed in such a way that they can be used as dusters also. This is a fast equipment and work well because of the high velocity of air current produced in the system. This type of duster operates more or less similar to that of a rotary duster, except that the fan is propelled with a petrol engine.

37:3. Sprayers

Sprayers are used to deliver the chemicals as fine droplets on plant surfaces. Sprayers not only break the liquid into fine droplets but also ensures uniform application on the plant surfaces.

37:3.1. Essential parts of sprayers:

Sprayers consist of different parts, each with defenite function. The important parts of a typical sprayer is discussed below.

Fig. 37.2 Motorized knapsack srayer cum duster

Tank: The liquid to be sprayed is stored in a tank which is made of corrosion resistant materials like brass or polythene. An agitator may also be provided in the tank. Some type of sprayers do not have a built in tank.

Pump: In order to propel the spray liquid and to break it into fine dropletes, some pressure is to be applied inside the tank. In compression sprayers, an air pump is provided for producing high pressure inside the tank. This pneumatic pressure forces the spray lipuid through the spray lance, and also help in breaking the liquid into fine droplets. In a mist blower, instead of pneumatic pressure, a high velocity air current is used for the propulsion of the liquid. A blower is provided here in the place of a pump. However, in hydraulic sprayers, pressure is developed by the direct action of the pump on the spray fluid. This presssure forces the liquid through the nozzle. Plunger pumps, rotary pumps, and centrifugal pumps are hydraulic pumps and used in different types of hydraulic sprayers.

Valves: Valves are provided in various points of the sprayer to check the direction of flow of air and liquid. The common compression knapsack sprayer has an important valve at the bottom of the pump to prevent the entry of spray solution.

Spray lance or gun: The spray lance or gun is provided for adjusting the spray to the desired plant part. It is a tube of convenient length and shape made of high corrosion resistant metal. Flexible hose is used for connecting the spray lance to the tank.

Spray release and cut off devices: There will be a trigger mechanism with provision to release or cut off the flow of liquid. This is attached at the beginning of the spray lance in most of the sprayers.

Nozzle: The nozzle is fitted at the extreme end of a spray lance or gun. Nozzle breaks the spray liquid coming through the spray lance into fine droplets. The spray pattern and droplet size can be changed by altering the nozzle. Different spray patterns are used for the effective application of fungicides, insecticides, and herbicides. Hollow cone or solid cone patterns are suitable for applying insecticides and fungicides. For herbicide application, flat fan and flood jet are more suitable.

37:3.2. *Types of sprayers*

Hand sprayer

It is a very small hydraulic pump commonly used in households for spraying chemicals against houseflies and mosquitoes. This will be enough for spraying pesticides in a small kitchen garden.

Stirrup pump or bucket sprayer

Stirrup pump does not have a built-in tank. It consists of a pump, adjustable foot rest and spray lance with a long hose. The spray liquid is taken in a bucket or suitable container, and the pump is immersed in it before working. This is a cheap and simple hydraulic sprayer and is sufficient for treating small areas or bushes.

Hydraulic Knapsack sprayer

This type of sprayer is convenient for carrying on the back of the operator. The material used for the sprayer is of light weight metal or polythene. A pump is provided and the operator can work it continuously by rocking the handle which comes in his front.

Compression Knapsack sprayer

Compression knapsack sprayer (Fig. 37.3) consists of a tank and a pump housed in it. The tank is commonly made of brass or galvanised iron. The pump is worked to create sufficient pneumatic pressure inside the tank. The pressure built up in the tank forces the spray liquid into the lance, and it comes out through the nozzle as fine droplets. The tank should be filled only three-fourth of its capacity to leave sufficient space for the air to build up pressure. This type of sprayer is most commonly used in agriculture and public health. An area of 0.5 to 1 hectare can be covered in a day using this sprayer. It is suitable for carrying out spraying in field crops and vegetables. However, this type of sprayer has some disadvantages too. As the spraying is carried out, the pressure inside the tank will come down. To maintain the pressure, frequent pumping is needed. The capacity of the tank ranges from 9-12 litres. Considerable time is also needed for frequent filling of the tank and pumping. The sprayer is provided with a belt, with which it can be carrried on the shoulder of the operator.

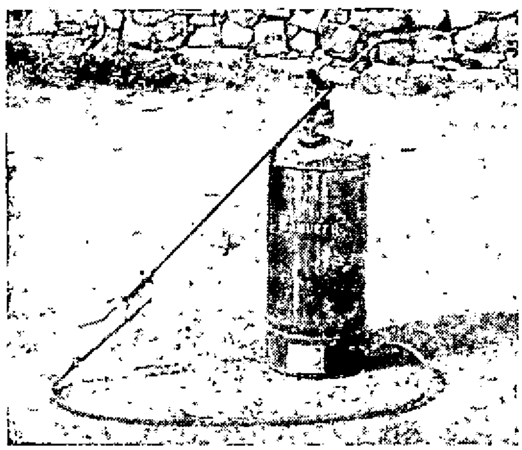

Fig. 37.3. Manually operated compression knapsack sprayer

Rocking sprayer

This type of sprayer (Fig 37.4) does not have a built-in tank. Rocking sprayer, also called rocker sprayer, consists of a pump assembly mounted on a platform, an operating lever for the pump, and a pressure chamber usually made of brass. The suction hose from the pump will be fitted with a strainer at its end, and it is immersed in the spray fluid taken in a suitable container. The spray lance is fitted at the end of a long flexible delivay hose. Tke rocking movement of the operating lever of the pump helps in building up pessure inside the pressure chamber, and this forces the sucked liquid into fine spray through the nozzle. Rocking sprayer is commonly used for spraying tree crops like coconut, arecanut, citrus, and climbers like pepper.

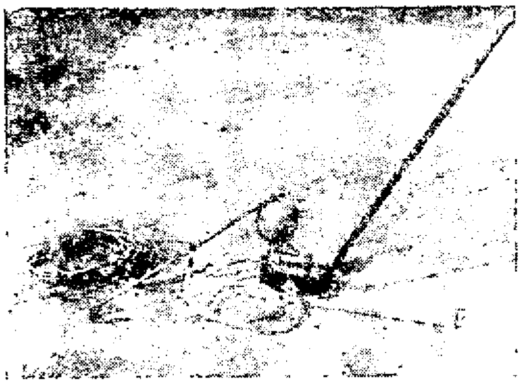

Fig. 37.4 Manually operated rocking sprayer

Power operated sprayer

Power operated sprayers are used for covering large areas in short time. Motorized knapsack sprayer cum duster known as mist blower (Fig. 37.2) is in common use. There are several other big models of power sprayers that can be carried manually or mounted on vehicles.

37:4. Equipments used for seed treatment

Seed dressing machines

Seed dressing machines are used for treating the seeds with fungicides or insecticides before storage or sowing. The hand operated model is commonly used and it consists of a drum fitted on a stand. (Fig. 14.1). For more details on seed dressing machines see the section on seed treatment in Chapter 14—Seed production and handling in this book.

37:5. Other plant protection equipments

There are several other plant protection equipments also, used for various purposes. Important among them are listed here.

Rat fumigation pump

It is used to blow toxic fumigants into rat burrows to kill them.

Soil injector

Soil injector, also known as soil gun, is used to apply liquid pesticides into the soil particularly near the root zone of crops.

Granule applicator

This is used to apply granular formulation of pesticides uniformly into the soil.

Bird scarrers

This is a device used to scare away birds and wild animals like jackals by producing sound from the crop area. It has three essential chambers, a chamber to hold calcium carbide, a smaller chamber placed inside the former to hold water and a cumbustion chamber attached to the main chamber. Water acts with calcium carbide, generating acetylene which explodes producing noise.

Rat traps

There are several kinds and designs of rat traps employed for catching and killing rats.

Books for supplementary reading

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Appendix

VOCATIONAL HIGHER SECONDARY EDUCATION

SYLLABUS IN AGRICULTURAL VOCATION

FIRST YEAR

Total Hrs—120

A. Theory

1 *Agriculture*— Definition — scope — impact of Agriculture in the economic importance of country—area and distribution of important crops of Kerala—water resources of Kerala and their utilisation.

2 *Weather and Climate*—weather elements — monsoons — meteorological equipments and their uses — rain guages—wet and drybulb, maximum, minimum thermometer.

3 *Soil*—Definition—soil profile.

4 Weathering of rocks—agencies involved—type of rocks—igneous, sedimentary and metamorphic rocks.

5 Soil formation—Soil development—factors involving.

6 Physical properties of soil—colour—texture—structure—soil water — soil moisture constant — soil air — soil colloids — organic and inorganic colloids—field capacity and permanent wilting point.

7 Soil acidity—pH—reason for acidity.

8 Essential elements—micro and macro elements — functions — deficiency symptoms—effect of the over supply of elements.

9 Soil groups and soil types of Kerala.

10 Soil erosion—definition — reasons — types—soil conservation practices.

11 Soil organic matter—humus— its role in soil fertility — advantages of addition of organic matter in soil.

12 *Green manuring*—green leaf manuring—important green manure crops and green leaf manure crops—advantages of green manuring.

13 Organic manure—types—their chemical composition — preservation and processing of organic manures.

14 Soil sample—definition—collection of dry land and wet land soil samples—method of sending soil sample to soil testing laboratory.

15 *Agronomy*—definition — objectives—seed—definition—importance of seed—seed dormancy—difference between seeds of local varieties and hybrid varieties—impact of hybrid seeds in crop production of paddy, coconut, tapioca, rubber, banana, sugarcane, cardamom, pepper, pulses, oil seeds.

16 Seed treatment -benefits — types of seed treatment — conditions under which seed treatment is done —seed treating products—seed treatment of important crop seeds—use of seed dressing drum.

17 Seed testing— purpose — sampling procedure—method of purity analysis—reporting results.

18 Seed germination test — methods using paper, sand, soil, wet cloth rolling method.

19 Seed moisture—methods of moisture determination.

20 Seed drying—objectives — methods-sun drying—forced air drying— extent of drying required for seeds of different crops—rice, pulses, groundnut, sesamum, vegetables.

21 Seed storage — general principles — storage needs—factors affecting seed longivity in storage.

22 Various classes of seeds — nucleus seed — foundation seed — certified seed — their multiplication — seed certification objects—N. S. C.

23 *Tillage* — definition — objectives — primary and secondary tillage—ploughs, harrows, cultivators — other equipments — rotovators attached to tractors—seed drills — planks— clod crusher—tiller drawn ploughs—tractor drawn ploughs.

24 *Weed*—definition— characteristics—origin—distribution—uses — harmful effects.

25 Weed classification — persistence of weed in soil — dormancy of weed seed—factors affecting dormancy and germination of weed seed.

26 Prevention of weed infestation in new area.

27 Weed control method—classification —mechanical methods—cropping and competition method—biological method.

28 Chemical method of weed control—classification—herbicidal formulations —WP, WSP, EC and G—advantages—method of application—time and rate of application—important herbicides—their mode of action—time, method and crops in which applied—weed controlled.

29 Important weeds of garden land and wet land of Kerala and their control measures.

30 *Horticulture*—definition— importance —propagation of fruit crops—sexual and asexual—their advantages and disadvantages.

31 Layering – types—merits and demerits —layering in important fruit crops—principles.

32 Budding—different methods— advantages and disadvantages—budding in important crops—principles.

33 Grafting—different methods—grafting in different crops—principles.

34 Propagation of fruit trees—mango, sapota, jack, pineapple, guava, papaya, banana.

35 Ornamental gardening—types of garden—parts— principles—garden design and maintenance.

36 Lawns—establishment and maintenance of lawns—grasses suitable for establishing lawns.

37 Ornamental trees, shrubs, flowering plants, climbers, hedges and edges—their characters and examples—rockery.

38 Commercial flowers—roses—jasmine, chrysanthemum.

39 *Entomology*—definition—scope— insects—beneficial-harmful – productive —general characters—mode of feeding—type of mouth parts.

40 Balance of life in nature—adaptation of insects.

41 Development and type of metamorphosis in insects.

42 General classification of insects—principles.

43 Bee management—Bee keeping.

44 *Pest*—definition—method of control—physical, mechanical, cultural, chemical and biological—crop varieties resistant to pest attack.

45 *Pesticides* — classification —nature—precautions in handling pesticides—merits and demerits.

46 Important pesticides—mode of action

47 Pesticide application—principles of spraying—preparation of spraying solution—calculation of the strength of chemicals.

48 Plant parasitic nematodes—methods of injury caused.

49 *Plant protection equipment*—sprayer, duster—parts and use—precaution in handling spraying equipments—miscellaneous plant protection equipments—bird scares, cynogas pump.

50 *Insect collection*—devices used for collection—hand net—killing bottle—insect pins—stretching boards—relaxing box—pinning box—insect store box. Method of arranging insect pest in collection box—labelling.

51 Rearing of insects—despatch of insects to specialists for identification.

52 *Plant pathology*—definition—introduction to the study of plant pathology—importance of plant diseases—losses caused by plant diseases—history of development of plant pathology.

53 Cause of plant diseases—classification—importance of fungi, bacteria, viruses, methods of study of plant diseases—symptoms of plant disease—Koch's postulate method.

54 Survival and dissemination of plant pathogens—methods of infection.

55 Plant disease forecasting—method of assessment of plant diseases.

56 Different methods of plant disease control—physical, cultural, biological and chemical—control by resistant varieties.

57 Classification of fungicides—copper, mercury, sulphur, systemic—other fungicides—antibiotics and their uses.

58 Application of fungicides—methods of application—different formulation of fungicides—compatibility of fungicides.

59 Collection of diseased specimen—despatch of diseased specimens to specialists for identification.

B. Programme for Practical Training

Total Hours—440

1 Identification and specimen collection of local and high yielding varieties of rice, pulses, groundnut and vegetables.

2 Seed sampling for testing—composit—submitted—working samples for rice, pulses, groundnut and vegetables.

3 Germination test—computing germination percentage—minimum germination percentage for rice, pulses, groundnut and vegetables.

4 Seed treatment—familiarisation with seed treatment chemicals—specimen collection—seed treatment for paddy seeds, pulses seed.

5 Weed control—study of the label and general characters of the formulations.

6 Calculation of herbicide requirements—calculating the herbicide required for unit area—WP, WSP, EC and G—identification and specimen collection.

7 Precautions in handling of herbicide in field and methods of treatment during accidents.

8 Preparation of spray solution—dilution of herbicides—filling of tanks and methods of spraying in the field—method of application of granular herbicide in the field.

9 Identification of dry land and wet land weeds of Kerala—specimen collection.

10 Inspection of paddy field for seed production—isolation distance—roguing—precautions in harvesting, threshing for preserving seed quality.

11 Identification and collection of different soil types of Kerala.

12 Collection of soil samples—dry land and wet land—method of sending samples to soil testing laboratory—familiarisation with soil testing results.

13 Collection of different crop plants showing nutrient deficiencies and their identification by visual methods.

14 Familiarisation of liming materials for correcting solid acidity.

15 Different methods of layering, budding and grafting.

16 Preparation of land and planting of grass for lawn—identification of grasses used for lawn making.

17 Cultivation of ornamental plants in pots—preparation of potting mixture.

18 Identification of ornamental plants, trees, flowering plants and raising nurseries and maintenance.

19 Identification of commercial flowers.

20 Identification of insects, setting, preservation, arranging in sets in collection box and labelling.

21 Collection of important types of symptoms of damage caused by insects on plants and their preservation.

22 Acquaintance with beneficial, harmful, and productive insects.

23 Acquaintance with bee hives, bee box, bee equipment, bee management.

24 Pesticides—familiarisation—identification—collection—pesticide formulations—preparation of spray solutions—calculation of the strength of chemicals.

25 Acquaintance with plant protection equipments.

26 Use of component parts—repair and maintenance—application of pesticides—spray, dust, granule, fumigant, bait in the field.

27 Acquaintance with parasitic nematodes—nature of damages on plants—control measures.

28 Rearing of insects—despatch of insects to specialists for identification.

29 Familiarisation with general symptoms of bacteria, fungi and virus diseases.

30 Assessment of losses caused by plant diseases in the field.

31 Familiarisation with different fungicides—preparation of 1% bordeaux mixture—testing for acidity—preparation of Bordeaux paste—Bordeaux mixture with rosin soda—Cheshunt compound.

32 Seed treatment with fungicides—dry and wet treatment—paddy, pulses and groundnut.

33 Soil treatment with fungicides

34 Preparation and use of foliar fungicides in the field.

35 Calculation of dilutions of fungicides.

36 Collection and preservation of plant disease symptoms—method of sending diseased specimens to the specialists for diagnosis.

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