This is the first of a series of three volumes on *Agriculture in India* which includes:

**VOLUME II: CROPS**

**VOLUME III: ANIMALS**
The Panchayats are respected for their fairness, wisdom and prompt action in all matters relating to village life.

[Courtesy: The Ford Foundation in India].
AGRICULTURE
IN INDIA
VOL. I: GENERAL

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ASIA PUBLISHING HOUSE
BOMBAY . CALCUTTA . NEW DELHI . MADRAS
LUCKNOW . LONDON . NEW YORK
FOREWORD

In a country like India where agriculture is the mainstay of millions, an attempt to study and discuss the problems of this vast subject is always welcome. There is in fact a great need for books such as the one now compiled by a team of authors who are experts in their respective spheres.

Designed as a text-book for use in multipurpose high schools in India and based on the draft syllabus for higher secondary schools under the Ministry of Education of the Government of India, Agriculture in India is a useful publication, which gives in brief much important information on agriculture.

Apart from discussing plant forms, their functions and the chemistry of agriculture in general, the book makes an interesting survey of soil and crop management of some of the agricultural commodities sown and harvested in India. It also deals with animal industry such as cattle, sheep and goats, poultry, fish, bee-keeping and forest and wild life.

Though there is considerable pressure on land in India, agriculture can be considerably improved if we could increase some of the basic requirements of our soils. These are: (i) abundant supply of irrigation water, (ii) control of floods that visit us almost yearly, (iii) proper manuring of the soil and, (iv) consolidation of holdings, which are proverbially small in our country.

The need for authoritative and authentic information on Indian agriculture has been greatly felt in recent years due to the successive five year plans launched by the country. Each year the farmers of India remove from the soil some 8 million tons of plant foods, but only 2 million tons are put back. This gap of 6 million tons has to be made up if we are to retain the fertility of the soil.

Every type of soil in India can be made more productive by a judicious application of fertilizers and green manures. The value of fertilizers and the part they play in raising food and cash crops has been recognised by farmers all over the country. In fact, there is such great demand for fertilizers that it is proposed to increase the consumption of nitrogenous fertilizers from about 360,000 tons at the end of the Second Plan to one million tons in terms of nitrogen, and of phosphatic fertilizers from about 67,000 to 400,000 tons of
FOREWORD

P₃O₅, and 200,000 tons of potash (K₂O) by the end of the Third Plan in 1966.

India suffers from a shortage of water though her total water supply is more than any other major country in the world. This is due to lack of irrigation facilities, which, however, could be improved to a considerable extent. India uses only a small percentage of the water that her rivers could supply for irrigation purposes, and though marked progress has been made in recent years to divert this water to the fields, much has still to be done. It has been estimated that if all the water now flowing annually in India’s rivers were spread out evenly all over India, it would cover the entire country to a depth of about 20 inches.

I have great pleasure in contributing this Foreword to this very useful and fairly comprehensive publication. I feel confident that apart from serving as a text-book for teachers and students, it may be found of great use by the farming community at large. For such use, of course, it will have to be translated in various Indian languages. I look forward to there being a demand for this in due course.

P. S. DESHMUKH

Former Minister for Agriculture,
Government of India and President of the Bharat Krishak Samaj
(Farmers’ Forum, India)

New Delhi,
February 10, 1962
PREFACE

In 1957 the Ministry of Education published, Draft Syllabus for Higher Secondary Schools, to serve as a guide for Indian teachers in the presentation of subject-matter to pupils in the classroom. Also the Syllabus was issued to establish a pattern for use by writers in preparing text-books intended for both teachers and pupils.

We are happy to announce that this book on Agriculture in India was outlined on the basis of the Syllabus and written by a team of Indo-American authors for use in the Multipurpose Higher Secondary Schools in India. The need for suitable text-books is urgent throughout India’s rapidly expanding education system. This is especially true for a subject such as agriculture whose facts and practices cannot simply be borrowed from other countries, but must be accumulated and developed in the country of their use.

The Planning Commission has also stressed the need for text-books in the Third Five Year Plan by stating that:

“Although the concept of the Multipurpose school has been readily accepted and the scheme has rapidly expanded, certain difficulties have been encountered, such as the lack of teachers trained to teach the practical subjects, insufficient teaching material, specially text-books and handbooks . . .”

This book, written in English, will be of value specially for use by teachers. Our next greatest need is for this and other secondary books that are printed in the regional languages. I am pleased to announce, however, that already one of the present authors has signed a contract to translate this book into Hindi. Plans are also progressing satisfactorily for translating the book into other Indian languages.

PREM N. KIRPAL
Secretary and Educational Adviser
to the Government of India,
Ministry of Education, New Delhi

New Delhi,
September 15, 1962
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INTRODUCTION

An Indo-American team of authors has laboured for three years to produce a book in three volumes that is easy to read, comprehensive, practical, conveniently arranged, and well illustrated. This text is evidence that they have succeeded.

The publication of *Agriculture in India* is in accordance with India’s priority for agriculture and agricultural production. The Third Five Year Plan states:

“In the scheme of development, the first priority necessarily belongs to agriculture; and agricultural production has to be increased to the highest levels feasible.”

The objective of this book is to provide a text suitable for use in the multipurpose high schools of India. Translations into Hindi and other regional languages are in progress. These objectives of the authors coincide with those of the Government of India (Third Five Year Plan).

“The problem of text-books has been assuming greater urgency in recent years. Steps will have to be taken to select, train, and encourage writers and illustrators. The problem of translation of standard text-books into various languages and the writing of original books in these languages have become important in view of their greater use.”

Substantial effort has been directed to the development of secondary schools for agricultural areas. Two major limitations have been the lack of trained teachers and the scarcity of teaching materials, especially text-books and references. The publication of these volumes is a contribution to the solution of one of the two major problems.

The authors here present *Agriculture in India* as a contribution to the progress of India during the Third and future Five Year Plans. Its aim is to assist in educating agricultural leaders to help farmers to produce an abundance of food, feed, fodder, and livestock products. The three volumes present to students of multipurpose
high schools scientific knowledge about General Agriculture, Crops, and Animals which will aid in producing adequate food for a developing and dynamic society as it moves toward goals of improved nutrition, increased health, and general welfare of the people of rural and urban areas.

August 10, 1962
College of Agriculture,
Poona-5
Maharashtra State.

DR. GEORGE MONTGOMERY
Chief of Party
Kansas State University—
U.S.A.I.D.—India Team.
ACKNOWLEDGEMENTS

HUMBLY and gratefully the Indo-American team of authors pause during the usual last-minute rush of completing this book to acknowledge the assistance given them in its preparation.

For encouragement and other assistance given in writing this book, the authors give acknowledgement to the following persons: Shri Vas Dev, formerly Under Secretary, Indian Council of Agricultural Research, New Delhi; Mr. J. P. L. Guinn, I.C.S., Secretary to Government, Education Department, Hyderabad, Andhra Pradesh; Dr. George Montgomery, Chief of Party, Kansas State University—U.S.A.I.D.—India Team, Poona, Maharashtra State; Shri J. Raghbotham Reddy, farmer, Member of the Legislative Council, and Vice-President of the Andhra Pradesh Krishak Samaj, Hyderabad; Dr. E. R. Towers, formerly Group Leader, Secondary Educational Programme, Ohio State University—U.S.A.I.D.—India Team, New Delhi; Mr. Merril K. Luther, Specialist in Agricultural Education, on the same team; Dr. T. C. Joseph, Professor of Botany, Shri M. Ramanatha Menon, Plant Physiologist, and Shri Renga Aiyer, Lecturer in Entomology—all at the Agricultural College, Trivandrum, Kerala State.

The authors acknowledge the assistance given by the Government of Mysore State for granting permission for one of the authors to contribute to this book.

To the following members of the Staff of the Technical Cooperation Mission to India who critically reviewed portions of the original typescript, the authors owe a debt of gratitude: Dr. E. Hixson, formerly Agricultural Education Advisor; Mr. Armin R. Grunewald, formerly Soils Advisor; Dr. L. M. Humphrey, Agronomy Advisor; Mr. W. S. Speer, formerly Soil Conservation Advisor; Mr. Robert H. Engle, formerly Fertilizer Advisor; Dr. Gulbert R. Muhr, Soil Testing Advisor; Mr. M. H. Taylor, Soil Conservation Advisor; and Mr. George Knierim, Agricultural Extension Advisor (Water Use). Other persons who reviewed selected chapters include Mr. J. G. Bruton, Central English Institute, Hyderabad, Andhra Pradesh; Shri Syed S. Hashmy, formerly Deputy Secretary to Government, Department of Agriculture, Hyderabad, Andhra Pradesh; Dr. K. C. Naik, formerly Chief of Indian Council of Agricultural Education,
ACKNOWLEDGEMENTS

New Delhi; and Shri Rai Prithvi Raj, formerly Special Officer for Rural University, and formerly Director of Agriculture, Andhra Pradesh.

Special acknowledgement is made to the following persons who worked overtime and with a personal interest in the preparation of this book: Shri Ashby F. Romeo, Administrative Assistant; Shri Seetaram Iyengar, Stenographer; Shri K. S. John, Stenotypist; Shri R. S. Satwik, Draftsman; and Shri Pat Romeo, Artist.

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Chapter 1

RURAL ORGANIZATIONS—THE PANCHAYAT

Many years ago, people living in Indian villages used to have a system of village government of their own. This was called the village panchayat or gaon sabha (village organization). The office-bearers of the panchayat were elected by the people of the village. The panchayat used to look after the welfare of the entire village community. The functions of the panchayat covered all aspects of rural life and varied from the building of roads, the running of schools and poor houses, to defending the village against invaders. It had to look after the social, cultural, and economic life of the villagers. The panchayat also had powers to collect taxes and settle disputes. The panchayat was respected for its fairness, wisdom and prompt action in all matters relating to village life (Frontispiece).

This village organization, existing since the vedic era, began to lose its effectiveness in the course of time. When British rule started in the country, a central government was established and the power and authority of the panchayat were slowly lost.

Bearing in mind the service that the panchayats were rendering to the community, attempts were made later to set them up again in the villages, but with no great success. In 1935, the Village Panchayat Acts were passed in several provinces, and in 1946 new laws were enacted to re-organize the panchayats. With the importance and encouragement thus given, panchayats began to be set up again slowly and today there are more than 177,000 panchayats functioning in our country, serving over 495,000 villages. When the whole country is covered by these organizations there will be about 200,000 panchayats working.

PANCHAYAT SYSTEM

The panchayat is a system of local self-government of the villagers. Normally, all adults who live in the village (or a group of villages) form the gaon (village) sabha. This sabha elects the members for the
executive bodies of the panchayat. It also elects a President and a Vice-President. In some States, these two office-bearers are elected by the panchayat which itself is elected by the gaon sabha. The gaon sabha or the general body of the villagers meets once or twice a year and supervises the work of the panchayat.

The way a panchayat is organized differs, however, in some places. In Bihar, for example, all adult residents of a village form the panchayat. They elect a mukhya (chief) who selects his own executive committee. Assam has two types of panchayats, the primary and the rural. The primary panchayat includes all adult residents of the village and elects its own executive committee. The rural panchayat consists of representatives of the primary panchayats elected on the basis of one person for every two hundred members. The primary panchayats work under the direction of the rural panchayat.

The number of members composing the panchayat also differs from place to place. Generally, it depends upon the population of the area. There is also a limit to the number of members a panchayat can have. This varies from five to nine members in the Punjab to fifteen to thirty members in Uttar Pradesh. The minimum age for membership of a panchayat is fixed at twenty-one, except in Madhya Pradesh where it is twenty-five.

Normally, a panchayat remains in office for three years. Then a new panchayat is formed.

According to the Panchayat Act, the Government can declare any village or group of villages a panchayat area in which a panchayat has to be set up. Similarly, State Governments have declared the units of population for which a panchayat can be set up. In Madras, for example, it is five hundred and in Assam, twenty-five thousand.

The panchayats, under the Panchayat Act, can take up a very large number of useful items of work, such as public health and sanitation, water supply, street lighting, maternity and child welfare, registration of births and deaths, and village defence. They can provide for the education and the recreation of the villagers, take up the construction and repairs of roads, tanks, wells, and bunds, arrange for the relief of the poor and the victims of floods and famines, develop agriculture, improve livestock, promote cottage industries and set up village cooperatives.
THE PANCHAYAT

PANCHAYATS AND THE STATE GOVERNMENT

In the last few years, panchayats have taken an active part in the preparation of development plans for the villages in the Five-Year Plans. To do all this work, the panchayats need money. They have, therefore, been given the power to levy taxes on persons, property and business. In most States, the panchayats levy a general property tax, taxes on land revenue or rent of land, a profession tax and a tax on animals and vehicles. The rates at which such taxes can be levied, and the conditions under which this is done are laid down by the State Government. In some States, the panchayats can ask villagers to put in their labour free for public purposes. Where necessary, the Government also gives grants for the panchayats to carry out their work.

The work of the panchayats is looked after by State Governments. Each State has a field staff for the purpose. The panchayats are served by full or part-time secretaries, who are specially trained for the work. The Government sees that the panchayats do not misuse their funds or powers, encourages them to function properly and helps in their development.

PANCHAYAT SAMITIS AND ZILLA PARISHADS

The village panchayat has to be responsible for all the development work undertaken in its area, if it is to serve the village communities to the fullest extent.

A beginning in this direction has already been made in Andhra Pradesh and Rajasthan. In these States, the village panchayats are organized into panchayat samitis and zilla parishads. A panchayat samiti is formed of the representatives of the village panchayats in a Development Block. The zilla parishad is the apex of the panchayat organizations at the District level.

The village panchayats, panchayat samitis and zilla parishads have been allotted revenue from tax collections, and are made responsible for all the development work in their respective areas. The Block Development Organizations have to function in these areas under the direction of the panchayat samitis and zilla parishads. By 1961, the States of Madras, Mysore, Assam, and Orissa had already
passed Acts for adopting a similar system in these States and the other States propose to take up similar legislation soon.

**SUMMARY**

The *panchayat*, a form of village government, has been in existence in India since ancient times. It had wide powers and looked after the social, cultural and economic life of our villagers.

The *panchayats* lost their importance during foreign rule. After Independence, attempts have been made to re-organize the *panchayat* throughout the country so that people may have a voice in deciding their own future. State Governments help the *panchayat* in taking an active part in village development. Now attempts are being made to organize the *panchayat* into *panchayat samitis* and *zilla parishads*.

**QUESTIONS**

1. Why is a *panchayat* called a village government?
2. In what different ways do you think the *panchayat* of your village serves the villagers?
3. How does a State Government help the *panchayat* in its work?

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*The Panchayat*, Publication Division, Government of India, 1956
Chapter 2

LAND REFORMS

LAND is the stronghold of our people. Seventy per cent of the people of India earn their living directly from the land, and the progress of agriculture is, to a large extent, the progress of the country.

The farmer who produces wealth from land should have the opportunity and facilities for developing the land he cultivates so that he can improve agriculture and get increased returns.

The system of land ownership has much to do with the development of agriculture. So, much depends on whether the cultivator owns the land or is a tenant; and if a tenant, under what conditions he holds the land, the size of the land he holds and whether it is all in one place or is scattered.

LAND OWNERSHIP

In India, until 1947, the land system was far from being helpful to the farmer. Half the land was held by zamindars, who formed but four per cent of the rural population. Three-fourths of the rural people held only sixteen per cent of the land, consisting mostly of small farms. A large number had no land of their own and worked as tenants or farm labourers.

The land system that was in force was based on the principle that all land belonged to the Government, which collected rent from those who cultivated it.

During the British days in India, the Government found it difficult to collect rent or revenue from individual farmers, so it appointed agents to collect such rent from the farmers or tenants on its behalf. The agents were given wide powers and were to pay rent to the Government at fixed rates. This system came to be known as the zamindari system.

In addition to this, there was also the ryotwari system. Here, the Government collected revenue directly from the ryots (farmers) who had been settled on the land.

Sub-letting of land became common in the course of time in both systems. Though the Government collected revenue at a
fixed rate from the agents, it was common for the agents from time to time to increase the rent they obtained from the tenants.

As population increased, rents charged by agents rose higher and higher, cultivation was extended, and the value of land increased. In some areas, tenants had to pay a rent of as much as two-thirds of the gross value of all farm produce they obtained from the land. The landlord or agent spent none of this money for land improvement.

While the landlords grew rich due to such a land system, the tenant remained poor — getting but a small share in return for his labour. Nor had he any security of tenure. The landlord could send him away at any time and appoint another farmer in his place. A tenant had very little interest in the land he tilled under such circumstances. As the hardship of the tenant increased, the production from land decreased.

There were also the landless farm labourers. In 1947, there were fifty million of such labourers in the country. They could barely find employment for six months in the year. They suffered most when there were natural calamities such as floods and droughts.

**THE NATIONAL LAND REFORM PLAN**

Attempts were made from time to time in some areas to introduce land reform laws so that the tenant could get permanent rights and the rents charged by landlords could be controlled. But tenancy legislation on a large scale was taken up only after India’s independence in 1947. The National Plan, drawn up in 1950–51, provided that the land system should be so changed that the benefits of labour could go to the man who tilled the land, and to enable him to work the land so that it could be a source of wealth to the whole community.

The Plan recommended that the programme for land reforms should include:

1. Abolition of agents who collected rent from the land.
2. Reduction of rents, giving permanent rights of land to tenants or enabling them to be landowners by paying a reasonable price for the land allotted to them.
3. Fixation of the maximum area for land holdings and distribution of surplus land to the landless.
Pl. I. Land reform laws have given this farmer the security he needs to adopt the best farm practices in order to obtain the highest net income. [Courtesy: Frank Shuman].

Pl. II. Credit service.
Cooperative banks are organised to provide farmers with loans to increase agricultural production and not for use in paying for bigger weddings. [Courtesy: Roy L. Donahue].
Pl. III. An improved rice tiller and puddler that has been designed for use in the river delta soils of Andhra Pradesh. It is owned and used by a village Cooperative. [Courtesy: ROY L. DONAHUE].

Pl. IV. Cotton is being carried to a cooperative gin to have the seed separated from the lint. [Courtesy: M. G. KAMATH].
4. Consolidation of fragmented holdings and prevention of further fragmentation of land.
5. Development of cooperative farming and cooperative village management.

RESULTS OF LAND REFORM

Agents to collect rent have been abolished now in all States of India and the Government deals directly with the cultivators. Vast areas of waste lands and grazing grounds have been brought under the control of the State Governments or the panchayats. The agent or landlord in many States can now hold only a limited area for his personal cultivation; and this area, only if he supervises the farm operations himself or resides in the same or a neighbouring village or contributes his personal labour in cultivating the land.

Several States have brought down the high rent the tenants were paying to one-fourth of the gross produce, or even less in some cases.

In some States, tenants have been given full security of tenure by law. In most States, it is now possible for tenants to become landowners by paying a reasonable price for the land, the price to be fixed by the Government. In many areas, the tenant can pay for the land in instalments. The landlord is also paid compensation for the land taken away from him.

To settle landless labour on land, ceilings or limits on the area any individual can hold have been fixed in many States. Some States have put a ceiling on existing holdings; others only on future purchases. The surplus land so obtained is distributed among the landless people.

Small and scattered holdings, common in our country, are a great handicap in agricultural development. It is necessary to bring these holdings together to make units of larger areas that are more economical to operate. Holdings should also be prevented from being further cut into small and uneconomic pieces. In many States a law prevents any more fragmentation of holdings. In many others the scattered holdings are being brought together to make compact farms.

Small and middle class farmers have limited finances to use in improving their farms. Such farmers may get better returns from land if they form cooperatives. The Central and State Governments
are now encouraging the formation of farming cooperatives. A large number of them have already been formed in various parts of the country. All surplus lands obtained as a result of land reforms and through other sources are being given to farming cooperatives, formed mostly by landless rural labour. Attempts are now being made to see if the village as a community cannot take up all the village land and manage it on a cooperative basis, so that the individual may work for the community and the community for the individual — with benefit to both.

Land reforms have been given great importance by the Central and all State Governments. These are providing the farmer with the security he needs and are giving him the fullest possible share of what he produces from the land (Plate I).

**SUMMARY**

Land is important for the Indian people. However, for centuries, very few farmers have owned the land they tilled. The zamindari and ryotwari systems of land ownership merely exploited the farmers. The landowners got the major share of the produce and the farmer-tenants and landless farm labourers suffered.

After Independence, a National Land Reform Plan was drawn up, and in all States land reforms were taken up. Tenants are now being given land ownership rights and security of tenure. Landless labour is being settled on land and holdings are being consolidated. Cooperatives are being encouraged.

**QUESTIONS**

1. What was the system of land ownership during British rule? Why was it not favourable to farmers?
2. What did the National Land Reform Plan recommend?
3. In what ways have land reforms been of assistance to farmers?

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Chapter 3

FARMERS' COOPERATIVES AND ORGANIZATIONS

The average farmer in India earns a poor living out of the small farm that he owns. Even though he may desire to raise his farming and living standards, he finds the job difficult because of several handicaps. On a small-sized farm, he finds the scope for improvements limited. He feels the acute need for credit to meet the requirements of his farm and home. He has to purchase his essential supplies such as seed, manures and fertilizers, cattle feeds and implements and tools from the market at high prices. His economic condition is such that he must sell his crops at the time of the harvest; he cannot wait to sell them when prices are higher.

Partly because the average farmer cannot read or write, the moneylender, the petty trader, and the middleman exploit him and take away a good share of his profits. Individual farmers, in spite of their best efforts, cannot get over these difficulties because of their poor economic condition. A remedy lies in cooperation. What is not possible through isolated action by individual farmers may be attainable if they join a farmers' cooperative.

A farmers' cooperative is an organization in which farmers come together voluntarily and work as equals through self-help and mutual aid for the common good of all. Such a cooperative is democratic. Each member has equality of vote. "One man, one vote" is the rule, irrespective of the number of shares held by him. Membership of such a cooperative is open to all farmers; so are its benefits. A cooperative is organized to provide farmers with the services and supplies they need, cheaply and efficiently. Unlike a private firm or a limited company, the earning of large profits is not the motive of the cooperatives.

A farmers' cooperative functions in a limited area such as a well-organized village or a group of small villages; therefore all the members are known to one another. This makes them work in mutual trust and for the common good of all. Each member of a cooperative cannot buy more than a limited number of shares. In this way a sense of equality is created.
In a farmers’ cooperative, service comes first. Only a small portion of the profits earned is divided among members as dividends at the end of each year. A certain portion of the profits goes to what is called a reserve fund. This is invested safely and is used for improving the working of the cooperative, or for meeting any losses it may incur. A small portion of the profits is also set apart as a common goodwill fund to be used for assisting a farm family or an individual in distress. The remainder is given as rebate (repayment) to members, according to the amount of business each one has conducted with the cooperative. A cooperative of this nature encourages thrift among its members and goodwill for one another. If worked properly, it can bring about an improvement in the economic condition of its members.

A farmers’ cooperative may be organized to serve one specific purpose, such as (1) supplying credit on easy terms (credit cooperative) (Plate II); (2) purchasing and selling stores (supplies) (stores cooperative); (3) marketing of agricultural produce or its products (marketing cooperative); (4) consolidating holdings (land consolidation cooperative); or (5) farming in cooperation (farming cooperative). Sometimes, instead of organizing separate cooperatives for meeting different needs, it is advantageous to have a single cooperative with two or more functions. Such a cooperative then becomes a multipurpose cooperative.

The cooperative movement was started in India in 1904. At present, about two hundred and fifty thousand cooperatives exist with a membership of more than twenty million. Their share capital and reserves amount to Rs. 1,870 million. The cooperatives serve about two hundred and fifty thousand villages.

**CREDIT COOPERATIVE**

Most farmers need cash to invest on the farm, to meet expenses during the growing period of the crop, to meet urgent family needs, or for social functions. They have to wait for one full crop season before they can have ready cash on hand. A credit cooperative can devote itself to the grant of such short-term loans to the farmer members to meet their needs during the agricultural season. The loans may be granted on the personal security of its members. Many credit cooperatives have been re-organized into multipurpose cooperatives.
STORSES COOPERATIVE

Farmers need such supplies as seed, manures and fertilizers, tools and implements and other appliances, cattle feeds, food, clothing and other household requirements. These they obtain from the small trader at very high prices. There is no guarantee of the quality or quantity of the goods supplied. Many a time, supplies also are not available.

These difficulties can be overcome if farmers organize a stores or supplies cooperative. Such a cooperative can buy, at a wholesale price, all the stores needed by the members and sell the same in small lots to the members at prevailing retail prices. Whatever profits the cooperative thus earns are distributed at the end of the year among the members as rebate.

Farmers are thus able to get a guaranteed quality and quantity of the stores they need. They will also develop a sense of thrift. A stores cooperative can also purchase and stock farm equipment and machinery which small-holders need but cannot buy because of the high cost, and loan them out on a moderate hire rate (Plate III).

In addition to seed, fertilizers, implements, and tools, a stores cooperative can purchase and sell such other necessities as insecticides, chemicals, kerosene oil, and iron and steel meant for farm implements and buildings.

MARKETING COOPERATIVE

It is not enough if a farmer takes up improved practices and secures increased crop yields. He should also be able to sell his produce at the best possible price. The farmer, however, is unable to store his produce and wait for a favourable market price to sell it, as he needs cash immediately after the harvest to meet his immediate requirements.

Since the farmer sells his produce independently, he has to offer it in small lots which do not attract good buyers. It is the middleman who purchases the produce from him and pockets a good share of the profits. The use of faulty weights and measures in the sale further reduces the farmer’s gains. In many cases, the farmer himself is tempted to mix inferior grade produce with a superior one in the hope that he may earn more profits. But, in reality, he loses
further, as he gets paid at the rate at which the inferior grade is sold.

In many places the Government has regulated private markets to help farmers sell their produce at a maximum profit. Where they desire to do so, farmers can form agricultural marketing cooperatives. Cooperatives can be successfully run if the market conditions are first studied and the best mode of selling the produce decided upon. The members can bring their produce to the cooperative for storage, and obtain some advance on the same for meeting their immediate cash needs. The produce can be sold when the market prices are favourable. If this procedure is not convenient, then the members can bring their produce on a particular day, and sell it for cash. It will also be possible for members to obtain a cash advance during the crop season, to be adjusted when the produce is sold later (Plate IV).

A marketing cooperative should have the necessary godown accommodation for storing the produce brought in by members. This, however, will not be required if the arrangement is to sell the produce on the spot. For storing, due care also has to be taken to see that the produce is properly packed. Warehousing corporations set up by Government also provide space to individual farmers or cooperatives for storing farm produce at a small charge in their godowns. Where farmers' marketing cooperatives cannot arrange for their own godowns, they should take advantage of this facility where available.

Farmers located around urban areas, where the demand for milk and milk products is high, may organize dairy cooperatives for marketing milk and milk products. Such cooperatives are able to enforce rigid standards for ensuring uniformity and high quality in products that are offered for sale to consumers. As a result, consumers are willing to pay an increased price for good quality products. If such a cooperative is properly organized, the members can arrange for such facilities as common milking sheds, medical treatment for the milch animals, purchase of fodder and feeds at concessional rates, and securing of loans for the purchase of new animals. Where the cooperative is located at a distance from the urban centres and milk cannot be easily transported over long distances in good condition without costly equipment, the cooperatives can deal with milk products such as cheese, cream, butter, and ghee. A large number of such cooperatives are successfully working near many Indian cities and towns.
Farmers who maintain poultry can organize similar cooperatives for the mixing and sale of poultry feeds and the collection, grading, and marketing of eggs and poultry. A cooperative can also deal in fruits and vegetables, or sell honey and wax and many other products produced on the farm.

**LAN D C ONSolidAtIoN Co OperAtIve**

In India, the individual land holdings of farmers are usually small. These small holdings are often scattered about in various places. This makes efficient management of the farm very difficult. The farmer wastes his time and energy in moving from one field to another. It is also difficult to adopt improvements on such small pieces of land. Where a large area has been cut up into small fields and each field is banded for demarcation, the area occupied by the bunds is lost to cultivation.

In recent times, the evil of fragmented and scattered holdings has attracted great attention from both the Government and the farmers. In many States, laws have been enacted to prevent the further fragmentation of holdings. In consolidating fragmented holdings located at some distance from each other and owned by one individual, fields have to be exchanged so as to give the farmer a single, consolidated plot of land. In many cases farmers themselves have organized cooperatives for this purpose. Such cooperatives are called _cooperatives for the consolidation of holdings_. In these cooperatives, members agree to the decision of the majority in the redistribution and exchange of fields. Such cooperatives can also aid, through mutual agreement between the members, in the prevention of further fragmentation of land. Disputes on the quality and area of land to be exchanged, the re-demarcation of boundaries, and the site of the new consolidated land with respect to the new owner can also be easily settled through mutual agreement. Such cooperatives can also lay out roads and pathways in the area to make transportation from the field to the village easier and more economical.

**F A R M I N G C O O P E R A T I V E**

When farmers desire to cooperate in almost all aspects of farming, they can organize a _farming cooperative_. A farming cooperative
may be one of the following four kinds, some of which have been successful and some have not:

1. A better farming cooperative
2. A joint farming cooperative
3. A tenant farming cooperative
4. A collective farming cooperative

**Better Farming Cooperative**

In a *better farming cooperative*, members agree to carry out improved practices decided upon by them as the most suitable and profitable for the area, such as the use of improved implements or chemical fertilizers, or the growing of fodder crops (Plate V). The members may also take up joint farming or joint harvesting, or joint use of machinery (Plate IV). Each member, however, is free otherwise to farm as he pleases. He retains the rights over his own land. He pays for the services he receives from the cooperative, and obtains a dividend at the end of the year.

A cooperative can also be organized for undertaking agricultural operations such as the construction and maintenance of irrigation channels, the deepening of wells, deep ploughing, or the building of farm roads. These operations cannot be easily undertaken by individual farmers because of the labour and cost involved. Members of such a cooperative can jointly purchase costlier equipment such as tractors and accessories, power-driven gins, lift irrigation machinery and sugar cane crushers.

**Joint Farming Cooperative**

In a *joint farming cooperative*, the members pool their holdings which are not large enough to permit farming to be profitable, and cultivate them jointly, adopting improved practices. Each member receives wages for his daily labour. When the produce is sold at the end of the season he gets a dividend in proportion to the area of land contributed by him and a share of the income from the produce in proportion to the labour contributed by him. Such a cooperative jointly makes its purchase of seeds, fertilizers or equipment and undertakes land improvement work.
TENANT FARMING COOPERATIVE

In a tenant farming cooperative, land is taken up freehold or leasehold and divided into smaller holdings. Each one of the holdings is leased out to a tenant cultivator who is a member of the cooperative society. The whole land is cultivated according to a plan laid down by the cooperative. But how it is to be executed is left to the decision of the individual members. The cooperative also provides such necessities as credit, seeds, and manures to the members and helps in the marketing of the produce. Each tenant member pays a fixed rent for his holding, but the produce of the holding is his own and can be disposed of in the manner he likes. The cooperative distributes the profits at the end of each year to the members in proportion to the rent paid by each.

COLLECTIVE FARMING COOPERATIVE

A collective farming cooperative also holds land in freehold or leasehold, and undertakes joint cultivation for its members who pool their labour resources for which they are paid wages at a prescribed rate. Since the cultivation is on a large scale, it is possible to have mechanization which may mean more profits to the cooperative. At the end of the year, the profits are divided among the members in proportion to the labour contributed by each.

MULTIPURPOSE COOPERATIVE

When it is not practical for farmers to organize a number of cooperatives, each with one specific function, it would be advisable for them to organize a multipurpose cooperative. Such a cooperative, for example, can be formed to handle credit, better farming, marketing of farm produce as well as for the supply of farm or home needs. The functions it undertakes, however, should be of use to all members and not to only a few of them.

A large number of multipurpose cooperatives are functioning today in India, and most of them combine credit with purchase and sale of members’ produce.

To make these cooperatives effective for increasing agricultural production by improved methods, it has recently been decided that there should be one service cooperative in each village. These
cooperatives will not only look after the credit requirements of cultivators, but also help them obtain seeds, fertilizers, plant protection chemicals, and cement, iron, and steel at favourable prices. It is only by organizing such service cooperatives that the needs of villagers can be fully met.

FARMERS FORUM

A number of programmes have been launched by the Government for improving farming, standards of farm living and developing the rural community. The panchayat helps farmers solve some of their problems. The village cooperative assists them to get a better share of what they produce, and to increase their farm income.

Yet, these agencies alone cannot give the farmers all that they need or solve all their problems. They should have an effective voice in deciding what type of development plans they need. They should be able to tell the Government what policies will protect their interests and benefit them most.

In many countries, farmers organize themselves into a union or association. Such a farm organization gives the member farmers the chance to get together and express their opinions on the problems before them and decide on what they should do.

Such organizations negotiate with the Government on agricultural prices and marketing control, promote the farm business, and protect the interests of the farmer members. They cooperate with the Agricultural Services and Extension Services in establishing demonstrations and arranging for farm supplies. They help set up farm cooperatives. They also promote, in other ways, the welfare of the farming community.

In India also, some farmers’ associations had been organized in a few places and were working in a limited manner. But recently, with the help of the Government of India, a movement was started for organizing “Farmers Forums” or Krishak Samaj (Sabhas) in the different States. Such Sabhas are being set up at the village, taluk (sub-division of a district), district and State levels. There is the Bharat Krishak Samaj or the Farmers Forum of India, which helps in setting up such organizations all over the country.

A farm organization or krishak sabha can bring all farmers together to understand and find solutions to their problems, protect and promote the interests of the farm producers, and formulate
Pl. V. Wheat grown cooperatively will produce a good harvest. Cooperative farming is a new venture in India. [Courtesy: M. G. Kamath].

Below: Pl. VI. The Gram Sevaks who serve in the National Extension Blocks are given intensive training. In this instance they are learning how to plant rice by the Japanese method. [Courtesy: Frank Shuman].
Pl. VII. The wheat specialist who developed a rust-resistant wheat talks to the farmer who has chosen to plant the improved variety.

[Courtesy: Roy L. Donahue].

Below: Pl. VIII. A demonstration rice farm where improved varieties and cultural practices are tried. Left—No fertilizer; right—properly fertilized (Kerala State). [Courtesy: Fertiliser Association of India].
State and national agricultural policies. The organization gives the individual farmer the opportunity he needs in planning for his own future and for that of his community.

Farm organizations of this nature have been set up now in all States in India.

**FARM YOUTH CLUBS**

Today’s farm boys and girls are our rural citizens of tomorrow. They must learn improved methods of farming and farm living, cooperate in community improvement work and get ready to share the responsibilities of a growing nation.

In many countries of the world today, Young Farmers’ Clubs or Farm Youth Clubs provide the facilities they need to be better farm men and women of tomorrow. In India too, farm youth clubs are being set up in different places.

A farm youth club or *yuvak kishak sangh* or *yuvak mandal* can help rural boys and girls develop good ideals and standards of farming and farm living, community life and citizenship.

The club can help these boys and girls develop healthy habits of living, learn new crafts and occupations, and put their leisure hours to a useful and intelligent purpose. Young boys and girls who join these clubs take up “projects” such as rearing chicks or raising vegetables or embroidery or cooking with the help of a “leader” who is trained in this type of work and who can guide them from time to time. What they learn they demonstrate to other boys and girls, and thus more young people and eventually all of India is benefited.

**SUMMARY**

The standard of farming and farm living in India is low because the farmers suffer from certain handicaps. Individually they are unable to raise these standards, but they can do so if they work collectively through cooperatives.

A farmers’ cooperative is an organization in which farmer members come together voluntarily, and work for the common good of all. It is democratic. Each member enjoys the same equality as any other and has a voice in its activities. In a cooperative, service comes first, and profit-earning last.
A cooperative is meant to serve one function, such as the supply of credit, purchasing and selling of stores and supplies, marketing of agricultural produce or products of subsidiary industries, consolidation of holdings or farming in cooperation. A cooperative may also combine some of these functions and be a multipurpose one.

The credit cooperative grants short-term loans on easy terms to its members. The stores cooperative provides the stores and supplies needed. The agricultural marketing cooperative enables members to sell their products at favourable market rates. Marketing cooperatives can also help sell milk and milk products, eggs and poultry and other products produced on the farm. A land consolidation cooperative helps members consolidate their scattered holdings through mutual agreement. A farming cooperative helps farmers get a better living out of land through collective efforts.

In recent years the Farmers Forum, a national farmers' organization, has been established, with branches in each State. The purpose of the Farmers Forum is to provide a medium through which the interests of the farmers can be protected.

Farm Youth Clubs have been organized in many States in India for the purpose of providing recreation and guidance in scientific agriculture for the young people of the villages.

QUESTIONS

1. What are farmers' cooperatives? Why can farmers succeed collectively when they cannot individually?
2. Name the different types of farmers' cooperatives. Which one of them is suitable for your village?
3. Why are farmers not able to get a good price for their produce? What solution would you suggest?
4. What is the purpose of the Farmers Forum?
5. What function is served by Farm Youth Clubs?

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Chapter 4

AGRICULTURAL SERVICES

Farmers need someone to explain to them how farm improvements can be made. They need help in getting supplies of improved seed, fertilizers, implements, cattle feeds, and chemicals for fighting pests or diseases. They need help in getting the services of experts to treat a sick farm animal, or help in getting their soils tested. They also need credit to help them buy a new implement, dig a well, or construct bunds.

Such help comes from the Agricultural Department, the Community Development Department, the Animal Husbandry and Veterinary Department, the Irrigation Department, the Cooperative Department, and the Revenue Department of the respective States. The kind of services and the type of help available, however, vary slightly from State to State.

INFORMATION

Most of India’s villages are already covered by the National Extension Service which works in several Blocks in each District. At each Block, there is a Block Development Officer and his Extension Staff working to help rural people gain better living standards.

In each Block are several gram sevaks (village level workers) generally ten in number. The gram sevak meets farmers and provides them with information on improved agricultural practices and also arranges to obtain supplies for them. He arranges a number of demonstrations on improved farm practices, so that farmers can see for themselves how these practices are to be taken up and what benefit they may expect from them (Plate VI). When farmers have a problem, the gram sevak offers a solution if he knows what to do, otherwise he seeks help from the Agricultural Extension Officer at the Block Headquarters.

Villages not covered by the National Extension Service are served directly by the Agricultural Department. For each district there is the District Agricultural Officer under whom there are Agricultural Demonstrators or Inspectors. Farmers obtain the information they need from these officers.
In each State, there is an Agricultural Information Unit, attached to the Agricultural Department. This Unit publishes leaflets, pamphlets and other publications on agriculture in the local language for use by farmers. Often, farmers write to the Agricultural Information Officer of the Unit for any information they need.

When farmers want specific information on a more complex problem for which they cannot get answers from the gram sevak, they contact specialists in various agricultural subjects working in the Agricultural Department. In some States, these specialists are located at the State Agricultural College. Here is a list of the most common agricultural specialists and some of their duties.

<table>
<thead>
<tr>
<th>Officer</th>
<th>Subjects dealt with</th>
</tr>
</thead>
<tbody>
<tr>
<td>HORTICULTURIST</td>
<td>Horticultural problems, supply of fruit plants, seeds of vegetables</td>
</tr>
<tr>
<td>AGRICULTURAL CHEMIST</td>
<td>Soils, analysis of soil samples, fertilizers, water, milk, and feeds</td>
</tr>
<tr>
<td>AGRICULTURAL ENTOMOLOGIST</td>
<td>Plant pests and their control</td>
</tr>
<tr>
<td>PLANT PATHOLOGIST</td>
<td>Plant diseases and their control</td>
</tr>
<tr>
<td>ECONOMIC BOTANIST</td>
<td>Crops, grasses, seed-testing, and economic plant products</td>
</tr>
<tr>
<td>AGRONOMIST</td>
<td>Improved farm practices, crop production</td>
</tr>
<tr>
<td>AGRICULTURAL ENGINEER</td>
<td>Implements, tools, lift irrigation</td>
</tr>
<tr>
<td>SOIL CONSERVATION OFFICER</td>
<td>Soil conservation</td>
</tr>
</tbody>
</table>

In addition, there are other specialists, dealing with individual crops, such as the Paddy Specialist, Millets Specialist, Cotton Specialist, and Sugar cane Specialist. They conduct research and advise farmers on problems or improvements pertaining to the particular crop (Plate VII).

In some States, the Agricultural Department runs demonstration farms on the holdings of farmers themselves. Here the farmers take up the improvements suggested by the Department, and the Department in turn some times guarantees that if the farmer incurs any loss due to carrying out the improvements, it will make good the loss. These demonstration farms provide a good opportunity for others in the neighbourhood to see improved practices and to be convinced of their practical value (Plates VIII and XII).
Similarly, the Animal Husbandry Department of each State has a number of specialists. The Poultry Development Officer, the Sheep Development Officer, the Livestock Development Officer and the Dairy Development Officer advise farmers on problems and improvements relating to farm animals. Farmers approach or write to these officers for expert advice when needed (Plate IX).

SERVICES AND SUPPLIES

Each Department of the State Government which is connected with rural development has some service to offer to farmers. The following are the most important ones.

SEED AND FERTILIZER SUPPLIES

The gram sevak arranges for the supply of improved seeds, fertilizers, chemicals for fighting against diseases and pests, and improved implements to farmers. In many areas, there are seed stores run by the Cooperative Department. The seed stores stock mainly seeds of improved varieties for supply to farmers. They may also stock fertilizers, implements, chemicals for pest and disease control, and cattle feeds such as oil-cakes.

The Agricultural Department multiplies seeds of improved varieties on the research stations, seed farms and private farms and supplies them to farmers. These are available at the seed stores or with registered seed growers. Seeds of green manure crops and fertilizers are also made available through cooperative stores. The Agricultural Department is assisting cooperative societies in maintaining agricultural depots at the headquarters of each taluk (subdivision of a district) where supplies of seeds and fertilizers are made available to farmers. Where these facilities are not available, the gram sevak arranges the supplies through the Block Development Officer.

Seeds are tested for their quality and germination by the Economic Botanist of the Department of Agriculture before they are supplied to farmers.

IMPLEMENTS

Improved implements are supplied by some cooperative stores or by the gram sevak. The agricultural depots under the Agricultural
Departments stock selected implements for demonstration in farmers' fields or for sale. The implements can also be taken by farmers on hire for a small fee. Sometimes, the implements are sold at subsidized rates.

SOIL CONSERVATION

The Soil Conservation Section provides assistance to farmers in measures to stop soil erosion. Some States have special units which take up bunding work. Apart from expert guidance, farmers can also get the work done on a subsidy-loan basis which is of great help to them (Plate X).

DEEP PLOUGHING

Where deep ploughing with tractors has to be done, or waste land has to be reclaimed, Government's tractors are made available for hire at concessional rates.

DIGGING WELLS

Government encourages digging of wells for irrigation purposes. Loans and subsidies for this work are given by the Agricultural Department in some States. In some places, for deepening and repairing old wells, similar help is given. In some States, putting temporary bunds across nalas (drains) or streams is encouraged through the grant of subsidies (Plates X and XI).

PLANT PROTECTION

Whenever a crop disease or pest breaks out on a large scale, the Agricultural Department sends a team of plant protection staff with the necessary equipment, such as dusters or sprayers and chemicals to fight them. This service is free in some States. In others, the farmers are charged the cost of the chemicals used by the team. A fifty per cent subsidy is given by some States.

HORTICULTURAL SQUADS

In a few States, specially trained staff go out into villages to help farmers lay out and plant their orchards. They survey the field,
prepare a planting scheme and mark the places in the field where fruit plants are to be planted.

The Departments in all States grant long-term loans for the planting and fencing of new orchards or rejuvenating old orchards.

SOIL TESTING

Farmers should get their soil tested to find out what manures and fertilizers are most suited for the crops to be grown. Farmers can send soil samples for analysis in the laboratories of the Agricultural Chemist of the Agricultural Department. Recently, at least one soil testing laboratory has been opened in each State which tests the soil samples and advises farmers on the fertilizers to be used.

The Agricultural Chemist also analyzes fertilizers, irrigation waters, feed stuffs, and farm products, either free or at a small cost.

PROTECTION FROM WILD ANIMALS

In areas which are situated near jungles, Government encourages farmers to form gun clubs for hunting and shooting wild animals which damage agricultural crops. These gun clubs may be given subsidies and also ammunition at concessional rates.

TREATING FARM ANIMALS

A large number of veterinary hospitals and dispensaries have been established in each State. Farm animals are treated for diseases and ailments at these places free of cost. In addition, touring veterinary officers visit villages, treat animals for diseases, and take up disease prevention through vaccinations and inoculations. Farmers can meet the officers for advice on any of their livestock problems.

BREEDING BULLS

In certain States, farmers are given financial help for maintaining breeding bulls. The bulls are supplied to them at concessional rates.

KEY VILLAGES AND ARTIFICIAL INSEMINATION

Key villages have been set up in all States for helping farmers to develop their livestock. In the key villages, breeding, feeding, disease
prevention and marketing of animal products are taken up on improved lines, and farmers get very good help in all matters pertaining to these four activities. The service is free.

Artificial Insemination Centres set up in many villages also help farmers breed their cows and she-buffaloes to better bulls so as to obtain better calves. This service is also free.

POULTRY SUPPLIES

In most States, the Poultry Development Officer looks after poultry development. He supplies birds of improved breeds and eggs for hatching to poultrymen. These are made available at concessional rates. In some places, desi cocks belonging to farmers are exchanged for the cocks of improved breeds free of cost. This enables farmers to upgrade their poultry flock cheaply. Assistance in the management of poultry flocks, disease prevention, and marketing of eggs and poultry meat, are also available from this officer.

SHEEP DEVELOPMENT

As in the case of poultry, the Sheep Development Officer of the State helps farmers improve their sheep flocks through the supply of breeding rams. He also helps in the marketing of wool.

LIVESTOCK DEVELOPMENT

The Livestock Development Officer helps farmers in developing their cattle herds through the supply of cattle of improved breeds, and also feed stuffs. Similarly, the Dairy Development Officer of the State helps farmers maintain dairy herds and gives assistance in the management and feeding of dairy herds, and in the marketing of dairy products.

IRRIGATION

Many States offer concessional rates for the use of irrigation water when farmers take up the growing of additional crops on the same land or grow green manure crops. In many cases, the irrigation water for the additional crops grown is offered either free or at a concessional rate.
Pl. IX. A poultry research and demonstration farm has just received some modern poultry equipment for trial. The eggs in the basket are from an improved strain of poultry. State poultry farms conduct research and demonstrations for benefit of the farmers and private poultrymen on improved breeds, better feeding practices, adequate but cheap housing, and efficient poultry management (Maharashtra State). [Courtesy: EARL N. MOORE].
Pl. X. Technical and financial assistance to plug this gully was given to the farmer by the Agricultural Extension Officer. The result was good gully control and the creation of a farm pond as a source of water for livestock and irrigation (Maharashtra State). [Courtesy: Roy L. Donahue].
SEED FARMS*

In India, improved varieties of sugar cane have completely replaced the old varieties that were low in yield and susceptible to disease and lodging. As a result the country's sugar production has doubled during the last twelve years. Similarly, the bulk of the cotton area is now sown with improved varieties. This has resulted in India being more or less self-sufficient in her cotton requirements. Rice and wheat are two of the most important food crops wherein improved varieties have largely replaced the local ones. Consequently, the production of these crops has increased by twenty-five to thirty-five per cent during the last decade. Breeding of improved varieties of crops is now spread to most food and non-food crops, fodders, fruits, vegetables, and flowers.

Plant breeding is a slow process and in certain cases, as in coconut, it may take twenty years to produce a superior variety. Production of superior varieties of crops is only the first part of the story. Unless the improved variety is multiplied and distributed under expert supervision and guidance, it soon degenerates into a low-yielding crop and the labour of decades is lost.

The work of multiplication and distribution starts with the plant breeder. He produces from plants with superior parentage, pure, viable, disease-free and pest-free seeds. This is called the *nucleus (breeders') seed*. In India, *nucleus (breeders') seed* is usually multiplied on Government farms. Proper care is taken to ensure that the field on which the *nucleus (breeders') seed* is grown is not contaminated by seed of similar but inferior plants. A crop grown from *nucleus (breeders') seed* is carefully harvested, taking care to eliminate all *rogues* or undesirable plants in mixture. The *nucleus* crop is threshed, properly dried, and stored under conditions that will ensure the highest viability (germination power) of the seed. This *nucleus (breeders') seed* is then supplied to State Seed Farms which are scattered throughout India.

The *nucleus (breeders') seed* is multiplied on the State Seed Farms to produce *foundation seed* and is distributed to *registered farmers* in a systematic and organized manner. Wherever the seed produced by the *registered* seed growers is pure, viable, and free from pest and

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* Prepared by M. S. Pawar, Deputy Agricultural Commissioner, Ministry of Food and Agriculture, New Delhi.
disease attack, it is sold to villagers as improved seed. The improved seed so obtained is then grown, harvested, and sold to other villagers (Plates XIII and XIV).

With crops such as rice, a village would need more than one variety. For example, in the upland where rice is grown as a dryland crop, special upland varieties are needed. For wet-land conditions, different varieties are needed. Again, if the village is along the sea coast, a variety resistant to salt is required. Or where two or more rice crops are grown in a year on the same piece of land, different varieties would be required to suit the first, second, and sometimes the third crop seasons. Even during the same season, farmers prefer to grow coarse, high-yielding varieties for their own use, and fine varieties for sale, as the fine varieties give a greater return in rupees per acre. To meet all these requirements, several varieties of rice must be supplied annually to each village.

To supply the seeds necessary for five hundred thousand Indian villages is a big problem. Storage, transportation, and timely distribution of pure seed from village to village calls for careful organization within the State Departments of Agriculture and the willing cooperation of farmers. Such cooperation from the farmers is usually forthcoming, and so the work of seed multiplication and distribution is progressing fairly rapidly. All of the five hundred thousand villages of India will be supplied with improved seed as soon as these are made available by the crop breeders. In spite of the best of care, however, farmers' seeds get contaminated. Therefore, to maintain high yields, every three or four years new seeds should be obtained from the local Agricultural Officer.

CREDIT

In most States, loans are made available to farmers at a low rate of interest to take up certain agricultural improvements, and the repayment is to be made over a number of years. State loans, for example taccavi loans, are available from the Revenue Department. Farmers get these loans by applying through the Block Development Staff or through the Agricultural Department. Sometimes, the loans are given in kind and not in cash, that is, in the form of fertilizers, seeds, and implements against the value of the loan.

Apart from the loans, subsidies for taking up farm improvements are also granted by the Government. In many States, subsidies are
available for digging wells, putting bunds across streams, making compost from farm or village waste, maintaining improved breeds of cattle, installing lift irrigation and so on. The type of help and the amount of subsidy given vary from State to State. There are also other types of loans made available to farmers by the Cooperative Departments.

**SUMMARY**

Farmers need information on improved farm practices. They also need help in getting their supplies such as improved seeds and fertilizers. They need expert advice and help in solving farm problems. So also they need credit for taking up improvements on the farm.

The *Gram Sevak* and the Agricultural Demonstrators or Inspectors normally provide the necessary information to the farmers. Where specialized advice is needed, it is given by Specialists of the Agricultural Department. Similarly, help in developing poultry and sheep and solving livestock problems is given by the various officers of the Animal Husbandry Department.

There are many types of services available to farmers; seed, fertilizers, implements and similar supplies are made available through seed stores or agricultural depots. Block Development Officers arrange for certain supplies.

State Governments make available to farmers expert advice and assistance in such matters as soil conservation, deep ploughing, well digging and soil testing. Treating farm animals against diseases and ailments form an important service of the Animal Husbandry and Veterinary Departments.

Most States make loans at low rates of interest available to farmers. Sometimes, these loans are given in kind, such as the supply of improved seed.

**QUESTIONS**

1. As a farmer, what do you think your most urgent needs are? Where will you go if you need help in controlling a pest attack on your crops?
2. What are the services available to farmers from the Animal Husbandry or Veterinary Department?
3. Why does a farmer need credit? If there is a Cooperative Credit Society in his village, what type of loan can a farmer get from his State Government? For what purposes?
Chapter 5

FARM MANAGEMENT

A large number of farmers just manage to make a living out of their lands. There are others, though fewer in number, who have turned farming into a business and are earning large profits.

Every farmer should make farming a profitable business. His aim should not only be to get the maximum output from the land, but also to see that the products obtained are superior in quality. Then he will be able to earn a good income for himself and his family. To be able to do this he should manage the farm with skill, put his resources to the best use and take to scientific farming methods.

Production from land depends upon many factors. The lay of the land (topography), the rainfall, water supply, drainage, and the occurrence of pests and diseases, are some of the factors. There are others like capital and equipment, market conditions, taxes and laws affecting farming and the farmer, which are economic factors that also influence production.

A study of all these factors is necessary for the farmer to decide whether he should take up the raising of agricultural crops or fruit gardening, vegetable farming or cattle rearing, poultry keeping or dairying as his farm business. It is easier to know what to raise if he knows the physical factors on the farm. But he should also know how much of each to produce. This will depend on the demand for the commodity in the market and how much money it may bring in relation to the farmer’s cost of production.

To be able to manage a farm well, the farmer should have a good knowledge of agriculture as an art and as a science and should be alert to pick up new methods given out by the Agricultural Department. He should also have some experience in buying and selling, so that he can buy his requirements and sell his products at favourable prices.

CHOICES TO BE MADE

Sometimes it pays the farmer to produce just one commodity if there is a good demand for it. Then the farmer specializes in that commodity. He utilizes all his resources to get the maximum
production of the commodity with the minimum of expense. Sometimes, it may be better to produce more than one commodity. Then the farmer can *diversify* his farming. Each system has its own advantages and disadvantages. In a farm business the farmer has to consider how far it will be beneficial if he takes up one system or the other.

By adhering to the cultivation of only one commodity, such as cotton, the farmer is able to make full use of the factors of production. He and his workers will also learn the necessary skills in the operations to be carried out. Here, the management of the farm is easier and the equipment and other necessities will be at a minimum.

When more than one commodity is to be produced (or where more than one type of business is to be taken up), land, labour, equipment and other factors are made better use of throughout the year. Labour, which would be idle when the crop season is over when only one crop is to be grown, could be fully employed throughout the year. A number of crops grown in rotation in different plots in the farm will mean a better use of land and also an increase in soil fertility. It will also reduce the risk of complete loss of income due to drought, pests or diseases; because even when one crop is lost the farmer will have others from which to get some income.

Where more than one farm enterprise or business is to be combined — for example, dairying and raising of fodder grasses, production of crops and raising of cattle or poultry and crop production — they will be complementary to each other and result in a saving in expenses and an increase in profits.

The farmer also has to consider whether he should take up the cultivation on the farm himself or lease out the land to tenants. If a more intensive type of farming is desired, it is better that he does the farming himself. Sometimes it pays to join a farm cooperative handling a few or all the farm operations.

The size of the farm is important in farm business. The size is limited by the area of land available, the amount of money the farmer can invest, and the area he can manage by himself without difficulty. Normally, the bigger the size the greater are the advantages it will have, as on such a farm, capital and labour are more efficiently used and overhead charges are kept low. There is also scope for mechanization and improved marketing of produce. However,
the minimum that the farmer should have is a size sufficient to provide him and his family members full employment and to bring sufficient profits to make a good living.

In many cases, it is profitable to mechanize the farm. Under the average conditions, however, the farmer will find bullock power the best. The type of equipment needed in either case depends upon the kind of enterprise undertaken, the size of the farm, the financial resources available, the type of soil, and the requirements of his crops.

The farmer must choose new crop varieties, adopt a new irrigation system, start or improve the poultry enterprise, join an artificial insemination ring, or join the Farmers Forum or Village Cooperative (Plates XIV to XVI).

LAYOUT OF THE FARM

A farmer can manage his farm better if he has his homestead on the land itself. A proper layout of the farmstead, of roads, and irrigation and drainage channels is necessary to manage the farm well. The layout should suit the lay of the land, the enterprise to be undertaken and the crop rotation to be followed. A good layout helps in carrying out farm operations efficiently with a minimum of labour.

If a farmer has the choice it is better to locate the farmstead on high ground. If in the hills, it should be so located that it receives enough sunlight and is sheltered from strong winds. Trees should be planted at suitable places to provide shade, green leaf manure, fuel, and timber.

The size, shape and location of fields should be such that farm work can be economically carried out. If the land is sloping, bunds for the control of soil erosion and for conserving water should also be included.

On level land, a small number of larger fields should be planned. Fields rectangular in shape are easier to work. As far as possible, a field should be uniformly level and of the same soil type. Water channels should be so laid out that the water supply covers the maximum area. The area which is to be intensively cultivated, such as a kitchen garden or vegetables for sale, should be as near the farmstead as possible.
To enable the farmer to manage the farm efficiently, he should follow a sound cropping system. This means following a systematic rotation of crops on several fields in such a way that one crop follows another in a definite order. At the same time, the annual area under each crop should remain more or less the same during the entire period of crop rotation.

A good crop rotation maintains and increases soil fertility and makes possible a better use of land, resulting in higher crop yields. It also helps in reducing crop pests and diseases.

**FARM RECORDS**

The keeping of simple farm records is important in managing a farm with profit. These records and accounts show the farmer such important facts as the yield of the different crops and livestock, the dates of various farm operations, how much labour is required and how it is distributed during the crop season, the increase or decrease in the capital, and annual receipts and expenses from which the profits or losses for the year can be calculated.

Farm records also enable the farmer to measure the progress during a certain period, and find out the strong and weak points in his enterprise, so that he can strengthen the weak points and run the farm more efficiently. His plans for the future can also be based on recorded facts and not on guess-work.

The more important farm records a farmer should keep are: a diary, cash register, production register, feed register, wage register, seed register, general register, and an inventory.

**DIARY**

A diary is a very useful daily record of the operations conducted on the farm, equipment used, labour employed, and money received and paid. The weather conditions and important events of the day also find a place in the diary. The daily entries may be made as shown in Table on the next page.

**CASH REGISTER**

A record of cash received and cash paid is maintained in this register. The left-hand page can be used to enter the money received
Weather: Rainy, first good rain of monsoon

<table>
<thead>
<tr>
<th>Operation</th>
<th>Men</th>
<th>Women</th>
<th>Bullocks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Preparing paddy nursery, half an acre</td>
<td>1</td>
<td>-</td>
<td>2</td>
</tr>
<tr>
<td>2. Trimming bunds</td>
<td>½</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>3. Cutting grass for cattle</td>
<td>-</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>4. Ordered paddy seed from Agriculture Officer today — new variety</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Get fertilizer next Monday from the Cooperative</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Asked neighbours today about the new Cooperative Bank — see about this on Monday when I get the fertilizer</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

and the right-hand one for the money paid out. The form given below may be followed for this record:

<table>
<thead>
<tr>
<th>Cash received</th>
<th>Cash paid out</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date</td>
<td>Date</td>
</tr>
<tr>
<td>Particulars</td>
<td>Particulars</td>
</tr>
<tr>
<td>No.</td>
<td>No.</td>
</tr>
<tr>
<td>Qty. or Rate</td>
<td>Qty. or Rate</td>
</tr>
<tr>
<td>Total Amt. recd.</td>
<td>Total Amt. paid</td>
</tr>
</tbody>
</table>

Periodically, say once a month, a summary should be prepared, giving the receipts and expenses item by item, such as manual labour, bullock labour, implements, seeds, fertilizers and water rates.

Production Register

This register is the record for entering the produce, especially of crops obtained from a given area. The following form will be useful for this purpose:

<table>
<thead>
<tr>
<th>Crop</th>
<th>Area (acres)</th>
<th>Total production</th>
<th>Yield per acre</th>
<th>Remarks</th>
</tr>
</thead>
</table>

Payments made to labour for paddy, wheat or other crops, for harvesting, threshing, and winnowing should be entered in the
Pl. XI. A demonstration farm where an experimental flowing (artesian) well has been drilled to irrigate rice. [Courtesy: ROY L. DONAHUE].

Pl. XII. Lucerne on a farmer’s field that was established by the Agricultural Extension Service as a demonstration for other farmers to follow. The man and boy are showing the growth of lucerne during the past seven days. [Courtesy: FRANK SHUMAN].
Pl. XIII. A research farm where superior varieties of jowar are being developed for the farmers of India. As soon as superior varieties are developed, *nucleus breeder’s seed* is supplied to Government farms to multiply for use by *registered seed farms*. The registered farms further multiply the superior seed for sale to all farmers (Andhra Pradesh).

[Courtesy: ROY L. DONAHUE].
Pl. XIV. A farmer must decide whether to buy superior seed of hybrid maize (shown here) or buy cheaper and inferior seed of desi maize. [Courtesy: ROY L. DONAHUE].

Pl. XV. The farmer must decide whether to start a new dairy herd, or improve his present herd. [Courtesy: ROY L. DONAHUE].
Pl. XVI. The farmer must decide whether to supplement his present irrigation facilities (left) by digging a well and installing an oil engine (right). In many States a loan may be granted by the Department of Agriculture for the purchase of an oil engine or electric motor and pump. [Courtesy: Left — AGRICULTURAL COLLEGE, BAPATLA, A.P. Right — ROY L. DONAHUE].
Production Register. The by-products obtained from the crop, such as fodder, should also be recorded. The farm products consumed by the farm family should also be shown here.

FEED REGISTER

This register is a record for entering all the cattle feeds, such as dry fodders, green fodders and concentrates like oil cake, and grain. Since the feed is issued to all animals and not to each one separately, the total quantity issued each day along with the price may be entered. Later, the expenses incurred on the feed given to each animal can be worked out. The entries in this register may be made as follows:

<table>
<thead>
<tr>
<th>Month</th>
<th>Dry fodder</th>
<th>Green fodder</th>
<th>Concentrates</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Qty.</td>
<td>Value</td>
<td>Qty.</td>
</tr>
</tbody>
</table>

When the feeds are farm-grown, the value may be determined at prices at which they can be sold in the market.

WAGE REGISTER

Separate entries are made in this register for the permanent labour force employed and the casual labour hired. For permanent labour, the date of employment, monthly or annual wages (paid in cash and kind), the value of meals, clothing, and footwear provided are entered. For casual labour, the dates and the operations for which it is employed, and the wages paid in kind and cash are entered. The charges paid for repairs to implements and appliances should also be entered in this register.

SEED REGISTER

This is a record showing the kind, quantity and the value of seeds purchased or stocked on the farm.

GENERAL REGISTER

This register is a record of miscellaneous items of expenditure, such as land revenue, water rates, replacements for machines and tools, and manures and fertilizers.
INVENTORY

This gives a record of all the property the farmer owns. The record shows the number and the value of each item, such as land, buildings, water supply, livestock, equipment, machinery, farm produce, feeds, fertilizers, and the cash on hand and in the bank, and the amounts to be paid or received. Each head of cattle and other livestock should be listed separately and the age and value of each entered.

The first inventory can be taken at any time, but it should usually be at the beginning of the major crop season. The second and subsequent inventories should be taken exactly twelve months later.

The form shown on next page may be followed for the inventory.

The value of some items of property, such as machinery, buildings, and equipment should be reduced with use. This reduction in value year after year is called depreciation. This must be considered in putting down the value of such items in the inventory.

Farm records and accounts, when correctly kept, give the following useful information:

1. Net worth of the farm enterprise. This is made out from the inventory.
2. Total or gross income. This is the total value of the produce obtained from the farm, whether sold or kept for use.
3. Expenses. The money spent on manual and bullock labour or power, seeds, manures and fertilizers, implements, irrigation charges, land rent and revenue, expenses for spraying and other costs.
4. Net income (or loss). By deducting the total expenses from the gross income (including the change in value of inventory), the net income or loss is obtained. For example, if the gross income for twelve months were Rs. 2,000, the increase in inventory Rs. 100, and the expenses Rs. 1,000, the net income would be Rs. 2,000 + Rs. 100 − Rs. 1,000 = Rs. 1,100.
5. Use of labour. Labour, manual and bullock, accounts for two-thirds to three-fourths of the total expenses on the farm. Hence the details of labour employed and entered in the diary will give an idea to the farmer how much labour is employed and on what jobs, and how he could readjust the jobs and affect a saving.

When the inventory is taken and accounts are compiled at the close of each year the farmer should go through them carefully to find out the weak and strong points. From the information available he should be able to find out how he can increase his net income and reduce his expenses.
<table>
<thead>
<tr>
<th>Item</th>
<th>Quantity or No.</th>
<th>Price per unit when obtained (Rs.)</th>
<th>Total value now (Rs.)</th>
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<tbody>
<tr>
<td>1. Land</td>
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<td>Irrigated</td>
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<td>Non-irrigated</td>
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<td>2. Buildings</td>
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<td>5. Manures and fertilizers</td>
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<td>6. Feeds and fodders</td>
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<td>7. Seeds</td>
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<td>8. Cash in hand</td>
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<td>9. Amount to be received</td>
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<tr>
<td>10. Amount to be paid</td>
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</table>

**Grand Total**
One way to increase farm income is to increase crop yields per acre. Another way is to start raising poultry. The size of the farm business also counts. If the farm is sufficiently big, large-scale cropping can be taken up and labour usefully employed. The income will increase if more paying crops are grown with the same resources of water, fertilizer, and labour.

A look at the various items of expenditure in the records will help the farmer to find out how he can reduce them, especially on labour and work animals, without reducing their efficiency. Sometimes the farm records will show that net farm income was increased because of more expenditure on fertilizers, improved seeds, and effective insecticides. The layout of the farm may often be changed to affect a better use of labour.

**SUMMARY**

Farmers should be able to make agriculture a paying business. To be able to do this, it is not enough to get greater yields from their fields. They should also see that the products obtained are superior in quality and are sold at the most favourable prices.

Production from the land depends upon many factors. Farmers must study these factors so that they may decide what crops they should grow, how much of each and what type of farm enterprise if taken up will give the maximum profits.

The layout of the farm has much to do with the saving of labour and expense and the farmer will have to see to it that the layout is such that the land is put to the best possible use.

Farmers should also see that they follow a sound cropping system as it has many advantages to offer.

To manage a farm with profit, farmers must keep some simple farm accounts and records. These will help them to know whether the farm is giving them a profit or not. The records will help them locate weak points in their farming practices, and thereby show ways of strengthening them. They can plan their future programme on the facts that have been recorded rather than on guess-work. The accounts and records to be kept are simple and can be easily maintained.

**QUESTIONS**

1. What factors influence farm production? Apart from these, what else should a farmer know to make farming a paying business?
2. What type of farm enterprise can be taken up in your area? In what way is a farm of a big size better than a small-sized one?

3. Draw a rough sketch of your farm on a sheet of paper. Mark the farm house, the wells, all other buildings and roads. Mark also the shape of the fields. On each field, write out the type of soil. Is this layout helpful for easy management? Would you change the layout? If so, how? Draw another sketch and show an ideal layout.

4. What are the benefits of keeping farm records? Name all the registers or records that you would like to keep. How will you work out what profits you made from your farm last year?

REFERENCES

SINGH, ARJUN, Farm Accounts, Farm Bulletin, Directorate of Extension, Ministry of Food and Agriculture, New Delhi, 1961
Chapter 6

PLANT FORMS*

Ever since the appearance of animals and man on earth, plants have served them as a primary source of food. But not all animals feed directly on plants. The flesh-eating animals eat other animals which live entirely on plants. Thus, directly or indirectly, all animals including man ultimately depend on plants for their food. Besides food, which is man's first need, plants provide him with materials for clothing, shelter and medicine as well as many raw materials for industry and commerce.

For his existence man has had to make use of the resources of nature. In this attempt he began by collecting food from plants growing wild in nature; later he obtained food by growing crop plants around his dwellings just sufficient to meet the needs of his family. In course of time primitive man tilled the soil and grew crops to provide for the needs of the community. Beginning with the domestication of plants on a small scale, this practice changed to the growing of plants on a large scale. In like manner, man has changed from being a hunter and has become a manager of animals. To rear animals man has to provide them with feed and shelter. This has meant that not only has he to produce food for himself but also for the animals that depend on him. The world population of man and domestic animals has been increasing rapidly thus increasing the demand for food and feed.

A good knowledge of plant science is essential for successful farming. In the following pages the authors hope that sufficient information on plant science is provided so that an intelligent application of the knowledge can be made in crop and animal production. Only by the application of this knowledge can man expect to adequately feed himself and his animals.

PLANT SCIENCE

The science that deals with plant life is called Botany. Botany can be studied from different aspects such as form and structure, growth

* For definition of terms consult Glossary at the end of Chapter 7, p. 103.
and reproduction and production of plants. The last aspect is known as crop farming.

Plants vary in form, organization, and function from the simplest one-celled invisible or microscopic bacteria to the most highly organized, complex and many-celled giant trees of the forest. Bridging these extremes are a number of plant types belonging to different groups which exhibit an ever-increasing complexity of form, organization, and function such as the fungus, algae, moss, lichen, fern, cycad, and the conifer (Plates XVII and XVIII). Man has put to use, in one form or another, plants belonging to all the different groups. Some of the uses to which plants have been put are given in Table I.

<table>
<thead>
<tr>
<th>Use</th>
<th>Kind of plant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Food</td>
<td>Grain: rice, wheat, jowar, bajra, tur, gram</td>
</tr>
<tr>
<td></td>
<td>Oilseeds: sesamum, groundnut</td>
</tr>
<tr>
<td></td>
<td>Fruits: banana, mango, orange</td>
</tr>
<tr>
<td></td>
<td>Vegetables: potato, tomato, bean, pea, cabbage, cauliflower, gourd</td>
</tr>
<tr>
<td>Sugar</td>
<td>Sugar cane, palmyra, sugar beet</td>
</tr>
<tr>
<td>Spice</td>
<td>Pepper, cardamom, clove, nutmeg, cinnamon, ginger, mint</td>
</tr>
<tr>
<td>Beverage</td>
<td>Coffee, tea, cocoa</td>
</tr>
<tr>
<td>Drug</td>
<td>Cinchona, ergot, penicillin</td>
</tr>
<tr>
<td>Narcotic</td>
<td>Tobacco, poppy</td>
</tr>
<tr>
<td>Perfume</td>
<td>Rose, jasmine, lavender</td>
</tr>
<tr>
<td>Essential oil</td>
<td>Sandal, eucalyptus, camphor</td>
</tr>
<tr>
<td>Dye</td>
<td>Indigo, henna, turmeric, safflower</td>
</tr>
<tr>
<td>Fodder and Forage</td>
<td>Grasses (guinea, elephant, sudan)</td>
</tr>
<tr>
<td></td>
<td>Legumes (lucerne, berseem)</td>
</tr>
<tr>
<td>Fibre</td>
<td>Cotton, flax, jute, hemp</td>
</tr>
<tr>
<td>Fuel</td>
<td>Casuarina, babul (Acacia)</td>
</tr>
<tr>
<td>Timber</td>
<td>Teak, sal, mahogany, rosewood, pine, walnut</td>
</tr>
</tbody>
</table>

Table I shows that there are thirteen kinds of uses that man makes of plants and plant products. These uses are for food, sugar, spice, beverage, drug, narcotic, perfume, essential oil, dye, fodder and forage, fibre, fuel, and timber.
A plant has two distinct parts, the *shoot system* which remains above ground and grows in air and light and the *root system* which grows in the soil. The shoot system is generally green and consists of parts such as stem, branch, leaf, flower and fruit. The root system is usually colourless and is divided into the main root, lateral or secondary roots, and rootlets (root hairs) which are their size (Figure 1). Among the different structures of the plant, the root,

![Diagram of root and shoot system](image)

**Fig. 1.** The root system and shoot system of the mustard plant (*left*). The growing point and the root hairs of the root system are shown. On the *right* is a highly magnified section of the surface of a root showing the plant cells, nucleus, and a single root hair. [Redrawn from: HAMMONDS and WOODS].

stem, and the leaf are termed the *vegetative organs* and the flower, fruit and seed are known as the *reproductive organs*. The vegetative organs are concerned with the growth and development of the plant; whereas the reproductive organs ensure the continuity of the plant by giving rise to new plants under suitable conditions (Figure 2).

Each part of the shoot system serves a different purpose. The stem and its branches perform two functions. First they provide support
Fig. 2. *Bhendi* plant and its parts.
(1) bud, (2) flower, (3) fruit, (4) leaf, (5) petiole of leaf, (6) stem,
(7) branch, (8) roots.

[Courtesy : H. R. ARAKERE].
to other parts of the shoot and thus expose the leaves to the influence of light and air which are necessary for their development. Secondly they serve in conducting the substances in solution from the root to the leaf and other aerial parts and from the leaf back to the roots. Thus, support and conduction are the two important functions performed by the stem and the branches. The function of the leaf is to produce food material required for the growth and development of the plant. The flower bears the reproductive organs from which develop the fruit and seed. The production of seeds is the ultimate aim for which plants exist, as seeds give rise to new plants.

The root system with the main roots and its many branches provides anchorage to fix the plant firmly to the soil. The innumerable branches of the root which ultimately become divided into the fine and delicate root hairs get closely associated with the soil particles. This association with the soil particles helps the roots to absorb plant food elements from substances dissolved in soil water (Figure 3). The two main functions performed by the roots are therefore anchorage and absorption.

Fig. 3. Root hairs of plant growing among soil particles.

r.h. — root hair. a. — air space. w. — water.
s. — soil particle.

[Courtesy: L. S. S. Kumar].
SEED AND ITS PARTS

Seeds of crop plants are borne inside a covering such as a hull, husk, or pod (Figure 4). Upon ripening the seeds are liberated and are capable of independent growth and development to form a new plant when suitable conditions exist.

A seed consists of the following parts: (1) seed coat, (2) cotyledon, and (3) germ or embryo. The seed coat or testa serves as a protective covering during the dormant or resting stage of the seed. Within the cotyledon or the seed-leaf is stored food material which helps to nourish the developing embryo in its growth at the time of seed germination. When suitable conditions are present for germination of the seed, the embryo or the immature plant develops first into a seedling and later into a mature plant.

The embryo consists of two parts, the plumule or the immature primary shoot and the radicle or the immature primary root. The plumule and the radicle together form the primary axis of the embryonic plant.

Seeds are classified according to the following characters: (1) number of cotyledons present, (2) position of cotyledons after germination, and (3) the part in which the reserve food material is stored.

Seeds of plants may have one or two cotyledons. When one cotyledon only is present the plant is called a monocotyledon (the prefix mono meaning single) and when two cotyledons are present, the plant is known as a dicotyledon (di signifying two) (Figure 5).

SEED GERMINATION

In a dry seed, life is dormant; that is, in a state of inactivity or rest. When soaked in water seed such as bean absorbs water and
FIG. 5. Structure of Seed

A. DICOTYLEDONOUS SEED (BEAN)
P. — plumule (shoot), } embryo
R. — radicle (root)

B. MONOCOTYLEDONOUS SEED (MAIZE)
P. — plumule (shoot) } embryo
R. — radicle (root)

C. GERMINATING BEAN SHOWN IN A AND ITS PARTS

[Courtesy: L. S. S. Kumar].
swells. After a few hours the seed coat bursts on account of the swelling of the cotyledons and the elongation of the peg-like radicle. This coming to life of the dormant seed is known as germination. The plumule which had remained protected between the cotyledons grows and pushes itself out and the rudimentary leaves develop and expand into the first pair of true leaves. The elongation of the primary axis forms the main stem. The radicle develops fast and gives rise to the main root. The part of the seedling above the cotyledons which, by its elongation, raises the plumule is known as the epicotyl. The part below the cotyledons which helps to pull the cotyledons out of the soil is termed the hypocotyl (Figures 6 and 7).

Fig. 6. Stages in germination of the dicotyledonous seed of the bean plant.

[Courtesy: L. S. S. Kumar].
For the germination of seed, three factors are necessary: (1) moisture, (2) temperature, and (3) oxygen.

Dry seed can withstand extremes of cold or heat without the germ losing its power of germination. Seeds of most legumes (pulses) and cereals retain their vitality in storage for several years. When moisture becomes available the seeds germinate with the awakening to life of the embryo.

A suitable temperature is required for the germination of seed. At high temperatures the growth is rapid but under extremely high temperatures growth may cease and the seeds die. Cold slows down

![Diagram of maize plant germination stages.](image)

**Fig. 7.** Stages in the germination of the mono-cotyledonous seed of the maize plant.


*Courtesy: Roy L. Donahue.*
the growth and extremely cold temperature can injure the germ within the seed and prevent germination.

Although it is difficult to observe, seeds *respire* (breathe), that is, take in oxygen and give out carbon dioxide. In an atmosphere completely devoid of oxygen seeds fail to germinate. Seeds placed in a dish of shallow water will germinate while those placed in a bottle of boiled water, sealed to exclude all air will not germinate. (This may be tried as a class demonstration.)

**SEED TESTING**

Unless the seed used is satisfactory, the resulting crop may be disappointing. In order that a farmer may be sure of raising good crops, he should test the seed for germination prior to planting. If it is not practicable for each farmer to test the seed, it should be bought from reliable dealers who certify to the suitability of the seed after carrying out the required test.

The quality of seed is based on the following important characteristics: (1) purity, (2) germination capacity, (3) speed of germination, (4) weight, and (5) other characteristics such as uniformity of size, shape, colour, brightness, and smell (Plate XIX).

**PURITY**

In a given sample of seed, everything which is not the genuine seed of a specific variety is an impurity. The impurity generally consists of husk, chaff, bits of straw, dirt, seed of other crop plants and weed seed. The quality of the seed sample depends on the percentage of purity. To determine the percentage of purity a representative sample of the seeds is taken and weighed. From the sample all the impurities are separated and weighed. From this the weight of pure seed is found and its percentage of purity calculated.

**GERMINATION CAPACITY**

The germination capacity is the ability of the seed to germinate and produce a normal seedling. A sample of seed, however uniform in colour, shape, size, brightness, and smell cannot indicate its germinable capacity which depends on the soundness of the embryo.
The only satisfactory way of determining this is to sow a sample of pure seeds and observe the results. Two lots of a hundred seeds each are taken from a pure sample and each lot is sown in soil in an earthen pot which is regularly watered. From the date of sowing a count is made for ten days of the number of seeds that have germinated each day, and those which have germinated are removed after the count is made. The total number of seeds that have germinated in ten days gives the percentage of germination. The average percentage of the two lots tested will be a more reliable indication of the germination percentage of the entire batch of seed. (This may be tried as a class activity.)

A low percentage of germination may be due to (1) the presence of immature seeds in which the embryo is not fully developed, (2) the loss of the power of germination of the embryo as in the case of very old seeds, or (3) injury to the embryo.

By determining the purity percentage and the germination percentage, it will be possible to determine the percentage of useful seeds present, as given in the following example:

\[
\begin{align*}
\text{Purity percentage} & \quad 98 \\
\text{Germination percentage} & \quad 94 \\
\text{Useful percentage} & = \frac{\text{Germination percentage} \times \text{Purity percentage}}{100} \\
& = \frac{98 \times 94}{100} \\
& = 92
\end{align*}
\]

**SPEED OF GERMINATION**

Samples of the same kind of seeds but of different origin will differ in their speed of germination under identical conditions. These differences may be due to the differences in the seed coat, age, ripeness or other causes.

The time taken for seed to germinate varies with the species. Seeds of some species germinate within a few hours; some take a few days and others may not germinate for many months.
Pl. XVII. An example of one of the lower forms of plant life is the green moss that often grows on rocks at the edge of the water.  
[Courtesy: ROY L. DONAHUE].

Pl. XVIII. *Lichens* are lower forms of plant life (seen here as white patches) that grow on rocks and help to make soil from the rocks.  
[Courtesy: ROY L. DONAHUE].
Above: Pl. XIX. The quality of seed is based upon its genetic purity, germination percentage, weight, and minor characteristics. This pile of bags contain improved seed of hybrid *nakka* (maize) that was developed in India. It has been put in 24-pound bags, tagged, and sealed to protect the farmer (Andhra Pradesh). [Courtesy: Earl N. Moore]

Pl. XX. *Langda* (cockle bur) seeds have a bur that sticks to clothing or to fur of animals and thus are transported long distances. [Courtesy: H. R. Arakeri].
The delay in germination may be the result of an impervious seed coat which prevents the entry of water into the seed. The seed of many of the leguminous plants do not germinate quickly and these are called "hard seeds". Hard seeds do not swell immediately on being soaked. Hard seed can be made to germinate by treating them with hot water, or by chemical treatment, or by mechanical means such as by scratching the seed coat.

**WEIGHT**

Sound seeds are heavier than unsound seeds. Shrivelled and empty seeds are lighter in weight. The sound and unsound seeds can usually be separated by dipping them in water. The sound seed will sink to the bottom and the unsound seed will float. It is necessary to discard unsound seeds before sowing.

**OTHER CHARACTERISTICS**

Uniformity of form, colour, brightness, and freshness of smell are indications of the purity and soundness of seeds. Old and musty seeds lack lustre, give off an unpleasant odour, and may be shrivelled. Sound seed is plump, of bright lustre and has a characteristic odour of freshness.

Besides all the points previously mentioned in regard to good seeds to be selected for sowing, care should be taken to see that the seeds are true to the varietal characters for which they have been developed.

**ROOT**

The radicle of the young plant elongates and develops into the *primary* root. In whatever position the seed may lie at the time of germination, the radicle grows downward and into the soil. After the primary root has attained some length, branches or secondary roots arise from it. These grow at right angles or at a sloping angle and downward from the primary root. These in turn give off branches to form an extensive network of roots. From the ultimate branches of the root arise the delicate hair-like structures which are called root hairs. All of these together form the *root system*.

The root hairs come into very close contact with the soil particles and absorb water that is present between the particles. Water and the dissolved substances taken in by the root hairs pass from cell to cell into the smaller roots and then into the bigger ones until they
Fig. 8. A comparison of root systems.
(1) Monocotyledonous plants have fibrous root system as represented by the cereal crops such as wheat and rice. (2) Dicotyledonous plants have a tap root system as represented by lucerne and most of the pulses such as red gram.

[Courtesy: H. R. ARAKERI].
finally reach the main root, from where they move upward through special conducting channels to pass into the stem and ultimately into the leaves.

The root grows by elongation of its tip, which is protected by a covering known as the root cap, the presence of which prevents injury to the delicate growing tip. The younger roots are nearer the growing tip and the older ones farther away from it.

The branch or lateral roots do not arise from the surface of the primary root but develop from the tissues inside. If a well-developed root of a plant such as mustard is slit open vertically it will be observed that the lateral roots arise from the core of the root.

The roots of the dicotyledonous and the monocotyledonous plants show distinct differences. The dicotyledonous plants such as bean, groundnut and lucerne, have a tap root from which all the subsidiary roots arise. In the monocotyledonous plants such as wheat, rice and maize, the primary root stops its growth very early and in its place a number of roots of the same size arise in a cluster from the base of the stem, and are known as fibrous roots (Figures 8 and 9).

Besides the important functions of fixation of the plant to the soil and absorption of water and dissolved nutrients, the roots serve other useful purposes such as storage, support, clinging, and "breathing."

**ADVENTITIOUS OR BRACE ROOT**

Roots which do not arise in the normal manner from the base of the stem but grow from other parts of the stem or leaves are said to be adventitious or brace roots. These are commonly found in monocotyledonous plants such as wheat, maize, and sugar cane. In the last two crops the adventitious roots arise from nodes situated above the level of the soil. These roots grow into the soil and support the stem. Large adventitious roots are characteristic of plants such as screw pine and other plants growing in tidal lands and seashores which are subject to a fluctuating level of water (Figures 9 and 10).

**FLESHY OR TUBEROUS ROOTS**

In some plants roots serve as the storage organs of reserve food material. Such roots are fleshy and large in size and are of a different shape. The roots of carrot, radish, dahlia, tapioca and turnip are examples of fleshy roots (Figure 11).
Fig. 9. The maize plant, an example of a monocotyledonous plant, has brace or adventitious roots and fibrous roots as the main roots. [Courtesy: Rockefeller Foundation].
CLinging ROOTS

Clinging roots are generally found on climbing plants and grow from the nodes of the climbing stem. They help the stem to cling to a support such as a wall, a post, or a tree. Examples of plants with clinging roots are pepper (Piper nigrum) and betel vine (Piper betle) (Figure 12).

HANGING ROOTS

Hanging roots develop on branches of large trees above the ground level and grow toward the soil. Some of these may grow from heights of twenty to thirty feet. On striking the soil they grow
into it and the parts above ground become like trunks and provide support to the branches from which they arise. These roots are a special feature of the banyan tree in which a single plant spreads and forms what appears to be a grove of several trees, but in fact these supports are but the transformed hanging roots of the same plant.

"Breathing" roots

"Breathing" roots are characteristic of certain plants growing in salt marshes near the sea coast. Unlike other normal roots which grow downward into the soil these grow upward into light and air. They have a large number of pores or holes on their surface through which air passes into the root to aerate the inner living tissues.

Fig. 12. Clinging roots of betel vine.  
[Courtesy: L. S. S. Kumar].
STEM

The plumule or young shoot develops into the primary shoot consisting of the stem. The stem bears the structure called the leaf. The place where the leaf is attached to the stem is thicker and is known as the node or "joint" and the portion of the stem between two nodes is called an internode. When the plant matures, flowers develop on the stem.

In a young seedling a bud is present at the tip of the primary shoot and this consists of a compressed or shortened stem with a number of immature leaves which are crowded together and which enclose the growing point. As growth takes place the shortened stem elongates and the young enfolded leaves grow to maturity. The growing point remains young all the time and continually adds to the length of the stem and the number of leaves. The growing point which is delicate and tender is protected by the enfolding leaves, the youngest being nearest the growing point.

Buds are either terminal or axillary (lateral). The terminal bud is situated at the tip of the growing shoot or stem. The axillary bud arises in the axil of a leaf, that is, in the upper angle formed between the base of the leaf and the stem (Figure 13).

Buds which produce the leaves are called leaf buds and those which give rise to flowers are termed flower buds. When buds arise in an unusual manner, from any part of the stem or upon leaves and roots, they are called adventitious buds.

Plant stems are classified into the following types:

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AERIAL STEMS

Aerial stems are the stems that grow above the soil.

Herbaceous stem. Herbaceous stems are soft and are often green in colour. They are found in plants which live for one season only
(annual) and among a few plants that live for a long time (perennial). Common examples of plants with herbaceous stems are rice, wheat, jowar and most other crop plants.

*Woody stem.* Plants which live for many years develop considerable quantities of wood tissue which make them hard and firm. *Trees* and *shrubs* are plants with woody stems. Trees have a single main stem or *trunk* which has no branches for some distance from the

---

*Fig. 13. Branch of a plant showing its parts.*

T. Bd. = terminal bud.  
Int. Nd. = internode.  
L. = leaf.  
L. ax. = leaf axil.  
ax. Bd. = axillary bud.  
Nd. = node.

*Courtesy: L. S. S. Kumar.*
ground. In shrubs there is no distinct main stem; the primary branches are nearly of the same thickness and arise from a point at or near the ground. In some plants the upper part of the stem may be tender and herbaceous and the lower part hard and woody. All stems are herbaceous when very young. Examples of trees are mango, neem, and teak.

Climbing stem. Climbing stems are generally weak and need some support to grow into light and air. They grow upward, using suitable objects as supports. Plants may climb by means of clinging roots, petioles of leaves (Nasturtium), stiff prickles (rose) or by tendrils which are modified leaves (grape [Vitis species]) (Figure 14).

Prostrate stem. Plants with weak stems which are not able to climb lie prostrate on the ground and grow horizontally. Examples of plants with prostrate stems are cucumber, squash, and watermelon which are all members of the genus cucurbita.

Twining stem. Some plants hold themselves up by the entire stem twining round a support. Some of these twine to the right and the others to the left. Examples of plants with twining stems are yam (Dioscorea species), and hyacinth bean (Dolichos lablab).

UNDERGROUND STEMS

Underground stems grow within the soil and sometimes resemble roots. They are distinguished from roots by the possession of buds which arise from a leaf axil. These buds do not have a green colour as do some on aerial stems.

Rhizome (root stock). Rhizomes grow horizontally below the ground level. The internodes of these may be short and compressed as in ginger and turmeric. From the axils of the scale-leaves present on them, shoots develop and come above ground. At the nodes, adventitious roots are formed. The growth of the stem continues either by terminal or axillary buds. The rhizomes serve as storage organs of reserve food material (Figure 15).

Sucker. A sucker is an adventitious shoot which arises below ground from either the stem or the root of shrubs and trees. The adventitious stems or roots can live independently on separation from the parent plant. A sucker competes with the mother plant for nutrition and therefore should be removed when not required. Suckers may be used for propagation of new plants as in banana.
Fig. 14. The pea plant is an example of a plant with *aerial, climbing stems* (tendrils).


*Courtesy: L. S. S. Kumar.*
Tuber. A tuber is a short, thick, fleshy underground stem with very small scale-leaves. These have buds or eyes which on development give rise to aerial stems. Irish potato is a good example of a tuber (Figure 16).

Corm. A corm is a short, thick, fleshy stem with scaly leaves and adventitious roots having one or two buds at the apex. Elephant-foot yam is an example of a large corm while the corm of Colocasia is an example of a small one (Figure 17).

Bulb. This has a flat disc-like compressed stem on which are present a number of fleshy scale-leaves which overlap each other. The scale-leaves are fleshy and thick because reserve food material is stored in them. Enclosed within the scale-leaves is the undeveloped terminal bud with one or more lateral buds. Onion and garlic are examples of bulbs (Figure 18).

Most of the underground stem modifications serve as storage organs which help the dormant bud to tide over adverse
Fig. 16. Irish potato is a common example of a *tuber*.
*Courtesy: L. S. S. Kumar*.

Fig. 17. Elephant foot is an example of a *corm*.
(Longitudinal section).
o.c. — old *corm*. y.c. — young *corm*.
Sh. — shoot.
*Courtesy: L. S. S. Kumar*. 
environmental conditions and nourish the developing bud to produce a new plant when favourable conditions set in.

**LEAF**

The leaf arises on the stem at the node (joint) and is generally green in colour. A leaf consists of a stalk or petiole, a flat expanded green part called the blade and a basal part by which it is attached to the stem called the leaf base. To the leaf base are generally attached structures called the stipules (Figure 19).

The leaf is attached to the parent stem by a stalk. The leaf blade consists of a network of veins with the space in between filled by cells containing the green colouring matter known as chlorophyll.
The leaves of plants may be parallel veined or net veined. All of the monocotyledonous plants to which belong the cereals, millets, sugar cane and grasses have parallel veined leaves; while those of the dicotyledonous plants such as the legumes, cotton, mango, neem and rose are net veined (Figure 20). The size, shape, apex (point), margin, thickness, and texture of leaves show considerable variation and these characteristics are used in identifying plants.

Leaf modifications include: (1) Cotyledons or seed leaves, (2) Floral leaves, (3) Leaf thorns, and (4) Leaf tendrils.

*Cotyledons.* These are the first leaves which a plant bears and they contain stored food material to be used by the developing embryo at the time of seed germination.

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**Fig. 19. Parts of a leaf.**

Mn. — leaf margin. V. — vein.  
St. — stipule. Lb. — leaf base.  

*[Courtesy: L. S. S. KUMAR].*
Floral leaves. These form part of the flower and are generally of a bright and attractive colour.

Leaf thorns. Sometimes the leaves are turned into thorns which serve as protection for the plant (Figure 21).

Leaf tendrils. In some plants the leaves or leaflets are modified into tendrils which, by twining around other objects, help to support the growing stem. The pea plant is an example of leaves modified into tendrils (Figure 22).

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Fig. 20. Net veined leaf on left, such as found in bean, cotton, mango, neem, and rose; on the right is a parallel veined leaf as found in maize, millets, sugar cane and grasses. [Redrawn from: Hammonds and Woods].
FLOWER

The flower bears the reproductive organs from which is developed the fruit containing the seeds. A typical flower consists of a stalk which holds and exposes the flower in an advantageous position. The upper end of the stalk forms the receptacle or the seat on which the sepal, petal, stamen and the pistil are arranged in whorls or concentric rings.

Sepals are the scale-like, green parts at the base of the flower and are collectively called the calyx. They serve the purpose of protecting the other parts of the flower during the bud stage.

Petals form a ring inside the sepals and are always found in the same number as the sepals. All the petals are known as the corolla. Petals are generally coloured. In general language the colour of a flower is due to the colour of the petals.

Stamens are found within the ring of petals and vary in number according to the type of the flower. Each stamen consists of a thin stalk with a swollen tip known as the anther.

Anthers are the swollen tips of the stamen consisting of a structure which has four chambers called the pollen sacs. Within these are formed the pollen grains (male parts) which are usually round or

![Diagram](image)

**FIG. 21.** An example of a leaf thorn.
L. — leaf.  Th. — thorn (leaf thorn).

*Courtesy: L. S. S. Kumar.*
oval in shape. When the anthers are fully mature they burst and liberate pollen grains.

The *pistil* or *carpel* occupies the innermost part of the flower. The base of the pistil has a hollow box-like structure called the *ovary* or the *seed box* which contains the immature seed or *ovule*. These are the female parts of the flower. Above the ovary is the tube-like structure called the *style* which terminates in an expanded part called the *stigma*.

**Fig. 22.** An example of *tendrils*, the thread-like modified stems of pea.

[Redrawn from: Mehta].
Fig. 23. Above: Bisexual flower of hibiscus, shown here in longitudinal section.

Below: Unisexual flower on monoecious plant such as cucumber, shown in cross section.
Left: male flower.
St. - stamen. P. - petal.
Right: female flower.

[Courtesy: L. S. S. Kumar].
The **ovary** is the box-like structure at the base of the pistil in which are formed the immature seed or **ovule** (Figure 23). The ovary provides protection to the ovule till it becomes a seed. The ovary in course of time is transformed into the fruit containing the mature seed.

When both stamens and pistil are present in the same flower, it is called **bisexual**. When either stamen or pistil alone is present, the flower is termed **unisexual**. The unisexual flowers are of two types: the **staminate** or male, and the **pistillate** or female flower. If both staminate and pistillate flowers are present on the same plant, it is called **monoecious**; when they are present on different plants it is called **dioecious**. Wheat, rice, **jowar**, mango, orange, and grape are examples of plants having bisexual flowers. Maize is an example of a plant with unisexual flowers. Pumpkin, cucumber, bitter gourd, and snake gourd are **monoecious**. Papaya and date palm are **dioecious** (Figure 24).

**INFLORESCENCE**

When flowers are borne **singly** at the end of the main axis or laterally in the axils of foliage leaves, they are called **solitary** flowers. When they are borne in groups and arranged on a special type of axis they are called an **inflorescence**. In an inflorescence, the individual flowers arise in the axil of special types of leaves called **bracts**. The axis of the inflorescence is called the **rachis** or **peduncle** and the stalk of individual flower is termed the **pedicel**.

Inflorescences are of two types: (1) **racemose** (indefinite) type in which the main axis goes on growing, giving rise to flowers on side branches, or (2) **cymose** (definite) in which the main axis terminates in a flower. Other flowers arise laterally below the apex.

**RACEMOSE INFLORESCENCE**

Plants with **racemose inflorescence** may be classified into one of the following five types:

- **Raceme**. The axis is elongated and bears stalked flowers.

- **Spike**. The axis is elongated and bears sessile (no stalk) flowers, an example of which is wheat.

- **Corymb**. The axis is elongated and bears flowers arranged at the same level due to the pedicels or stalks of flowers being of different length. The lowest pedicels are the longest, followed by those of decreasing length.
Fig. 24. Types of flowers.

I Bisexual flower as present in rice, wheat, and pulses.
   (1) stigma, (2) anthers, (3) style, (4) corolla (all of petals), (5) petal,
   (6) calyx (all of sepals), (7) sepals, (8) receptacle, (9) stalk.

II Unisexual flowers on monoecious plant such as present in maize.
   (1) pistillate (female) flower (cob or ear), (2) staminate (male) flower
   (tassel).

III Unisexual flowers on dioecious plants such as in papaya.
   (A) Papaya plant bearing only pistillate (female) flowers. (B) Papaya
   plant bearing only staminate (male) flowers.
   (1) pistillate (female) flower with (3) stigma, and (4) ovary.
   (2) staminate (male) flower.

[Courtesy: H. R. ARAKERI.]
Capitulum (Head). Here the axis is a thick, flattened disc on which sessile flowers are arranged with the youngest at the centre and the older nearer the margin. Examples are niger and safflower.

Umbel. The shortened axis bears flowers with stalks of equal length.

Cymose Inflorescence

The arrangements of flowers in cymose inflorescence may be monochasium in which the main axis has only one lateral branch, or dichasium (forked cyme) in which the main axis has two lateral branches which in turn bear two branches again (Figure 25).

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**Fig. 25.** Types of inflorescence.

Racemose (above):
- a = raceme
- b = corymb
- c = spike
- d = umbel
- e = capitulum (head).

Cymose (below):
- f = scorpioid
- g = helicoid

\{monochasium\}

h = forked (dichasium).

[Courtesy : L. S. S. Kumar].
POLLINATION AND FERTILIZATION

In plants the production of seed is preceded by pollination and fertilization. The pollen grain formed within the anther produces the male germ cell and the ovule within the ovary produces the female germ cell.

Pollination is of two types. When the pollen from the anther is transferred to the stigma of the same flower it is termed self-pollination. The pollen from the flower of one plant reaching the stigma of the flower of another plant of the same species is called cross-pollination. In some plants, flowers do not open until pollination takes place and as a result only self-pollination is possible. In rice and wheat, self-pollination is the rule. Cross-pollination of flowers is brought about by natural agents such as wind, insects, water, snails and birds.

Wind pollinated flowers are generally small, inconspicuous and have little or no scent. The pollens of these flowers are dry and are produced in large quantities. The stigmas are feathery and are adapted to catch pollen grains.

Insect pollinated flowers are generally brightly coloured, and are usually scented. They have nectar (honey) glands, generally at the base of the petals from which a sweet liquid is secreted. The pollen is sticky and the stigma exudes a sticky substance to which the pollen grains adhere and germinate. In visiting from flower to flower in search of nectar, the insects unconsciously transfer pollens to bring about cross-pollination. Honey-bees, wasps, butterflies, beetles, and flies aid in cross-pollination.

After reaching the stigma, the pollen germinates and gives rise to a tube which grows down the style through the ovary into the ovule where it discharges the male germ cell. Within the ovule and inside the embryo sac the female germ cell becomes mature. When the male and the female germ cells come together they become fused and this process is called fertilization. The fertilization of the female germ cell (egg) by the male germ cell results in the formation of a zygote or a fertilized egg. The stimulus of fertilization promotes the development of the ovule to grow into the seed and the ovary into the fruit (Figure 26).

FRUIT

A fruit is a developed ovary and the seed a developed ovule. The ripened wall of the ovary becomes the pericarp (skin) of the fruit
which acts as the protective covering for the fruit and the seed inside.

The term *fruit* is widely applied to the different modified forms of the floral parts of the plant which provide edible material. *True fruits* are those that develop from the ripened ovary as in the case of tomato, cucumber, mango, and grape. The term *false fruit* is

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**Fig. 26.** The act of fertilization of a flower.

A — Pollen grains (male cells)

B — Pollen grain tubes move to the stigma of the female organ by growing down the style until they reach the ovary where actual fertilization (union) takes place to form seed in the fruit. One pollen grain must grow down the pollen tube to fertilize each ovule before a single seed is formed by their union.

*Courtesy: L. S. S. Kumar.*
applied to those which are developed from other parts. Thus, in the case of apple, pear, and cashew it is the receptacle that forms the so-called fruit (Figure 27). The fig, mulberry, pineapple, and jack fruit are false fruits developed from inflorescence.

The fruits may be single or aggregate. The mango is a single fruit, whereas custard apple and jack fruit are aggregate fruits.

Fruits are divided into two groups or classes: (1) Dry, and (2) fleshy. The dry fruits are further divided into (a) indehiscent, (b) dehiscent, and (c) schizocarp.

INDEHISCENT DRY FRUITS

In indehiscent dry fruits the pericarp is dry and hard and does not split or open along any lines. When the pericarp decays the seed becomes free.

Indehiscent dry fruits are classified into nut, achene, caryopsis, and samara.

Nut. A nut is a one-seeded fruit with a hard, woody pericarp (cashewnut) (Figure 27).

![Image of a nut with labels "Rec." and "Fr." indicating the receptacle and fruit respectively. Figure 27. False fruit (receptacle) of cashew is the large fleshy portion labelled Rec. The true fruit is borne below and is labelled Fr. (Longitudinal section). The true fruit is an example of an indehiscent, dry fruit (nut). [Courtesy: L. S. S. Kumar].]
Achene. An achene is a one-seeded fruit with a leathery pericarp containing a free seed (rose, sunflower, buttercup) (Figure 28).

Caryopsis. A caryopsis is a superior one-seeded fruit with the seed united with the pericarp (wheat, rice, grass seeds) (Figure 29).

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**Fig. 28.** A: Diagram of a sunflower head showing three achenes (one-seeded fruits), receptacle (disc), and bracts of involucre. Sunflower is a common plant in the plains of India.

B: Diagram of a vertical section through an achene (one-seeded fruit) of buttercup (marsh mallow). Buttercup grows in the cooler regions of north India.

*Courtesy: L. S. S. Kumar.*

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**Fig. 29.** An example of a caryopsis is a seed of rice.

*Courtesy: L. S. S. Kumar.*
**Fig. 30.** The pod of a pea is an example of a *leguminous*, dehiscent, dry fruit.  
*Redrawn from: Paterson.*

**Fig. 31.** An example of a *follicle*, a dehiscent dry fruit (*Calatropis* species).  
*Courtesy: L. S. S. Kumar.*
PLANT FORMS

_Samara._ A samara is a winged achene, with the pericarp having wing-like appendages (Dipterocarpus) (Figure 39).

**DEHISCENT DRY FRUITS**

_Dehiscent dry fruits_ are classified into _legume_, _follicle_, and _capsule._

*Legume._ A _legume_ is a pod formed from a single carpel which dehisces (splits) on both sides when ripe (bean, pea) (Figure 30).

_Follicle._ A _follicle_ is formed from a single carpel which splits on one side only (_Calatropis, Sterculia_) (Figure 31).

_Capsule._ A _capsule_ is a fruit developed from a compound pistil. When dry it may dehisce (split) regularly or irregularly, or open by means of pores (cotton, hibiscus) (Figure 32).

**SCHIZOCARP**

_A schizocarp_ is an aggregate fruit with united carpels. On ripening, the carpels may separate from each other but do not dehisce to liberate the seed. Each carpel contains a seed (_Abutilon, Coriander, Geranium_).

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![Dehiscent dry fruits](image)

**Fig. 32.** Examples of _capsules_, dehiscent dry fruits.


*[Courtesy: L. S. S. Kumar]*
FLESHY FRUITS

Drupe. A drupe is a fleshy fruit with a hard stone containing a seed (mango, coconut, almond) (Figure 33).

Pome. A pome is an accessory or false fruit in which the receptacle becomes fleshy with a core consisting of the carpels (apple, pear) (Figure 34).

Berry. Berries are fruits with a few or many seeds embedded in the fleshy pulp (grape, tomato, banana) (Figure 35).

Aggregate fruit. It is a cluster of ovaries borne on a common receptacle which on ripening may remain separate or coalesce. Strawberry is an aggregate fruit in which the receptacle swells and becomes fleshy. In pineapple, bread fruit, mulberry and jack fruit, the ovaries of a number of separated flowers become fused together to form a multiple fruit (Figure 36).

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Fig. 33. Examples of drupes are coconut and mango.

Left: Coconut (cross section)
- Ep. = epicarp (outer skin)
- Mes. = mesocarp (fibrous)
- End. = endocarp (stony)

Note: The small drawing in the centre is the top view of a coconut seed through any one of which the shoot comes out.

Right: Mango (longitudinal section)
- Ep. = epicarp (outer skin)
- Mes. = mesocarp (fleshy)
- End. = endocarp (stony)
- S. = seed.

[Courtesy: L. S. S. Kumar].
SEED DISPERSAL

The chief agents of dispersal of fruits and seeds are wind, water, animals, and an explosive mechanism of the pod. A few of the dry fruits split with violence and scatter the seeds widely (Figure 37). Some fruits have winged structures by means of which

Fig. 34. An example of a *pome* is apple (longitudinal section).
*Courtesy: L. S. S. Kumar*.

Fig. 35. An example of a *berry* is tomato (longitudinal section).
*Courtesy: L. S. S. Kumar*.

Fig. 36. Examples of *aggregate* fruits are jack fruit and pineapple.
*Left*: jack fruit (whole fruit); *Centre*: longitudinal section of jack fruit; *Right*: pineapple.
*Courtesy: L. S. S. Kumar*.
they may be carried long distances by the wind (Figures 38 and 39). Certain fruits, due to locking up of air in the mesocarp, become buoyant and are dispersed by floating on water. Some fruits develop burrs or hooks by means of which they stick to the fur of animals or clothing of man and may be carried far away and shed (Plates XX and LIX). Fleshy fruits are eaten by birds and animals and the viable seeds are discharged through their excreta or droppings.

**SUMMARY**

Plants are the primary source of food and therefore of great importance to all living things. They also provide man with materials for clothing, shelter, and medicine as well as many raw materials of industry and commerce. By care and selection, man has developed from plants growing in nature those which meet his needs.

The science that deals with plants is called *botany*. This is divided into several branches in order to study the form, structure and function of plants. Plants range from the simplest single-celled bacterium to the complex multi-cellular giant tree. These extremes are bridged by a number of different types of plants of differing character belonging to different groups.

Of the different parts of plants and the purposes served by them, the roots absorb water and food materials from the soil and also fix the plants to the soil; the stems support the aerial parts and conduct water and substances in solution to the leaves; the food is prepared in the leaves for growing parts of the plant; and from the flowers the fruits containing the seeds are developed. The seeds give birth to new plants. In most cases, plants begin and end their life as a seed.
The ultimate unit of function and structure into which a plant is divided is a cell. Groups of cells having similar structures and functions make up a tissue. Different tissues put together form the plant body.

The seed is composed of many different parts; the most important being the germ or the embryo, in which is the miniature plant

Fig. 38. Some seeds have *plumes* that permit them to be wind-borne. (*Calatropis*).

*Courtesy: L. S. S. Kumar.*

Fig. 39. Some seeds have *wings* that permit them to be borne by the wind. (*Dipterocarpus zeylanicus*).

*Courtesy: L. S. S. Kumar.*
that develops under suitable conditions. Air, moisture and temperature influence germination. A minimum of each of these factors is necessary for seed germination.

For agricultural purposes, pure, healthy and living seeds are necessary. The presence of these qualities can be determined by seed testing.

Roots are modified to serve the purposes of support, climbing, storage and breathing; the stems are modified to aid in climbing and in storing food material; and leaves are modified to protect and aid in climbing. Flowers are adapted to help pollination and fertilization. Fruits and seeds are adapted to aid their dispersal and propagation.

The seeds of plants are the result of the natural processes of pollination and fertilization, which results in the formation of seeds and fruits.

QUESTIONS

1. What are the important uses of plants to man?
2. What are the forms into which plant parts are modified and why?
3. What is the importance of seed testing? What are the characteristics of good seeds?
4. State the primary functions of root, stem, leaf, flower, fruit and seed.
5. What is pollination? State the different types of pollination and how these are brought about.
6. What is fertilization and why is it necessary?

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Pl. XXI. Transpiration of water from a plant results in a pull of water upward, as illustrated by a branch of a tomato plant. A fresh branch is sealed in the top of a tube full of water (Right). The bottom of the tube is in mercury. When the tomato branch is placed in sunlight where the temperature of the air is high and a wind is blowing, rapid transpiration (loss of water) from the plant results in a pull on the water in the tube, and mercury rises. On the left is a porous clay cup that loses water by evaporation and the result is a rise of mercury. A plant loses water by transpiration in a similar manner that a porous cup full of water loses water by evaporation. [Courtesy: Agricultural College, Bapatla, A.P.].
Pl. XXII. An example of sexual reproduction in plants is shown with papaya.

*Top*: Pollen grains from the male flowers are carried to the female flowers below by wind or insects. *Centre*: The female flower is pollinated and becomes fertilized. *Bottom*: The fertilized flower develops into a papaya fruit.

[Courtesy: Roy L. Donahue].
Chapter 7

PLANT LIFE*

The living plant is a dynamic organism in which several functions are continuously taking place. These functions are related to the growth, development, and reproduction of the plant, and are dependent on the presence of living protoplasm which is called "the physical basis of life". The activities of the protoplasm in combination with air, water, light, temperature, and soil are responsible for the maintenance of life in plants. When these vital functions in the plant cease, death soon follows (Figures 40 and 41).

The functions that take place in plants are absorption, transpiration, photosynthesis, respiration, and propagation or reproduction.

ABSORPTION

Plants absorb food elements in liquid form through the roots and in gaseous and liquid form through the leaves.

The air supplies oxygen and carbon dioxide while water supplies hydrogen for the growing plants. Elements such as nitrogen, phosphorus, potassium, calcium, magnesium, sulphur, iron and others are taken from the soil water and are absorbed through the root hairs by a process known as osmosis.

When plant cells are full of water, their walls are fully extended and the cells become turgid. It is this turgidity of cells that helps to maintain the form and shape of succulent parts of plants such as the leaf, the flower, and the tender shoots. An excessive loss of water results in the loss of turgidity of cells and as a result the leaf, flower, and shoot wilt and droop.

The living plant can be considered as a gigantic osmotic pressure system with each of the numerous cells of which it is composed being a small unit of this system. The cells of the roots, stems, branches, and leaves into which liquids are absorbed are bounded by cellulose cell walls which act as a permeable membrane, allowing the passage of water and dissolved substances inwards and outwards. But the cell walls of these cells have in addition a membranous lining of living protoplasm which has the power of selective permeability.

* For definition of terms, consult the Glossary at the end of this chapter.
This protoplasmic membrane controls the entrance and exit of water and dissolved substances from cell to cell within the plant as well as from the soil into the roots of the plant. It is this living membrane that prevents the water nutrients in the cells of the roots from diffusing out into the soil.

The internal structure of the plants shows that it consists of a series of cells placed next to each other as bricks are arranged in a wall. Since each cell is separated from its neighbour by a permeable cell wall, dissolved substances pass from cell to cell by osmosis. The movement of water and nutrients is regulated by the concentration of the liquid within the cell, called the cell sap (Figure 42).

![Diagram of a cell](image)

**Fig. 40.** A living cell from a green leaf (highly magnified) showing: Cell wall, that protects the cell; Cytoplasm, the living jelly-like substance of the cell; Vacuole, the open centre of the cell containing sap; Nucleus, the centre of life of the cell; and Plastids, the green cells in which food is manufactured.

The arrows indicate that the contents of the living cell are constantly in motion.

*Redrawn from: Miller.*

The sap in plant root cells is at a higher concentration than the surrounding soil water; therefore, the water moves from the soil into the cells of the roots. Within the plant there is a gradual increase in the concentration of the cell sap from the roots upward to the cells in the leaf. The existence of this increasing level of concentration enables the sap to be absorbed into the leaves which are at some distance from the roots.
Fig. 41. *Dead Cells* in cork magnified 100 times appear as a series of bare rooms or cells. The cells were at one time living, but are now dead. Cork comes from the bark of a certain oak tree. The bark of all trees appears similar when magnified. Cells from cork were seen for the first time under a microscope by Robert Hooke of England in 1665.  [*Redrawn from: Smith*].
Fig. 42. Left: Vertical section of onion. Right: cells of onion skin highly magnified. The onion skin cell at the upper right is drawn to show three dimensions. The contents of each living cell are in constant motion. The motion hastens the passage of plant nutrients from cell to cell through the cell wall, known as osmosis. [Redrawn from: Smith and Kumar].
PLANT LIFE

TRANSPERSION

Transpiration is the loss of water from leaves of growing plants. It is estimated that a maize plant loses as much as two hundred times its own weight of water during its life. Water is very important to plants to keep them erect. If more water is lost than absorbed, the cells lose their turgidity and the plants wilt and droop. Plants generally wilt in hot, dry, windy weather when root absorption is not keeping pace with the loss of water due to transpiration. Wilted parts recover their turgidity and normal shape when the deficiency of water in the cells is restored.

Absorption of water by roots can be affected by mechanical and other injuries, a fall in temperature of the soil, and poor aeration. Plants may wilt even in water-logged soil due to poor aeration.

The degree to which water is lost from plants depends on the nature of the cell wall. From surfaces which are well-protected by tissues such as cork, cutin, or cuticle, the loss of water by transpiration is negligible. From tender growing parts of the plant, loss of water by transpiration takes place quite rapidly. The greatest loss of water by transpiration takes place from the small pores (stomata) of the leaves of plants (Plate XXI). Beneath each stoma is an air cavity surrounded by cells which are loosely arranged. The water moves into the air spaces and passes into the outer air through the stoma. The stomata have guard cells, the opening and closing of which is controlled by the living protoplasm. When the guard cells are highly turgid the stomata are open and transpiration is great; when the guard cells are least turgid the stomata are closed and transpiration is nil (Figures 43 and 44). The turgidity of the guard cells and therefore the amount of transpiration is dependent mostly on external causes, such as:

1. The intensity of light
2. The humidity of the atmosphere
3. The temperature of the soil and air
4. The movement of air
5. The water content of the soil (soil moisture)

Light intensity. In darkness there is very little transpiration taking place; it decreases in diffused light and increases in bright light.
Atmospheric humidity. If the atmosphere near the plants is saturated with moisture, very little transpiration takes place; whereas, in a dry atmosphere a considerable loss of water takes place.

Temperature. A rise in temperature increases transpiration. As the day advances and the temperature increases there is a greater loss of water from growing plants.

Air movement. Strong currents of air remove the accumulated moisture in the neighbourhood of plants and as a result causes increased transpiration.

Soil moisture. When there is too little water in the soil, the amount of transpiration is greatly reduced.

PHOTOSYNTHESIS

Photosynthesis means the manufacture (synthesis) of food material in the presence of light (photos) by the chloroplasts or bodies

![Diagram of Stoma](image)

Fig. 43. Stomata occur mostly on the lower side of all leaves of plants and permit air (oxygen and carbon dioxide) to move in and out in the course of respiration, transpiration, and photosynthesis.

Left: During the day time the stoma is open and sugar is present in the chloroplasts of the guard cells as a product of photosynthesis.

Right: During the night time the stoma is closed and the sugar in the chloroplasts in the guard cells changes to starch.

[Redrawn from: Weaver].
containing the green colouring matter. These chloroplasts break up the molecules of carbon dioxide and water and recombine them to form sugar, starch, proteins, and fats.

Light, water, carbon dioxide and plant food elements from the soil are all necessary for the synthesis of foods by the plant (Figure 45). The factors that are essential for photosynthesis in the living plants are:

1. Carbon dioxide in the surrounding air
2. Chlorophyll in the tissues of the leaves
3. Sufficient light
4. Satisfactory temperature
5. Water
6. Plant food elements

Fig. 44. Lower surface of a leaf highly enlarged, showing:
Ep. = epidermis.    St. = stoma (plural, stomata).    g.c. = guard cells of stoma.    C.w. = cell wall.

[Courtesy: L. S. S. Kumar].
Fig. 45. During the day when the sun is shining, water and plant food elements move from the soil through the roots and upward into the leaves. Using energy from the sun, water and elements from the soil, and carbon dioxide from the air, the green chlorophyll manufactures food such as sugar and releases oxygen into the air. This process is called photosynthesis. At night, the plant uses some of the sugar as food for growth, takes in oxygen, and releases carbon dioxide, a process known as respiration. [Redrawn from: Hammonds and Woods].
Carbon dioxide (CO₂). Carbon dioxide is a gas found in the atmosphere in the proportion of three parts of carbon dioxide to every ten thousand parts of air. The air diffuses through the stomata into the intercellular spaces within the leaf. The CO₂ from the air is dissolved by the wet cell walls of the leaf cells and thus enters the plant.

Chlorophyll. Chlorophyll is the green colouring matter of plants present in chloroplast of cells. Two other pigments present are the orange-coloured carotin and the yellow-coloured xanthophyll. Plants devoid of chlorophyll are called chlorotic. If this condition is due to deficiency of iron it can be corrected by adding a small amount of iron sulphate to the soil or by spraying a solution of it on the leaves. An iron nail or two driven into the stem of the plants or scrap iron buried nearby helps to restore the green colour to the plant.

Light. In the absence of light, chlorophyll does not develop in plants. Young seedlings as they emerge out of the darkness of the soil are pale yellow in colour and after some days turn green due to the development of chlorophyll. Plants placed in darkness soon lose their green colour and become whitish-yellow in colour. When these plants are placed in sunlight the green pigment again develops. Some plants require direct sunlight for carrying on photosynthesis, while others need only diffused sunlight — as in the case of shade-loving plants.

Temperature. In tropical plants, photosynthesis takes place to a small extent at a temperature of about 5°C and increases as the temperature rises, reaching a maximum at about 30°C. Photosynthesis decreases with a further rise in temperature and at about 55°C it stops.

Water. Water supplies hydrogen to the process of photosynthesis and also serves as a solvent for all nutrients from the soil.

Plant food elements. All crop plants require elements from the soil such as nitrogen and phosphorus before they can carry on photosynthesis.

RESPIRATION

Like all living organisms, plants respire by taking in oxygen and giving off carbon dioxide. In plants the parts above ground obtain the required oxygen for respiration from the air. The living roots growing in the soil also need oxygen. If the soil is not well
aerated, root development is reduced and this in turn reduces crop yields.

Wherever living protoplasm is present, respiration goes on; it takes place in each living cell of the plant. The oxygen of the atmosphere reaches the cells in the interior of the plant through the intercellular spaces. These spaces are continuous and inter-connected throughout the plant.

Respiration is a physiological process which is exactly opposite to that of photosynthesis. In respiration the reserve food materials are broken down and oxidized, which results in the formation of carbon dioxide and water, with heat or energy liberated. In photosynthesis, carbon dioxide and water are synthesized by absorbing the heat energy of sunlight to form sugars and to liberate oxygen.

Respiration is a continuous process and takes place throughout the day and the night while photosynthesis takes place only in the presence of sunlight. In respiration, the stored food material is utilized by the plant for growth and reproduction. During respiration, the reserve energy in stored foods in the plant is converted to active energy; and in photosynthesis the energy of sunlight is converted and stored as potential energy in the form of synthesized food materials such as sugar.

The rate of respiration of plant parts differs. Actively growing and young parts respire more rapidly and to a greater degree than older parts. Thus, young developing buds, growing roots and germinating seeds respire more than stems, leaves, fruits and dormant parts such as bulbs, tubers and corms. Even the driest of seeds of plants which apparently seem lifeless respire to a very slight extent and give out carbon dioxide and heat.

Respiration is a destructive process and the dry weight of a plant decreases due to the breakdown of carbohydrates (sugars and starches) and fats. Photosynthesis is a constructive process and results in an increase in the dry weight of plants due to a storage of the synthesized food materials (Figure 45).

PROPAGATION OF PLANTS

The power of reproduction is characteristic of all living organisms. The methods by which plants propagate or reproduce are as follows:
PLANT LIFE

1. Asexual reproduction
2. Sexual reproduction
3. Vegetative reproduction

ASEXUAL REPRODUCTION

In asexual reproduction, the vegetative or the growing parts of plants produce special structures called spores which are formed without involving any sexual process. Such method of reproduction is commonly found in the lower order of plants such as bacteria, fungi and algae (Plates XVII and XVIII).

SEXUAL REPRODUCTION

Sexual reproduction results from the union of male and female germ cells after the processes of pollination and fertilization; the result is a true fruit inside of which are seeds (Plate XXII and Figure 26).

VEGETATIVE REPRODUCTION

In vegetative reproduction, a growing part of the parent plant separates and develops into a new individual.

Vegetative reproduction is brought about naturally in plants which produce tubers, rhizomes, corms, and bulbs (Figures 46 and 47). In potato the green plant gives rise to underground tubers at the end of special kinds of stems. The tubers lie dormant underground and during the next season each of them gives rise to one or more new plants. In ginger and turmeric, the older parts of the rhizome die and new shoots arise from young lateral branches to continue their existence as separate plants.

Some plants are reproduced from bulbs or corms. As the plants grow, bulbs or corms are developed and reserve food is stored in them. At the same time buds are formed on the bulb or corm. When the bud grows, the stored food is used to develop the plant and the old bulb or corm is exhausted and becomes disintegrated. The new plant forms new bulbs or corms.

In certain plants, buds arising on the leaves are capable of independent growth to produce new plants, as for example Bryophyllum, Begonia and some ferns. Bulbils or specialized buds formed
in the region of the inflorescence are also capable of vegetative reproduction, as in the *Agave* plant.

Artificial vegetative propagation is very commonly practised in agriculture and gardening. Some plants readily respond to vegetative propagation whereas others do not. The various methods of artificial vegetative propagation are cuttings, layering, budding and grafting.

*Cuttings.* For multiplication by cuttings a portion of a stem, root or leaf is cut from the plant and propagated. The stem cuttings are usually eight to ten inches long and include a few nodes. A portion of the cutting with one or two nodes is buried in the soil to promote root development. Shoots develop from the buds at the nodes above the ground. The cuttings should be planted in soil which is kept damp and warm. Desiccation of the cuttings by exposure to very strong sunlight, heat, and dryness should be avoided.

The stem cuttings may be taken from the hard, woody portion or the green herbaceous part. They should be taken from a portion of the stem which is sufficiently mature. In succulent plants pieces of herbaceous stem develop roots easily. Hardwood cuttings are, however, very difficult to root (Figure 48).

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**Fig. 46.** Natural vegetative reproduction may be by *rhizome*, crown, *tubers*, *bulbs* and *corms*. *Redrawn from: Hall*. 

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Fig. 47. A strawberry plant reproduces naturally by above ground rhizomes (Stolons).
[Redrawn from: Patterson.]
Fig. 48. Vegetative reproduction by cuttings may be from the root, stem, or leaf, depending upon the kind of plant.

[Redrawn from: HALL].
Layering. The method of layering consists in bending a branch in such a way that it can be buried into the soil. From the bent portion in the soil, adventitious roots arise. After the roots have developed the layer can be cut from the parent to become an independent plant. In order to aid the quick development of roots in a layered branch, either a tongue-like oblique slit is made through a node or ringing of the bark is done in the part to be buried in the soil (Figures 49 and 50).

*Fig. 49. Two methods of layering are illustrated.*

(1) In a pot full of soil, and (2) In the soil by burying a portion of the branches. [Courtesy: L. S. S. Kumar].

Budding. In budding an undeveloped or dormant bud is removed from one plant and inserted into a slit in the bark of the stem of another. The plant from which the bud is removed is called the scion and the plant that receives the bud is termed the stock. The inserted bud, after some care, becomes completely united with the stock so as to become a part of it and behaves as one plant. The root of the stock plant supplies the developing shoot from the
scion with water and nutrient elements. In return, the food material formed in the leaves of the scion nourish the stock to form new roots. In general practice, this type of budding is called shield budding.

The bud selected and the stem on which it is budded should be of young age and of the current season's growth; otherwise the union does not succeed. For removal of a bud a shield-shaped piece of bark containing the bud is peeled off and is trimmed to remove excess bark. In taking out the bud, a little portion of the wood of the parent plant is also removed; this is later separated from the bud and discarded. A short length of the petiole of the leaf is retained with the bud. On the stock a T-shaped slit is made and the flaps of the bark gently raised, the shield bud inserted, the flaps closed and tied firmly with banana or other suitable fibre, leaving the bud exposed. The fibre should be untied after a few weeks when the bud has started to develop into young leaves. The stages in the method of budding are illustrated in Figure 51.
Pl. XXIII. The minerals in rocks gradually weather until the elements in them become available for plant growth. In this way a soil is made. [Courtesy: Roy L. Donahue].

Pl. XXIV. These manure cakes will be used for fuel but the soils of India need the farmyard manure for increasing crop yields. [Courtesy: Roy L. Donahue].
Pl. XXV. Compost applied to the soil replaces some of the plant food elements lost by leaching, erosion, and crop removal. [Courtesy: Roy L. Donahue].
Fig. 51. Stages in shield budding.
*Left:* bud from superior plant. *Centre:* scion from inferior but closely related plant. *Right:* bud in place. [Courtesy: L. S. S. Kumar]

**Grafting.** In grafting, a short piece of stem of one plant known as *scion* is used for inserting into the stem of another plant termed the *stock*. The relationship of scion and stock is the same in grafted as in budded plants. While budding can be done with success on the herbaceous (non-woody) parts of a stem, grafting is possible only in woody stems. Grafting is generally of four types; (1) *tongue*, (2) *wedge*, (3) *saddle*, and (4) *rind (crown)*. In the first three types the scion and the stock are of nearly the same age and thickness, while in *rind (crown)* grafting the two may be of different thickness and age.

For tongue grafting the scion is given an upward sloping cut two to three inches long, and is notched. The stock is treated similarly but in the opposite direction so that on insertion the two parts join together exactly. The joined parts are covered with moss or clay and bandaged firmly to prevent air and water from entering. When the buds of the scion have grown six to eight inches in length, the bandage is removed and the grafted stem tied to a support (Figures 52 and 53).

Plants developed from such vegetative parts as bulbs, tubers, corms, cuttings, layers, buds, and grafts possess the morphological and physiological characters of the parent plant. Because of this
Fig. 52. Types of grafts.
[Courtesy: L. S. S. Kumar].

Fig. 53. Tongue grafting of a woody branch (scion) of the desirable kind of plant on a root of a closely related but very hardy plant, is common in the vegetative propagation of certain woody plants. [Redrawn from: Hall].
advantage, farmers and gardeners multiply plants by vegetative propagation whenever possible in order to maintain the valuable qualities of the parent plant.

In many fruit trees which produce seeds, the offspring raised from seeds show variation and differ in character and quality from the parent plant. Thus, many of the characters for which the parent plants were valued are lost in the progeny if propagated by seeds. To overcome this disadvantage plants are propagated by vegetative means such as budding or grafting. Another advantage of vegetative propagation is the saving in time in establishing mature plants. Examples of fruit trees that are budded or grafted are citrus and mango.

CLASSIFICATION OF PLANTS

The plant kingdom is classified into two large groups, cryptogams, and phanerogams; the latter being further divided into Gymnosperms and Angiosperms, as follows:

\[ \text{PLANT KINGDOM} \]

\[ \text{Cryptogams} \quad \text{Phanerogams} \]

\( \text{flowerless plants} \quad \text{flowering plants} \)

\[ \text{Gymnosperms} \quad \text{Angiosperms} \]

\( \text{plants with naked seed} \quad \text{plants with covered seed} \)

Cryptogams. Under this division are included bacteria, yeast, fungi, algae, lichens, mosses, and ferns.

Phanerogams:

(i) Gymnosperms. Cycads and conifers belong to this group;

(ii) Angiosperms. This includes a large majority of the flowering plants which are of agricultural importance. The angiosperms are further divided into two large groups: (a) monocotyledons, and (b) dicotyledons. These two groups (Figures 54, 55) are distinguished as follows:
Fig. 54. An example of a *monocotyledonous* plant is rice. Upon germination, the seed stays in the soil. [Redrawn from Narayanan].
Fig. 55. An example of a dicotyledonous plant is castor. Upon germination, the seed comes out of the soil. [Redrawn from: NARAYANAN].
### Monocotyledon

(example: rice)

1. Embryo has one cotyledon
2. Plumule is lateral
3. Primary root perishes and is replaced by fibrous roots
4. The leaves have parallel veins
5. Flowers are trimerous (occurring in multiples of three)
6. Vascular bundles are irregularly scattered and closed, and cambium is absent. There is no secondary thickening of stems

### Dicotyledon

(example: castor)

Embryo has two cotyledons
Plumule is terminal
Primary root persists and forms the tap root
The leaves are net-veined
Flowers are pentamerous (occurring in multiples of five)
Vascular bundles are open and arranged in a ring. There is a cambium which brings about secondary thickening of stems

### SUMMARY

The vital or living functions carried out by the plants are absorption of food material and water from the soil; giving off of water from the plant; synthesis or preparation of food materials; breathing or respiration; growth and development; and reproduction. The absorption of water and the dissolved substances in it from the soil takes place through the root hairs by the development of forces within the plants such as osmotic. The water within the plant is lost through evaporation from the cell surfaces from within the leaf through pores or holes called stomata. The loss of water is regulated by both internal and external factors.

The plant absorbs the raw material required for preparing food both from the soil and the air. Water and minerals in solution are taken from the soil. Carbon dioxide is obtained from the air. The first food formed in the plants is sugar. To prepare sugar, the essential things required are (1) water, (2) carbon dioxide, (3) sunlight, (4) temperature, and (5) the green colouring matter or chlorophyll. In the absence of any one of these, the sugar cannot be formed. Since sugar can be synthesized in the presence of light only, it is called photosynthesis. The sugar is later changed by the plants into starch for storage. Other food materials are also prepared within the plants such as proteins and fats. The seeds of rice and maize contain mostly starch; the seeds of legumes such as pea, bean and pulse are rich in proteins; and the seeds of groundnut, castor, sesamum and mustard contain an oil.
PLANT LIFE

Plants respire as animals and human beings do, that is by taking in oxygen and giving out carbon dioxide. All living things respire to release the energy necessary for growth by breaking down the stored food material. Even in dormant seeds, respiration is going on.

Plants are propagated by seed and by vegetative methods. Vegetative propagation consists in severing a part of a plant such as the stem, root, leaf or bud and planting them to develop a new plant. Several vegetative methods such as cuttings, budding, grafting, layering, are adopted for multiplying the plants.

Plants are classified into groups in order to understand their inter-relationship and for their identification.

QUESTIONS

1. How are plants propagated and why?
2. What is the importance of water to plants?
3. Why should the loss of water from plants be reduced? What is the difference between transpiration and evaporation?
4. Is light necessary for synthesizing food materials in plants?
5. Why do plants respire?

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GLOSSARY FOR CHAPTERS 6 AND 7*

Achene. A one-celled, dry indehiscent fruit in which the testa and the pericarp are not firmly attached
Adventitious. Out of the ordinary place, as applied to buds or roots
Albuminous. Full of clear protein similar to the white of an egg
Algae. A group of Thallophytes, such as certain scum and allied forms
Angiosperm. A plant of the angiospermae, one of the main divisions of flowering plants in which the seeds are in a closed ovary, not naked as in gymnosperms


**Anther.** The part of the stamen which contains the pollen

**Axis.** A line passing through a structure about which the parts are arranged

**Bacterium.** A one-celled, microscopic organism which is a low form of plant life. Bacteria are widely distributed in air, water, soil, bodies of living animals and plants, and dead organic matter. Lacking the green colouring matter, chlorophyll, they cannot manufacture their own food from carbon dioxide and water and must therefore get it from other sources

**Blade.** The expanded portion of a leaf

**Botany.** The science of plants

**Calyx.** The outer (lower) group of floral leaves of a plant, often smaller and green in colour as contrasted to the inner, more showy part, the corolla

**Cambium Layer.** A soft layer, strip, or cylinder of living cells which divides to form new tissues of a plant. The layer ordinarily extends over the plant body except at the growing tips

**Carotin, Carotene.** One of the yellow pigments widely distributed in plants, capable of being changed into vitamin A in the animal body

**Caryopsis.** A seed-like fruit with a thin pericarp fastened to the seed

**Chlorophyll.** The green compound found in leaves and other plant parts by means of which the plant converts water and carbon dioxide of the air into food through the energy of the sunlight in a process called photosynthesis

**Chlorosis.** Yellowness of normally green tissues due to partial failure of chlorophyll to develop

**Chlorotic.** Pertaining to or affected by chlorosis

**Corolla.** The petals of a flower collectively; the inner (upper) part of the floral leaves of the plant, usually more delicate and brightly coloured than the outer (lower) part, the calyx

**Cotyledon.** The first leaf produced when a seed germinates

**Cryptogam (Gr. gamos, marriage).** Any member of the cryptogamia; the class of flowerless plants so named by Linnaeus in the expectation that sexual reproduction would one day be discovered in them

**Cymose.** Subsequent flowers growing on successive lateral branches

**Dicotyledon.** A plant of one of the two great divisions of angiosperms, having embryos with two cotyledons (seed leaves), leaves commonly net veined, the parts of the flowers, in twos, fives or multiples of these, and the vascular bundles in the axes usually containing cambium

**Dioecious.** Bearing staminate (male) flowers on one plant and pistillate (female) flowers on another

**Embryo.** A young plant in its beginning, usually contained in a seed or surrounded by protective tissue

**Endosperm.** Nutritive tissue formed within the seed on which the embryo feeds while germinating

**Epicotyl.** The stem of the embryo or young seedling above the cotyledons

**Ferns.** One of the class of higher or vascular cryptogamous plants

**Fibrous.** Fibre-like, usually referring to root system of many small threadlike roots

**Filament.** Thread; stalk of stamen
Above: Pl. XXVI. Applying chemical fertilizers is essential if crop yields are to be increased. This man is broadcasting fertilizer before planting rice in Madras State. [Courtesy: Fertiliser Association of India].

Pl. XXVII. Cotton will grow well and produce satisfactory yields even on soils that are highly alkaline. [Courtesy: Roy Sellers].
Pl. XXVIII. Reclaiming alkali (salty) soils can usually be accomplished by heavy applications of gypsum (CaSO₄), adding an excess of irrigation water to leach the harmful salts downward out of reach of plant roots, and growing green-manure crops. Left: 3½ tons of gypsum per acre were applied, the land was flushed twice with irrigation water, and dhaincha was planted. The crop now seen is dhaincha. Right: No gypsum was applied but dhaincha seed was planted. The harmful salts have killed the dhaincha (Andhra Pradesh). [Courtesy: Roy L. DONAHUE].

Pl. XXIX. Foods rich in protein include chicken, mutton, bacon, beef, ham, and fish. [Courtesy: TEXAS EXTENSION SERVICE].
**Fungus.** A low form of plant life which, lacking chlorophyll and incapable of manufacturing its own food, obtains its food from dead or living plant or animal matter

**Gymnosperm.** Any of the lower or primitive group of seed plants whose (naked) seeds are not enclosed in an ovary

**Herbaceous.** Herb-like; that is, the stems do not develop woody tissues

**Hermaproditic.** Perfect flower, both stamens and pistils present

**Hilum.** A small depression of an organ, such as a seed, which usually marks the point at which the organ was attached to its base

**Humidity.** Moisture in the form of vapour

**Hypocotyl.** A part of an embryo plant in the seed; the first stem of a plant

**Inflorescence.** A flower cluster; the general arrangement and disposition of the flowers on an axis; the mode of development of flowers

**Lichen.** A compound plant consisting of a fungus (singular of fungi) and an alga (singular of algae) living symbiotically, forming crusts and tufts on stones, trees, and soils

**Monocotyledon.** A plant of one of the two great divisions of angiosperms, having embryos with one cotyledon; leaves commonly parallel-veined; the parts of the flower usually in threes; the vascular bundles scattered; and usually without cambium

**Monoecious.** Pertaining to a plant having both male and female reproductive organs on the same individual

**Moss.** A class of Bryophytes, small plants with simply constructed leaves, and no woody material, attached by rhizoids, the zygote growing into small spore-bearing capsules that grow parasitically on the parent plant

**Mycropyle.** A very small pore or hole

**Node.** The junction of two internodes in a culm; point of origin of a leaf

**Osmosis.** Diffusion of liquids through a porous membrane

**Ovary.** The ovule bearing part of the pistil

**Ovule.** The structure which after fertilization becomes the seed. All ovules comprise the ovary

**Pedicel.** Any slender stalk; especially one that supports a fruiting or spore-bearing organ

**Peduncle.** The stem that bears a flower or flower cluster

**Pericarp.** The wall of a matured ovary

**Petiole.** The stalk of a leaf

**Phanerogam.** A spermatophyte

**Phloem.** Tissue in plants through which foods are transported from leaves to roots

**Photosynthesis.** The process by which green plants make sugar from water and carbon dioxide with the energy of sunlight

**Pistil.** The female, ovule-bearing organ of a seed plant consisting of the stigma, style and ovary; adjective PISTILLATE

**Plumule.** The first bud of a plant when a seed germinates

**Protoplasm.** The basic substance of which all living matter is made. It is a greyish, semi-transparent, sticky substance within which physical, chemical and electrical changes are constantly taking place
Raceme. A simple inflorescence with spikelets borne on pedicels along an axis
Racemose. A branch growing continuously
Radicle. A rootlet; the first root of a plant
Respire. Take in oxygen and give out carbon dioxide
Scion. A detached shoot or another part of a plant that consists of more than
one bud, which may be propagated; specially such a part removed from
its place of growth and prepared for grafting
Sessile. Without a stalk of any kind
Stamen. The male reproductive organ of a flower; adjective staminate
Stigma. The part of a pistil to which the pollen grains become attached
Stipule. One of a pair of appendages borne at the base of a leaf
Stoma. A minute opening in a leaf or stem; a pore; plural stomata
Tendril. Slender, coiled organ used in climbing
Terminal. At the end
Testa. Seed coat
Turgid. Tightly drawn, swollen
Umbel. The arrangement of flowers arising from a common stalk forming a
more or less flattened or rounded cluster.
Vascular. Pertaining to the tissues of plants that conduct fluids
Xanthophyll. One of the yellow pigments present in green plants
Xylem. Tissue in plants through which water is conveyed to the stem from the
roots and which furnishes mechanical support to the plant
Yeast. Living cells used in brewing, which produces zymase and induces the
alcoholic fermentation of carbohydrates
Zygote. The product of the union of the two gametes
Zymase. Any of a group of enzymes inducing the alcoholic fermentation of
carbohydrates
Chapter 8

CHEMISTRY IN AGRICULTURE

CHEMISTRY is a science that deals with the composition of substances. In reality, every substance contains chemical elements and compounds. For example, common table salt from sea water consists of two elements, sodium and chlorine; together, as sodium chloride, they make the compound that we eat as table salt.

For convenience, chemists have assigned symbols to each element; sodium is written as Na, chlorine as Cl, and the compound sodium chloride as NaCl. In nature there are ninety or more elements and thousands of compounds.

There are elements and compounds in all substances, both living and dead. In this chapter we will discuss some of the simpler elements and compounds that are important in agriculture, including soil fertility, reclamation of alkali soils, plant life, and foods.

CHEMISTRY OF SOIL FERTILITY

Each year the farmers of India add approximately two million tons of plant foods to their soils but remove from the soils eight million tons in harvested crops. The difference of six million tons between the amounts of plant foods added and the amounts removed must be supplied by the break-down of soil minerals and by the fixation of nitrogen from the atmosphere. No one can say for certain if the soil minerals and the nitrogen-fixing organisms actually supply each year as much as six million tons of plant foods. If this much plant food is so supplied, it means that the fertility of the soils is barely being maintained. This is probably true because India’s crop yields per acre are among the lowest in the world and they have remained about the same year after year.

Crop yields per acre must be increased before India can produce all of the food she consumes. Crop yields per acre can be increased with the proper use of commercial fertilizers, farmyard manure, green manure crops, and compost.
When a crop is growing, it absorbs varying amounts of nearly all of the ninety or more elements that are found in the soil, air, and water. When the crop is sold from the farm, the plant foods are a loss to the farm and must be maintained or increased by:

1. The natural weathering of soil minerals (Plate XXIII).
2. The fixation of nitrogen from the air by certain bacteria (Figure 56).
3. The application of compost or animal manures (Figure 57 and Plates XXIV and XXV).
4. The application of commercial fertilizers (Plate XXVI).

Fig. 56. Roots of legume plants have nodules, inside of which certain bacteria live that use nitrogen from the air to enrich the soil. These are roots of lucerne.

[Redrawn from: Evans].
Although crops absorb ninety or more different elements, only sixteen have so far been proved essential for their growth. These along with their chemical symbols are:

<table>
<thead>
<tr>
<th>Element</th>
<th>Symbol</th>
<th>Element</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>CARBON</td>
<td>(C)</td>
<td>MAGNESIUM</td>
<td>(Mg)</td>
</tr>
<tr>
<td>HYDROGEN</td>
<td>(H)</td>
<td>IRON</td>
<td>(Fe)</td>
</tr>
<tr>
<td>OXYGEN</td>
<td>(O)</td>
<td>MANGANESE</td>
<td>(Mn)</td>
</tr>
<tr>
<td>NITROGEN</td>
<td>(N)</td>
<td>ZINC</td>
<td>(Zn)</td>
</tr>
<tr>
<td>PHOSPHORUS</td>
<td>(P)</td>
<td>COPPER</td>
<td>(Cu)</td>
</tr>
<tr>
<td>SULPHUR</td>
<td>(S)</td>
<td>MOLYBDENUM</td>
<td>(Mo)</td>
</tr>
<tr>
<td>POTASSIUM</td>
<td>(K)</td>
<td>BORON</td>
<td>(B)</td>
</tr>
<tr>
<td>CALCIUM</td>
<td>(Ca)</td>
<td>CHLORINE</td>
<td>(Cl)</td>
</tr>
</tbody>
</table>

The first three elements carbon, hydrogen, and oxygen, come from air and water. Nitrogen originally came from the air, but in this form only pulse (legume) plants and certain bacteria can use it. Other plants such as rice can utilize nitrogen only after it has been fixed in some stable chemical compound. The remaining twelve elements are supplied to the crop through the soil.

The minerals and organic matter in the soil decompose and thereby release plant food elements to the crops. Crops produce continuous low yields without the addition of any fertilizers, manures, or composts; and in most soils these materials must be supplied to obtain satisfactory crop yields.

The essential plant food elements that are most frequently applied to soils in India to increase crop yields are nitrogen (N) and phosphorus (P). To a lesser extent potassium (K) is used. To acid soils in high-rainfall areas, calcium (Ca) as lime (CaCO₃) is occasionally applied.

The nitrogen (N) fertilizer most commonly used in India is ammonium sulphate [(NH₄)₂SO₄] which is approximately 20.5 per cent nitrogen (N). Ammonium sulphate also contains sulphur which is an essential plant food element. Other nitrogenous fertilizers used to a lesser extent are urea [CO(NH₂)₂] containing 45 per cent nitrogen (N), and ammonium nitrate [NH₄NO₃] with approximately 32 per cent nitrogen (N), to which has been added lime (CaCO₃) to make it easier to handle.

Plants are capable of absorbing both the ammonium (NH₄⁺) and the nitrate (NO₃⁻) forms of nitrogen. The urea must be
Fig. 57. From the time that primitive man first observed that plants growing near cattle manure were larger, farmers have applied all available farmyard manure to their fields to increase crop yields. [Courtesy: H. R. ARAKERI].
changed by bacteria into the ammonium (NH₄⁺) form before it can be absorbed by crops.

Phosphorus (P) fertilizer is usually added to Indian soils as superphosphate. This is a complex compound containing three forms of calcium phosphate. In India, superphosphate contains 16 per cent water-soluble phosphorus. A secondary source of phosphorus (P) fertilizer is ground bone meal which is mostly tri-calcium phosphate [Ca₃(PO₄)₂]. Bone meal contains about 25 per cent total phosphate.

Potassium (K) fertilizers consist of potassium sulphate (48 per cent K₂O) and potassium chloride (50 to 60 per cent K₂O). A minor source of potassium (K) used as a fertilizer is wood ash, containing about 4 per cent K₂O and 40 per cent lime (CaCO₃).

Calcium (Ca) is often applied to the soil as wood ash, and as ground limestone with 75 to 90 per cent calcium carbonate (CaCO₃). Burnt limestone is also satisfactory, consisting of calcium hydroxide [Ca(OH)₂] and calcium oxide (CaO).

SOIL TESTING

How can a farmer determine how much fertilizer and lime his soil needs to produce the greatest net profit?

The answer to this question is found mostly in chemistry by soil testing of field samples. Answers are now being given through a new scientific approach by the Indian agriculturists. Arrangements have recently been made through the cooperation of the Central Government, the State Governments and the agency for International Development of the United States of America for the establishment of twenty-five soil testing laboratories. These laboratories have the most modern equipment and are supervised by well-trained and experienced soil chemists who understand the chemical principles involved in making the tests. The soil chemists are working hand in hand with the farmers and the agronomists in order that their recommendations may be simple and practical. These laboratories are organized in such a manner that they put scientific knowledge into practice. This service is free of charge for the farmers. To begin with, they will place emphasis on giving prompt answers to farmers regarding the major soil nutrients (nitrogen, phosphorus and potassium), lime requirement, and salinity.
When the soil chemist makes his recommendations he takes into consideration the results of the laboratory test, the soil characteristics in the field, the crops grown, the yields that have been obtained, and the fertility practices used. He is interested in whether the field is irrigated or rainfed. Where water is not likely to be a limiting factor, his fertilizer recommendations will be higher. He wants to know what crop is to be grown; its plant food requirements; and the predicted economic returns. He is also interested in knowing something about the cultivator; whether he is using good crop management practices; and his financial situation for purchasing fertilizers. Normally, with other good management practices, higher rates of fertilizer application will result in greater total profit per acre. The soil chemist, after evaluating all of the above factors, is in a position to give recommendations to the farmer in which the farmer can have confidence.*

* The locations of the twenty-five soil testing laboratories in India are as follows:

<table>
<thead>
<tr>
<th>State or Province</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Andhra Pradesh</td>
<td>Bapatla</td>
</tr>
<tr>
<td>2. &quot;</td>
<td>Rajendranagar</td>
</tr>
<tr>
<td>3. &quot;</td>
<td>Rajahmundry</td>
</tr>
<tr>
<td>4. Assam</td>
<td>Jorhat</td>
</tr>
<tr>
<td>5. Bihar</td>
<td>Hazaribagh</td>
</tr>
<tr>
<td>6. &quot;</td>
<td>Sabour</td>
</tr>
<tr>
<td>7. Delhi</td>
<td>Indian Agricultural Research Institute</td>
</tr>
<tr>
<td>8. Himachal Pradesh</td>
<td>Simla</td>
</tr>
<tr>
<td>9. Gujarat</td>
<td>Junagadh</td>
</tr>
<tr>
<td>10. Kerala</td>
<td>Trivandrum</td>
</tr>
<tr>
<td>11. Madhya Pradesh</td>
<td>Gwalior</td>
</tr>
<tr>
<td>12. &quot;</td>
<td>Jabalpur</td>
</tr>
<tr>
<td>13. Madras</td>
<td>Coimbatore</td>
</tr>
<tr>
<td>14. &quot;</td>
<td>Aduthurai</td>
</tr>
<tr>
<td>15. Maharashtra</td>
<td>Nagpur</td>
</tr>
<tr>
<td>16. &quot;</td>
<td>Poona</td>
</tr>
<tr>
<td>17. Mysore</td>
<td>Bangalore</td>
</tr>
<tr>
<td>18. &quot;</td>
<td>Mysore</td>
</tr>
<tr>
<td>19. Orissa</td>
<td>Sambalpur</td>
</tr>
<tr>
<td>20. Punjab</td>
<td>Ludhiana</td>
</tr>
<tr>
<td>21. &quot;</td>
<td>Karnal</td>
</tr>
<tr>
<td>22. Rajasthan</td>
<td>Jodhpur</td>
</tr>
<tr>
<td>23. Tripura</td>
<td>Agartala</td>
</tr>
<tr>
<td>24. Uttar Pradesh</td>
<td>Kanpur</td>
</tr>
<tr>
<td>25. West Bengal</td>
<td>Calcutta</td>
</tr>
</tbody>
</table>
From your Agricultural Officer you can get specific directions on how to take a soil sample for testing and a Record Sheet to be filled out for each soil sample. Although each laboratory may have slightly different instructions, the generally approved directions are as follows:

1. Treat each field as a separate sampling unit. If areas within a field are different in appearance, slope, drainage, soil texture, soil colour, or past treatment, sample each area separately. If a field is larger than ten acres, divide it so that each sample represents not more than ten acres.

2. Take a separate composite sample for each soil area or field. In taking soil samples, a soil tube, a soil auger, or a narrow-bladed *khurpi* (hand hoe) are satisfactory tools. In very friable soils, a large spoon or a sickle may be used.

3. Take a small, uniformly thin slice of soil from the surface to the plough depth from approximately ten spots over the field. Collect all the slices in a clean container, mix well in the container or on a clean paper or cloth, and reduce the sample to about one pint in size.

4. Avoid the sampling of non-representative areas such as old bunds, marshy spots, tanks, and areas near roads, trees, field boundaries, compost heaps, or buildings.

5. The soil is easiest to sample when its moisture content is such as to make it suitable for ploughing. The best time to take the sample is immediately after ploughing.

6. Do not sample a field within three months after an application of lime, ashes, compost, manure or fertilizers.

7. Break all clods or lumps before they become dry. Spread all wet soil samples in the shade so that they may become dry without artificial heat.

8. Place the soil sample of desired size (usually about one pint) in a clean cloth bag, paper bag, or a cardboard carton for posting to the soil testing laboratory.

9. Label each sample with a number and the cultivator's name. Show on a sketch map of the farm the source of each soil sample.

10. Fill out the information sheet as fully as possible. This will help greatly in making recommendations. *Place the information sheet with the soil sample before closing the package.*
AGRICULTURE IN INDIA

CHEMISTRY OF RECLAIMING ALKALI SOILS*

India has at least twelve million acres of land which are less productive because of alkali in the soil. Most of the alkali soils are in Punjab, Uttar Pradesh, and Rajasthan; but they also occur to some extent in other areas of low rainfall.

GYPSUM FOR RECLAIMING ALKALI SOILS

Large areas of alkali land can be economically reclaimed by the application of gypsum (calcium sulphate, CaSO₄). Gypsum is readily available in many regions of low rainfall, especially in Rajasthan. Alkali soils that are most easily reclaimed for crop production are sandy loams and loams with good under-drainage, and those which are low in soluble sodium (Na).

To determine whether or not a particular field can be reclaimed by gypsum, the internal drainage must be determined. If the drainage is good send a soil sample to the Soil Testing Laboratory that is nearest to you. If the test shows that about three tons of gypsum per acre is necessary, this amount should be added. The chemistry of the reclamation may be explained in this way. When sodium (Na) is present in fairly large amounts in the soil, the soil becomes hard and compact like a brick. The compacted soil will not permit water to pass downward readily, soluble salts therefore accumulate on the surface and in the root zone. The result is that the soil contains harmful salts as well as too little air for plant roots to grow (Figure 58). Under extreme alkali conditions all plants die; under milder conditions only the most resistant plants are able to grow.

Gypsum (CaSO₄) applied to reclaim an alkali soil supplies soluble calcium (Ca) which replaces a large part of the sodium (Na). By applying a large amount of irrigation water after the application of gypsum (CaSO₄), much of the sodium (Na) will be leached downward below the root zone. The surface soil is now full of calcium (Ca) which causes the fine soil particles to rearrange themselves into loose, open clusters. The result is a more open soil with fewer

harmful salts and a soil that now contains enough air for plant roots to grow normally (Figure 59).

To aid gypsum in the reclamation of alkali soils, a green-manure crop of *dhaincha* (*Sesbania aculeata*) is recommended. InCREASES IN THE YIELD OF RICE ON FARMERS' FIELDS IN UTTAR PRADESH FOLLOWING *DHAINCHA* ALONE, GYPSUM ALONE, AND A COMBINATION OF THE TWO ARE GIVEN AS FOLLOWS:

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Percentage of increase in the yield of rice over no treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Dhaincha</em></td>
<td>38</td>
</tr>
<tr>
<td>Gypsum</td>
<td>97</td>
</tr>
<tr>
<td><em>Dhaincha</em> plus Gypsum</td>
<td>170</td>
</tr>
</tbody>
</table>

It may thus be observed that on an alkali soil, *dhaincha* alone gave a 38 per cent increase, gypsum alone a 97 per cent increase, but *dhaincha* plus gypsum gave a 170 per cent increase in the yield of rice.*

* Please remember that a 100 per cent increase is the same as twice (double) the yield.
Common crops that are highly tolerant to alkali soils are barley, beet, cotton, date palm, kale, asparagus, and spinach. Very sensitive (not tolerant) crops include nearly all beans and such tree and vine fruits as pear, apple, orange, grapes and lemon. Under no circumstances should the crops that are sensitive to alkali be planted on alkali soils (Plate XXVII).

**Fig. 59.** How gypsum (CaSO₄) reclaims alkali soils. [Redrawn from: ALDRICH and SCHOONOVER].
Some mildly alkali soils will grow good crops if only tolerant crops are planted. With other soils that are more strongly alkali, gypsum should be applied, followed by the planting of tolerant crops (Plate XXVIII).

CHEMISTRY OF PLANT LIFE*

The only living part of a seed is the little germ or embryo. The rest of the seed consists of stored foods — starch, proteins, and minerals

![Diagram](image)

Fig. 60. A seed will sprout only when the temperature, water, and air are all satisfactory. In the above demonstration, three seeds of bean are fastened on a board which is standing in water. The bean under water did not sprout because of too little oxygen. The bean at the top did not have enough water. The bean at the water level had enough water and air. The temperature for all beans was about the same.

[Redrawn from: Narayanan].

which together with the embryo are wrapped in the hull. Inside the embryo are small quantities of sugar and oil to serve as a source of food for a few days after the embryo starts to grow. Around the embryo is a larger store-house (godown) of foods that must be sufficient to nourish the tiny plant until it can force its roots into the soil to obtain the minerals it needs and its green leaves into the air to use the energy of sunlight to make the organic foods it must have to live, grow and reproduce.

When a seed is planted in warm, moist soil, interesting things begin to happen. Water from the soil slowly enters the seed through the hull, the seed swells, and if the temperature is favourable, the dormant plant wakes up and begins to “breathe” faster (Figure 60).

Chemically, this means that the sugar within its cells begin to combine more rapidly with oxygen (O), forming carbon dioxide (CO₂) and water (H₂O) and releasing energy which can be used by the awakened young plant.

“Breathing” requires a continuous supply of sugars, and when those contained in the embryo are used, the living cells must begin to draw on the starch stored in the seed. Starch, however, is quite insoluble in water, and before it can be carried into the embryo, it must first be changed into sugars that will dissolve in water. The sugars produced from the starch dissolve in water, move into the embryo, and supply its needs for food. In a similar way, the cells produce substances (enzymes) that cause the proteins and oils to be digested into soluble sugars which can be used by the growing plant. Some of the stored minerals also dissolve in water and perform a variety of functions as the tiny plant develops from the seed.

Using energy released when the sugars are oxidized, the germinating embryo forces its primary rootlet downward into the soil and its stem and first leaves upward into the air. Soon after the leaves emerge from the soil they develop a green pigment (chlorophyll) and when the sun is shining on them they begin to carry on the chemical process called photosynthesis.

Photosynthesis is exactly opposite in effect as “breathing” (respiration). In the process of photosynthesis, carbon dioxide (CO₂) entering the leaves from the air through openings called stomata, and water (H₂O) absorbed by the roots from the soil, combine to form sugars and liberate oxygen (O). Chlorophyll acts as a catalyst (starter) for the reaction, and sunlight furnishes the energy.
this energy is stored as sugars for food which can be used by the plant for respiration and growth (Figure 61).

While the new leaves become green and start to carry on photosynthesis, secondary roots push out into the soil and begin to absorb water and mineral nutrients. At this stage the plant becomes an independent chemical factory capable of manufacturing the food it needs to grow. For the remainder of its life, as it grows, matures, reproduces, and dies, the plant will carry on a whole series of complicated chemical reactions in addition to photosynthesis. These reactions enable the plant to convert simple materials obtained from the soil and air into complex compounds composing its roots, stems, leaves and new seeds (Figure 62).

As every factory must do, the plant provides for bringing in raw materials and for storing finished products. In its stalk, streams of water carry minerals from the roots to the leaves, while other streams of water moving in the opposite direction carry sugars from the leaves to growing cells or to organs where they are to be stored. Some of the sugars first formed in photosynthesis are used directly by the cells of the plant for respiration. Some are changed to starch or oil and stored as reserve food. Others are converted to cellulose to form the structural parts of the plant, and still others by the addition of nitrogen, sulphur and phosphorus, are made into proteins, which are needed by the protoplasm of the growing plant.

When necessary, the plant can reverse these reactions and change the starch, oils and proteins back into sugars. All of these reactions except photosynthesis can take place at night as well as in day-time. Photosynthesis takes place only in the presence of light.

Research has shown that at least sixteen elements are necessary for the growth and reproduction of a plant. Oxygen (O) is the only element that the plant uses in uncombined or elemental form, and it is obtained from the air. Carbon (C) is supplied as carbon dioxide (CO₂) from the air and from water solutions of simple carbon compounds which enter through the roots of the plant. Water (H₂O) supplies the hydrogen (H) and combined oxygen (O), and under natural conditions all the other necessary elements must be obtained from the soil. It is these latter elements that can be supplemented when necessary by the use of commercial fertilizers.
Fig. 61. A green leaf is the primary food factory of the world. The green chlorophyll in the leaf uses minerals from the soil, carbon dioxide from the air, and energy from the sun to manufacture sugars. Some of the sugars such as those in sugar cane are used directly for human consumption, other sugars are changed to starch, proteins, or fats that are used as human or animal food. [Courtesy: Roy L. Donahue].
FIG. 62. Many chemical processes take place when a seed sprouts and develops into a plant, as illustrated by the sprouting of a bean. The germ swells and develops into a root and a shoot. The stored foods inside the seed are changed from carbohydrates and fats into sugars that are used by the young growing plant. After green leaves and permanent roots develop, the plant manufactures its own food from water and plant food elements in the soil, with the use of energy from the sun. [Redrawn from: Narayanan].
For about the first two months of their lives, plants grow rapidly and produce food materials for the increased number of living cells. Their leaves become broad and long, and more cells containing chlorophyll are formed. This increases their capacity for carrying on photosynthesis, and on sunny days these busy factories work from dawn to dusk at the business of combining carbon dioxide (CO₂) and water (H₂O) into new sugars and changing them into all of the combinations needed by the growing plants. Nor do plants quit work when the sun goes down; during the night the busy plant cells carry away the excess sugars from the leaves. Some of the sugars are for immediate use by the plant and others are changed to starches, proteins and fats and are stored for later use.

At this midway stage in the lives of the plants, the chemical miracle of reproduction begins. The major chemical efforts of the parent plants are now directed toward nourishing a new embryo and surrounding it with stored foods in the new seeds. Gradually the chemical process within the parent plants diminishes in vigour and finally ceases. Their task is done, and the new seeds either fall to the ground to produce new plants or are harvested as food for man or his animals. Some of the harvested seed must be saved for planting the next crop.

**CHEMISTRY OF FOODS**

Plants use soil minerals, water and air, and energy from the sun to manufacture their foods. Animals eat certain food products manufactured by the plant, and man eats both selected plants and some of the animals and their products. The primary source of food for man is the plant; the secondary source are animals such as goats and animal products such as milk and eggs.

Foods from plants and the meats and animal products used for food by man are very complex chemically. However, all of them contain varying kinds and amounts of six food ingredients, as follows:

- PROTEINS
- FATS
- CARBOHYDRATES
- VITAMINS
- MINERALS
- WATER
PROTEINS

Proteins consist of carbon, hydrogen, oxygen, sulphur, nitrogen and phosphorus. Foods high in protein are pulses, groundnuts, beans, meat, milk, eggs and fish (Figure 63 and Plates XXIX and XXX).

FATS

Fats contain carbon, hydrogen and oxygen and serve as a concentrated energy food. The common vegetable fats used as food are coconut oil, groundnut oil and sesamum. Animal fats comprise butter, ghee (butter oil), fish oil, lard (from hogs) and fat that is a part of red meat such as mutton and beef (Figure 64).

CARBOHYDRATES

Carbohydrates contain carbon, hydrogen and oxygen. Common examples of carbohydrates are sugars and starches. Foods high in carbohydrates are rice, wheat, jowar, and maize and the lesser millets such as bajra and ragi. These grains contain approximately 75 per cent carbohydrate. Gur, honey, and potatoes are also rich in carbohydrates (Figure 65 and Plate XXXI).

VITAMINS

The common vitamins are vitamin A, D, E, K, B Complex and C.

Vitamin A is found only in animals and animal products. Yellow animal fat, eggs, and cod-liver oil are rich in vitamin A. Green and yellow vegetables contain a substance (carotene) that is changed to vitamin A in our bodies and in the bodies of animals. Vitamin A deficiency results in the inability of a person or animal to see at night. This disease is often called "night blindness".

Vitamin D deficiency is known as "rickets" and is characterized by weak bones. Rickets can be prevented by exposing the body to sunshine or by eating cod-liver oil, fish, eggs, and liver.

Vitamin E deficiency in animals results in their inability to reproduce. Leafy vegetables, wheat germ oil, maize germ oil, cottonseed oil, milk, meat and eggs are rich in vitamin E.
Fig. 63. Sources of proteins in the Indian diet include meat, eggs, fish, groundnuts, milk, beans, and dal. [Redrawn from: "What Should We Eat?", Ministry of Health, New Delhi].
Vitamin K deficiency results in a loss of the ability of the blood of man and animals to coagulate (clot), and thus a wound may continue to bleed. Green leaves are rich in vitamin K.

Vitamin B Complex contains seven vitamins that are necessary for human nutrition. Vitamin B (thiamine) is supplied in pork, heart, kidney, pulses, nuts, and whole wheat. Vitamin B₂ (riboflavin) may be obtained by eating milk, liver, heart, kidney, other lean meats, cheese, eggs, whole grains, and leafy vegetables. Niacin may be obtained from meats, groundnut, pulses, rice polishings, nuts and whole grains. Vitamin B₆ may be obtained from muscle (red) meats, liver, vegetables and whole grains. Pantothenic acid can be obtained from liver, eggs, broccoli, cauliflower, lean beef, milk, sweet potatoes, Irish potatoes, tomatoes and molasses. Folic acid for proper nutrition may be obtained by eating liver, kidney, pulses, asparagus, broccoli, groundnut, cabbage, lettuce, nuts and whole cereals. Vitamin B₁₂ needs for the body may be supplied by eating liver.

**SOURCE OF FATS**

**GHEE**
(BUTTER OIL FROM MILK)

**DALDA**
(VEGETABLE OIL FROM COCONUT, GROUNDNUT, OR SESAMUM)

Fig. 64. Sources of fats in the Indian diet include ghee from milk and vegetable oils from coconut, groundnut, or sesamum. [Redrawn from: “What Should We Eat?”, MINISTRY OF HEALTH, NEW DELHI.]
Vitamin C (ascorbic acid) deficiency causes skin diseases, spongy gums, bleeding tissues and often death. Citrus fruits such as oranges, limes, and lemons are especially rich in vitamin C (Figures 66 and 67).

MINERALS

Elements that are essential for man and animals include carbon (C), hydrogen (H), oxygen (O), phosphorus (P), potassium (K), nitrogen (N), sulphur (S), calcium (Ca), iron (Fe), magnesium (Mg), manganese (Mn), copper (Cu), zinc (Zn), sodium (Na), iodine (I), chlorine (Cl), and cobalt (Co). Of these 17 elements, carbon, hydrogen, oxygen, chlorine, and nitrogen are not minerals.

A deficiency of calcium and phosphorus in man and animals results in weak bones and poor teeth. Iron deficiency causes a decrease in the number of red cells in the blood. Iodine deficiency results in a swelling of a gland in the neck, causing a condition known as “goitre”. A deficiency of other minerals in man and animals is not as easy to recognize.
Fig. 66. Foods high in vitamins and minerals include banana, apple, grapes, pear, lime, mango, carrots, green vegetables, curds, fish, eggs, milk and liver. [Redrawn from: “What Should We Eat?”, Ministry of Health, New Delhi].
Fig. 67. Whole cereal grains are rich in vitamins, minerals, and carbohydrates, and should be eaten in preference to refined products such as polished rice and white flour.

WATER

Pure water consists of two parts of hydrogen (H) and one part oxygen (O); it is usually written as $\text{H}_2\text{O}$. But the water that you see is never pure. Even the water that falls as rain absorbs impurities from the air. By the time the raindrop strikes the earth, it contains dissolved ammonia ($\text{NH}_3$) and also contains many particles of dust.

About 60 per cent of our body consists of water. A person may live for five weeks or more without food but for only a few days without water. Drinking an adequate amount of water is necessary to remain in good health. The average consumption of water per person is about a quart a day as a liquid and another quart a day in the food that he eats. When a person is exercising or working in hot weather at high altitudes his water requirement is several times this amount.
Pl. XXX. Eggs are rich in protein and should be in the diet each day.

[Courtesy: EARL N. MOORE].

Pl. XXXI. Bread contains mainly carbohydrates.

Left: Bread made from jowar; Right: Bread made from bajra.

[Courtesy: ROY L. DONAHUE].
Pl. XXXII. Rocks scale off (*above*) and crack (*below*) in the weathering process to form soil. [*Courtesy: Roy L. Donahue*].
SUMMARY

Every substance, whether living or dead, contains chemical elements. In this chapter are discussed certain aspects of chemistry in agriculture, including soil fertility, alkali soil reclamation, plant life, and foods.

If crop yields are to be maintained or increased, the essential chemical elements must be replaced. To determine the amount and kind of plant food elements that should be replaced in the soil, a soil test is necessary.

Gypsum is commonly used for reclaiming alkali soils and the chemistry of this process is explained. The chemistry of seed germination, respiration, and photosynthesis as a part of plant growth processes, are explained briefly.

Foods required by man include protein, fat, carbohydrate, vitamins, minerals, and water.

QUESTIONS

2. Name four ways in which soil fertility may be replaced.
3. Describe briefly how to take a soil sample for chemical testing.
4. Draw a diagram to illustrate reclamation of alkali soil with the use of gypsum.
5. Name the six food ingredients that are required by man.

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Chapter 9

CLIMATE AND SOIL

CLIMATE

The most important factor in crop production in India is climate and weather. Weather is defined as the condition of the atmosphere at any one time and place; whereas climate is the average weather.

To be successful the farmer must adjust his farming operations to the weather and climate. For example:

1. Ploughing after the rains begin and when the soil has become moist; to plough when the soil is dry would require more power than most farmers have available. Ploughing when dry results in a very cloddy soil that may require several months before it can be worked into a good seed-bed.

2. Sowing seeds only after the soil has been wetted to a depth of three or more inches; seed sown in moist soil that soon dries out will germinate and then die for lack of moisture.

3. Fertilizing the crop at a time to avoid loss of fertilizer by surface erosion or by deep percolation. In addition, the fertilizer must be in a continuously moist soil zone, otherwise plant roots cannot absorb it during a dry period.

4. Planning the cropping system in relation to rainfall and soil to permit inter-cultivation for the control of weeds. On black clay soils, for example, inter-cultivation is not possible during the monsoon rains.

5. Selecting the kinds of crops that offer the most protective cover during periods of most severe erosion hazard; that is, during the monsoon.

6. Choosing the kinds of crops that can be harvested during a dry period of the year. Crops maturing during the monsoon are frequently spoiled by the rains.

In 1945 the Indian Meteorological Department established a weather service for agriculture. The service keeps the farmers of India informed about the beginning and end of the monsoon in each district and provides other important information about the
Fig. 68. Rainfall in summer during the South-West Monsoon, showing prevailing wind direction (arrows), and atmospheric (air) pressure during the month of June. Points along each solid line have the same atmospheric pressure, expressed in equivalent inches of mercury. Vertical lines are degrees east longitude and horizontal lines are degrees north latitude. [Source: The Indian Cotton Atlas, Second Edition, Indian Central Cotton Committee, Bombay, 1959].
weather. Regional forecasting centres are located in Bombay, Calcutta, Delhi, Madras, and Nagpur. Farmers’ weather bulletins are issued daily by the regional centres and the information is published in newspapers and is broadcast over All-India Radio stations in the various regional languages. All farmers should take advantage of this weather service so that they may plan their farming operations more efficiently.

MONSOON RAINS

Nearly all of the rainfall in India comes from the moist air that is brought from the Arabian Sea by a wind blowing from the South-West. Since winds are named with reference to where they come from, these winds and the rains that they bring are known as the South-West Monsoon. The South-West Monsoon starts in Kerala about 1 June and moves northward, arriving in the Western Punjab about 15 July (Figure 68). At any one location, the South-West Monsoon rains are received mostly within a period of three to four months. Approximately 75 per cent of all rainfall is received during the South-West Monsoon from June to September.

During December to February, the winds blow from the North-East over India and bring additional rain to Jammu and Kashmir, Northern Punjab, Assam and the coastal areas in West Bengal, Orissa, Andhra Pradesh, and Madras. This season is known as the North-East Monsoon. Only about two per cent of the total rainfall in India is received during the North-East Monsoon.

Approximately ten per cent of India’s rainfall is received during the pre-monsoon period of March to May and 13 per cent is received during the post-monsoon period from October to November (Figures 69 and 70).

AVERAGE RAINFALL

Rainfall in India varies on the average from less than five inches a year in the deserts of Rajasthan to 425 inches a year in the Khasi Hills of Assam.* At the State capitals, the least average rainfall

*An inch of rain is that amount of water received in a straight sided vessel when placed in the open. For example, during a rain, if a tin can with straight sides were placed in an open field away from trees and buildings, caught one inch of water, we may say that one inch of rain has fallen.
received is in Jaipur, Rajasthan, with 24 inches; whereas the capital receiving the largest amount of rainfall is Shillong, Assam, with 85 inches a year (Table 11).

Rainfall in India is of the monsoon type and is received mostly within the period June to September. The actual number of rainy days at the State capitals varies from 36 in Jaipur, Rajasthan, to 122 in Shillong, Assam. In general, the less the rainfall received

Fig. 69. Average dates of the beginning of the South-West monsoon in India. [Redrawn from: RANDHAWA].
Fig. 70. Rainfall in winter during the North-East monsoon.

[Redrawn from: Oilseed Atlas].
the more variable is the amount from year to year. For example, at Jaipur, Rajasthan, the least amount of annual rainfall received was five inches and the greatest amount was 55 inches a year, a variation of eleven times. On the other hand, at Shillong, Assam, the driest year received 60 inches and the wettest year 126 inches, or a variation of slightly more than two times.

**TABLE 11—RAINFALL AT THE STATE CAPITALS AND NEW DELHI**

<table>
<thead>
<tr>
<th>State</th>
<th>Capital</th>
<th>Average number of rainy days per year*</th>
<th>Rainfall during driest year (inches)</th>
<th>Rainfall during wettest year (inches)</th>
<th>Average annual precipitation (inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Andhra Pradesh</td>
<td>Hyderabad</td>
<td>50</td>
<td>18</td>
<td>56</td>
<td>29</td>
</tr>
<tr>
<td>Assam</td>
<td>Shillong</td>
<td>122</td>
<td>60</td>
<td>126</td>
<td>85</td>
</tr>
<tr>
<td>Bihar</td>
<td>Patna</td>
<td>56</td>
<td>25</td>
<td>77</td>
<td>47</td>
</tr>
<tr>
<td>Gujarat</td>
<td>Ahmedabad</td>
<td>36</td>
<td>5</td>
<td>79</td>
<td>29</td>
</tr>
<tr>
<td>Kerala</td>
<td>Trivandrum</td>
<td>97</td>
<td>40</td>
<td>120</td>
<td>67</td>
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<td>Madhya Pradesh</td>
<td>Bhopal</td>
<td>59</td>
<td>39</td>
<td>60</td>
<td>52</td>
</tr>
<tr>
<td>Maharashtra</td>
<td>Bombay</td>
<td>74</td>
<td>33</td>
<td>101</td>
<td>71</td>
</tr>
<tr>
<td>Madras</td>
<td>Madras</td>
<td>57</td>
<td>22</td>
<td>79</td>
<td>50</td>
</tr>
<tr>
<td>Mysore</td>
<td>Bangalore</td>
<td>57</td>
<td>21</td>
<td>53</td>
<td>34</td>
</tr>
<tr>
<td>Orissa</td>
<td>Cuttack</td>
<td>74</td>
<td>36</td>
<td>91</td>
<td>60</td>
</tr>
<tr>
<td>Punjab</td>
<td>Chandigarh† (Ambala)</td>
<td>42</td>
<td>14</td>
<td>81</td>
<td>33</td>
</tr>
<tr>
<td>Rajasthan</td>
<td>Jaipur</td>
<td>36</td>
<td>5</td>
<td>55</td>
<td>24</td>
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<td>Uttar Pradesh</td>
<td>Lucknow</td>
<td>49</td>
<td>17</td>
<td>74</td>
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<td>West Bengal</td>
<td>Calcutta</td>
<td>84</td>
<td>36</td>
<td>98</td>
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<td>Srinagar</td>
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<tr>
<td>New Delhi</td>
<td></td>
<td>36</td>
<td>10</td>
<td>60</td>
<td>26</td>
</tr>
</tbody>
</table>

*A "rainy day" is any day that receives one-tenth inch or more of rainfall.
† The word "precipitation" includes rainfall plus snowfall reported as "water equivalent".
‡ Although Chandigarh is the Capital of Punjab it has no weather station; for this reason the weather data are given for Ambala, the nearest weather station.

*Note: The figures for rainfall are given to the nearest inch; thus 29.4 is given as 29, and 83.6 as 84.*
On an average, 11 per cent of the land area of India receives more than 75 inches of rainfall, 21 per cent receives from 50 to 75 inches, 37 per cent receives from 30 to 50 inches, 24 per cent receives from 15 to 30 inches, and 7 per cent of the area receives less than 15 inches of rainfall a year (Figure 71).

**RAINFALL IN INDIA**

**Fig. 71. Rainfall in India (Total). [Redrawn from: Oilseed Atlas].**
CLIMATE AND SOIL

DROUGHTS AND FLOODS

Some areas in India are more liable than others to both droughts and floods. These are: Eastern and Northern Punjab, Eastern Uttar Pradesh, Bihar, Western Rajasthan, and Central Maharashtra. In these areas, a flood may be expected about once every six years and a drought once every seven years. In other words, farmers in these tracts can expect either a flood or a drought about once every three years. Farming is very hazardous because of the uncertainties of the weather; for this reason, water and soil conservation practices should be adopted.

DROUGHTS

During the past seventy-five years, droughts have occurred at an average of once every fifteen years in the following areas in India: Assam, West Bengal, Orissa, Southwestern Punjab, Mysore, the Malabar Coast of Kerala and Northern Madras State. Tracts that have had droughts at an average of once every eight years during this period are: Bihar, Uttar Pradesh, Eastern and Northern Punjab, Kashmir, Western Rajasthan, and Central Maharashtra.

FLOODS

Floods occur when rainfall is received faster than the soil can absorb it or the nalas, streams and rivers can carry it within their channels. Destruction of forests, over-grazing of grasslands and over-ploughing of croplands all contribute toward less of the rain-water moving downward into the soil and consequently more of it moving over the surface to flood nalas, streams, and rivers.

Every year many areas in India receive rainfall at a fast enough rate to cause floods. The Meteorological Department records for the past seventy-five years show that all districts in India have received rainfall with an intensity of at least five inches in twenty-four hours. The greatest intensity of rainfall ever recorded in India was forty inches in twenty-four hours at Cherrapunji in the Khasi Hills of Assam. The average annual rainfall at this station is four hundred and twenty-five inches.

During the past seventy-five years, floods have been reported in the following areas with a frequency of once every fifteen years:
West Bengal, Kashmir, and Mysore. Areas where floods were reported with a frequency of once every eight years during this period were: Orissa, Bihar, Eastern Uttar Pradesh, Punjab, Western Rajasthan, Central Maharashtra, Southern Andhra Pradesh, and Northern Madras.

**HIGH WINDS**

High winds are common in India along the coast line of the Bay of Bengal from Calcutta to Madras, and along the coast line of the Arabian Sea from Bombay to Karachi. High winds in arid areas such as Rajasthan result in serious wind erosion. The damage to farm crops caused by high winds is as follows:

1. Standing crops such as sugar cane and jowar are blown over
2. Loss of moisture from the soil is increased
3. Wind erosion may be very serious
4. The yield and quality of crops may be reduced

Standing sugar cane may be tied in bundles of four or five stalks to prevent it from being blown over by high winds. A more permanent solution to guard against wind damage is to plant a windbreak on the windward side of the field. A windbreak usually consists of a single row of fairly tall trees, and on both sides of the row, one or more rows of low-growing trees or shrubs. If possible the trees and shrubs should be evergreen so as to offer the most protection against the wind in all seasons (Figures 72 and 73).

**FROSTS**

Most agricultural crops are very easily killed by air temperatures below 32 degrees Fahrenheit (32°F.) — also written as zero degrees Centigrade (0°C.) (This is the temperature at which water freezes). For that reason it is interesting to determine the areas in India which sometimes experience air temperatures as low or lower than freezing.

The following areas have had one or more days during the past seventy-five years of weather records that have been 32°F. or below: Jammu and Kashmir, Himachal Pradesh, Punjab, Northern Rajasthan, and Delhi. These days of frost have usually occurred during
December, January, or February. In other parts of India, frosts have never occurred.

In areas that are subject to frosts there are several ways in which a farmer can avoid frost damage. They are:

1. Select crops that are not sensitive to frost, such as cabbage and cauliflower;
2. Plant sensitive crops at such a time that they will mature before the frosts usually occur;
3. Select a sloping field for crops that are sensitive to frosts, such as tomatoes and vine crops. On sloping fields the cold air moves downward to lower levels; for this reason soils on slopes are less subject to frosts;

Fig. 72. Close-up of a weather vane to show wind direction that can be made in any workshop. [Redrawn from: Mudaliar].
Fig. 73. Winds over India.

*Above:* Average wind currents over India in January during the North-East monsoon. *Below:* Average wind currents over India in July during the South-West monsoon.

*[Redrawn from: Normand]*.
4. On the coldest nights, build a temporary windbreak around the field to heat the air. An experiment at Nasik, Maharashtra, proved that with a windbreak around the field made from jowar stalks, four hundred fires per acre increased the air temperature near the sensitive crops by about 10 degrees Fahrenheit (10°F.).

5. When frost threatens to kill the crop, the immediate application of irrigation water will reduce the hazard.

SOIL

To a person not trained in agricultural science, soil is dirt on the surface of the earth. A scientist, however, knows that soil is a "living" body covering the earth, consisting of weathered rocks, organic matter, water, air, and living organisms.

Soil is the most important natural resource because it is the medium for the growth of all food and fodder crops. Soil offers mechanical support, water, and essential plant food elements for plant growth. Understanding the soil and its proper use are necessary before the soil can be made to produce luxuriant crops.

SOIL FORMATION

All soils come from rocks (Figure 74). Rocks on the surface of the earth have been torn apart by changes in temperature and dissolved by rain until they supported plant and animal life. Plants and animals worked with the forces of climate to hasten soil formation. At any one place, the particular kind of soil that has been formed depends upon the kind of bedrock, the topography, and the movement of water to carry compounds from the slowly dissolving rocks.

In other words, the hills and valleys of the Earth are acted upon by Time, with the help of the sun and the rain and the plants and animals to make soil.

As soon as rocks have been sufficiently weathered to support plant growth we can say that a soil has been formed. But as we look at soils in different places, we immediately see that soils are not all alike. Then we may wonder what makes one soil different from another. Five factors are responsible for soil formation. These are:

1. Parent material  
2. Climate  
3. Living organisms  
4. Topography  
5. Time
Nature deposited sandstone in some places and shale or limestone in other places. In yet other locations, lava from the interior of the earth slowly pushed upward, exposing granite or basalt. But whatever bedrock Nature left, weathering by rainwater and the action of plants and animals have been working for centuries to wear the rock away. Thus, we can observe that the soils which have developed from sandstone are coarse-textured and sandy. Soils from shale are clayey in texture but not very fertile. Soils that develop from granite are usually sandy loams of low fertility. By contrast, soils that have developed from limestone or basalt rock are usually dark in colour, fine in texture, and very fertile. The black clay (cotton) soils of the Deccan are an example of soils that have developed from limestone or basalt (Plate XXXV).
CLIMATE AND SOIL

CLIMATE

Imagine that a large basalt rock as big as a palace suddenly appeared above the waves in the Bay of Bengal near Calcutta or Madras or in the Arabian Sea near Bombay. Very soon after the rock was exposed to the weather, the surface would start to wear away. Changes in temperature from day to night and from season to season would break the rock into scale-like pieces. Rainwater would dissolve some of the small pieces of rocks. In some of the tiny cracks and depressions, there would soon be enough water and available nutrients to support plant life (Plate XXXII).

LIVING ORGANISMS

After water and nutrients have become available, lower forms of life, such as lichens, are among the first to grow. After many years of growth and death of these tiny plants, the environment is thereby improved to such an extent that other plants of a higher form, such as mosses, grow, reproduce and die until the organic matter from their decaying tissues helps to make a better place for the seed-bearing plants to start growing. Many annual weeds will migrate into the area, followed in a few years by grasses and shrubs; then finally a jungle (forest) will gradually dominate the vegetation on what was once barren basalt rock (Plate XXXII).

Bacteria, fungi, and many birds and other animals are constantly a part of the environment during soil formation. The seeds of the plants growing on the rock are carried there by birds and animals. Animals and plants help to break the rock into finer soil material. Of the animal life that we can see, ants and termites are always busy assisting in the continuous formation of soils from rocks. The speed of soil formation will be influenced by the amount of water held by the rock. The amount of water held will in turn be influenced by the amount of rain and by the depressions in the rock.

The chemical composition of a soil depends upon the original mineral composition of the parent material and the weathering that has taken place. For example, soils developed under a warm and humid climate contain more aluminum and iron and very little calcium (lime).

An example of the relationship between rainfall and the calcium content of the soil may be cited from Punjab. On the Hissar
Plains the rainfall averages 11 inches per year. In contrast, the annual rainfall in the Kangra Hills averages 126 inches. The content of calcium in the soils of the Hissar Plains is twice that of the soils in the Kangra Hills. Also, the grasses growing on the high-calcium soils in the Hissar Plains contain 17 per cent more calcium (lime) than those in the Kangra Hills. The high rainfall in the Kangra Hills has leached out a large amount of the calcium from the soils and as a consequence the grasses and other vegetation are low in calcium.

TOPOGRAPHY

If the same basalt boulder in the Arabian Sea or the Bay of Bengal were tilted slightly so as to permit rainwater to drain more rapidly, the time required to develop a jungle would be increased. With less water staying on the boulder after each rain, plants would grow more slowly. This would result in less organic matter being returned to the rock to help the next generation of plants. On the other hand, if the same large boulder had a slight depression in the centre so as to hold more rainwater, the process of plant growth and plant succession would be faster. In like manner when the topography is hilly, soils develop slowly, while in flatter areas, soils develop more rapidly.

TIME

The number of years required to produce a soil from rock which will support the lower forms of plants, such as lichens and mosses may be only five to ten years. However, to produce three feet of soil for farm crops from the basalt rock just mentioned, may require several thousand years. When it takes so long for Nature to make a soil from rocks, it means that if we do not take good care of the soil, there will soon not be enough to grow sufficient food and fodder crops. The result would be world starvation.

SOIL COMPOSITION

Soils are composed of minerals, air, water and organic matter. Minerals in the soil vary in size from large rocks to grains of sand to fine clay. Air and water occupy the openings or pores. The openings are made by plant roots or by animals such as earthworms; or they represent spaces between the soil particles. Cracks in the soil, caused by wetting and drying, account for many of the
Pl. XXXIII. Annual plants will grow in cracks in rocks (above), followed in a few years by woody plants (below) in the process of making soil from rocks. [Courtesy: Roy L. Donahue].
Pl. XXXIV. Organic matter is called the life of the soil.

*Left:* Soil from a field that has been planted continuously to row crops for 40 years.

*Right:* Soil from a nearby field that has had a good crop rotation, including green-manuring crops. Note the darker colour of the soil and the many roots present.

*[Courtesy: U. S. Soil Conservation Service]*.
Pl. XXXV. *Black Soils* have an accumulation of lime (white layer at bottom) at variable depths. The area receives 30 inches of rainfall a year (Maharashtra State). [Courtesy: ROY L. DONAHUE].
Pl. XXXVI. *Forest and Hill Soils* are rich in organic matter on the surface. They occur mainly in areas of high rainfall; in this instance the area receives 60 inches of rain a year (Kerala State). [Courtesy: Roy L. Donahue].
openings. Organic matter is the food for life in the soil. Even the dead remains of plants and animals contain living bacteria and fungi. Plant roots, worms and insects such as ants are also a part of the living organic matter in the soil.

MINERAL MATTER

Soils are mostly mineral matter that came from rocks. Therefore, soils formed from different rocks contain different minerals according to the chemical composition of the parent rock. The individual soil particles are in various stages of disintegration and are of different sizes. The relative sizes of the particles in a soil is referred to as soil texture. After taking out the very coarse material, the remaining material can be separated according to size and classified into the three main groups called sand, silt, and clay.

Sand particles originate mainly from quartz and from other minerals that break down very slowly. Sand grains contain very few mineral plant food elements that are required for plant growth. Sand increases the space between soil particles and therefore permits a freer movement of water and air throughout the soil.

Silt particles are derived mainly from quartz and feldspar minerals. The feel of the silt particles is like flour. Silt particles are better suppliers of mineral nutrients than sand particles, since they are smaller and are in a more advanced stage of weathering.

Clay particles are very small and are derived mainly from feldspar minerals. They influence the physical and chemical properties of the soil to a very great extent. The clay particles serve as the principal godown (storehouse) for plant food elements such as calcium, magnesium, and potassium.

SOIL WATER AND SOIL AIR

Even compact soils have some space inside each soil granule and between the granules. This space is called pore space. The pore space is occupied by water and air in varying proportions. After rain, almost all of the pore spaces are filled with water. In a few days, part of the water is lost by percolation, part by evaporation, and a part by uptake and transpiration by plants. As water disappears, air occupies the pore spaces formerly occupied by water. Another shower of rain and the process is repeated. A soil in good condition
for plant growth will have half of the pore spaces filled with water and the other half filled with air.

The source of soil water is natural precipitation. Some portion of the rainwater enters the soil and the rest is lost to the streams in the form of surface run-off. The portion that enters the soil is called soil water. The soil water influences the root system of plants (Figure 75).

The soil air consists of the same gases as that of the atmosphere but soil air contains more carbon dioxide, more water vapour, and less oxygen. However, the composition of soil air is always changing. The proper balance between soil water and soil air is essential for the proper growth of plants. Irrigation, drainage, tillage, and rainfall are the principal factors which determine the proportion of the pore spaces that are filled with water and air.

**ORGANIC MATTER**

Some soils contain large amounts and some small amounts of organic matter. The accumulation of organic matter in the soil started when the first vegetation grew, died, and decayed in the soil. The main source of soil organic matter is plant residues, although animal residues also contribute some organic matter to the soil.

Organic matter influences the physical, chemical, and biological properties of the soil. Without organic matter the soil would be a dead mass of debris, since there would not be any activity of the micro-organisms. Organic matter supplies food for almost all micro-organisms and for this reason organic matter is called the *life of the soil*. Organic matter improves soil structure, increases the water-holding capacity of sandy soils, and increases the pore spaces of clay soils. Organic matter also imparts a dark colour to the soil.

Organic matter is the main storehouse of nitrogen. Small amounts of all other plant nutrients are also supplied when organic matter decomposes.

Virgin soil contains more organic matter than a soil which has been cultivated. Cultivation hastens the decomposition of organic matter and for that reason there is always less in cultivated soils. Virgin soils under grass vegetation usually contain more humified organic matter (humus) than virgin soils under jungle vegetation. Also it is true that virgin soils in a warm climate contain less organic matter than comparable soils in a cool climate.
Fig. 75. Root development of wheat in relation to the average annual rainfall received.

Left: Wheat grown where the rainfall was 30 inches. Middle: Wheat grown where the rainfall was 25 inches. Right: Wheat grown where the rainfall was 20 inches.

[Redrawn from: Weaver].

As soon as grass land or jungle land is ploughed, the decomposition of organic matter is hastened. With continuous tillage, the percentage of organic matter continues to decrease. The organic matter content of cultivated soils in India is very low and it is difficult to increase it because of the subtropical conditions and excessive tillage of the land. But even though it is difficult to increase the organic matter content of the soil, every effort should be made to add green-manure crops, compost, and farmyard manure because this practice increases crop yields (Plate XXXIV).

SOIL ORGANISMS

Some soils are very rich in living organisms. They contain animals such as rodents, insects, and earthworms, and various lower forms
of plant life such as algae, fungi, and bacteria. Some organisms are useful while others are harmful to plant life. The harmful insects and micro-organisms attack living plants and live on them. The useful micro-organisms are those which attack the plant residues and release the plant food material in simpler forms for use by the farm crops. For instance, owing to the decomposition of organic matter by micro-organisms, nitrates, sulphates, and phosphates are released from the organic matter and can be utilized for plant growth.

Other useful micro-organisms are those which fix atmospheric nitrogen. Some bacteria are capable of utilizing atmospheric nitrogen for building their body proteins. As these bacteria die, the fixed nitrogen becomes available for the growth of crop plants. Some of these bacteria work independently while others work in association with higher plants. Accordingly they are called non-symbiotic or symbiotic bacteria. Non-symbiotic bacteria work independently of crops whenever the proper soil moisture, temperature and nutrient conditions exist. Symbiotic bacteria live in the nodules on the roots of legumes such as lucerne and gram and combine the atmospheric nitrogen in a form which is useful to itself, the host plant, and to the crops which are grown later on the same soil (Figure 76).

SOIL GROUPS IN INDIA

The main groups of soils that are commonly recognized in India are as follows:

- Red soils
- Laterite soils
- Black soils
- Alluvial soils
- Forest and Hill soils
- Desert soils
- Saline and Alkaline soils
- Peaty and Marshy soils

RED SOILS

The red soils in India comprise almost the entire States of Madras and Mysore, and South-East Maharashtra, Central Andhra Pradesh, Southern Madhya Pradesh and Western Orissa. Most red soils are sandy loam or sandy clay in texture, low in lime (kankar), and red in colour on the surface. They are usually deficient in nitrogen, phosphorus, lime and organic matter but very responsive to good
Fig. 76. Soon after a legume (pulse) plant germinates, nodules form on the roots in which *symbiotic bacteria* enrich the soil by using and storing nitrogen from the air. The plant shown is Bengal gram.

[Redrawn from: Narayanan].
soil management practices, including the use of irrigation, green-
manure crops, farmyard manure and fertilizers.

LATERITE SOILS

Laterite soils are common on the tops of low hills in Western Andhra Pradesh, Mysore, Kerala, Southern Maharashtra, Madhya Pradesh, Orissa, and Assam. The soils are porous but rock-like. In places the laterite soil is cut and used as building stone. Laterites are red in colour and low in nitrogen, phosphorus, potassium, and lime.

BLACK SOILS

The black soils are located mainly in Maharashtra, Madhya Pradesh, Western Andhra Pradesh, and Southern Madras. They are mostly clay soils that form deep cracks during the dry season. An accumulation of lime is nearly always present at varying depths. Black soils usually respond to application of nitrogen and phosphorus fertilizers and to addition of farmyard manure and green-manure crops. Sometimes they are called "black cotton soils" because cotton is frequently grown on them (Plate XXXV).

ALLUVIAL SOILS

Alluvial soils occur in all States along rivers and represent the soil materials that have been deposited by the rivers when they are in flood (spate). They are variable in composition but are usually the most productive soils in any region. Nitrogen is nearly always lacking and often crops also respond to phosphorus fertilizer. Rice, sugar cane, and wheat are the main crops grown on alluvial soils.

FOREST AND HILL SOILS

Forest and hill soils occur at high elevations as well as at low elevations where the rainfall is sufficient to support trees. Approximately 17 per cent of India is occupied by these soils. Most of the forest and hill soils are too shallow, too steep, too stony, or too infertile to be used for the production of field crops. This group of soils serves a very useful purpose by supplying forest products
CLIMATE AND SOIL

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such as lumber and fuel, and by serving to protect hilly soils from erosion (Plate XXXVI).

DESSERT SOILS

Desert soils are mostly sandy soils that occur in the low rainfall tracts of Rajasthan and Punjab. The soils are well supplied with soluble salts (sometimes in excess), and are low in organic matter. Some of the soils are low and some are high in lime. Desert soils are often quite productive when irrigated. Without irrigation the soils are sometimes blown about by the wind, often covering roads, railways, and buildings (Plate XXXVII).

SALINE AND ALKALINE SOILS

Saline (salty) and alkaline soils occur in areas having slightly more rainfall than desert soils. The semi-arid areas of Bihar, Uttar Pradesh, Punjab, and Rajasthan are characterized by saline and alkaline soils. Such soils must be provided with adequate drainage when they are irrigated; if not, the salts accumulate to a degree where no crops can be grown (Plate XXXVIII).

PEATY AND MARSHY SOILS

Peaty and marshy soils, occurring mostly in Kerala and Bihar, are formed by plants growing in wet places. Upon the death of the plants they do not decompose (rot) rapidly because of excess water. After several hundred years, a layer of partly-decayed organic matter accumulates on the surface. Low-lying areas bordering the Arabian Sea and the Bay of Bengal commonly develop peaty and marshy soils. When properly drained and fertilized, these soils often produce very good crops of rice.

SUMMARY

To be successful, the farmer must adjust the time of ploughing, sowing, fertilizing, and harvesting to the weather. The South-West monsoon, from June to September, brings about 75 per cent of all rainfall received in India. Rainfall averages from less than five inches a year in the desert of Rajasthan to more than 425 inches in
the Khasi Hills of Assam. In any one year, both droughts and floods occur in some districts in India.

Soils have been formed from rocks by the action of climate, plants, and animals, and influenced by topography and time. The soil groups recognized in India are red, laterite, black, alluvial, forest and hill, desert, saline and alkaline, and peaty and marshy.

QUESTIONS

1. Why must the farmer adjust his farming operations to the weather? Name one specific example.
2. What is the primary source of moisture during the South-West monsoon?
3. What is the rainfall situation in your State Capital?
4. Name the five factors of soil formation.
5. Describe the Soil Group in the tract where you live.

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Chapter 10

SOIL AND WATER CONSERVATION AND DRY FARMING

There is barely enough productive land in India to provide adequate food, feed, and fodder for the people and the livestock.* Because of this pressure on the land, most of the soils have been over-cropped and over-grazed, and the trees and shrubs over-cut. Too little of the vegetation has been allowed to remain as a protective blanket to cushion the blow of the falling raindrops and the scouring action of the surface run-off water; the result is severe soil erosion, less available water for the growth of crops, and a continuously decreasing productivity of India’s soils (Plates XXXIX and XL and Figure 77).

The Central Soil Conservation Board estimates that two of every three acres of India’s crop lands are eroded and in immediate need of soil and water conservation practices. This is especially serious because these three acres must produce enough food for three people and most of the feed and fodder for three domestic animals. With excellent management, India’s most productive soil may yield enough food and feed to achieve the target; but when two-thirds of the crop land has been made less productive by erosion, the goal of self sufficiency will be very difficult to achieve. One partial solution to the problem is to improve soil and water conservation practices (Plate XLI).

National and State schemes alone, no matter how well-financed, cannot adequately solve the serious problem of soil and water

*The pressure of people on the land may be judged from the fact that in 1956 the average density of population in India was 285 persons per square mile, varying from 48 in Kashmir to 928 in Kerala. The total land per person in India averaged 2.2 acres, while the crop land per person was 1.2 acres. The pressure of livestock on the land was evidenced by the fact that the number of head of livestock per acre of total land area in India was 0.4; the livestock per acre of grassland was 11.0; and the number of livestock per acre of crop land was 0.8.

Although complete data were not available in 1962, the population since 1956 had increased from about 357 million to about 440 million persons, and with very little increase in total crop land. The pressure of people on the land, therefore, continues to increase.
Fig. 77. Models to illustrate the influence of bunds and grass on the control of soil erosion. The bare soil on the left is bunded, the soil in the centre is covered with grass, while the soil on the right is bare with no bunds. Water can be added from a sprinkling can to simulate rain. [Redrawn from: Evans].

conservation; nor can the cultivators alone work effectively. The responsibility is a triangular one with three segments; the Central Government to lead in conservation education and to work on major watersheds (catchments) that involve more than one State; the State Governments to develop conservation works that lie wholly within their own States; and the cultivators and landowners to cooperate with the Central and State Governments in the establishment and maintenance of soil and water conservation practices such as bunding, irrigation, drainage, strip cropping, contour tillage, proper grazing management, effective cropping systems, and recommended management of the forests (Plate XLII).

DEFINITION OF SOIL CONSERVATION

J. C. Ghosh, a Member of the Planning Commission, Government of India, has given a good definition of soil conservation:

Soil conservation is not merely fencing, contouring, strip-cropping, filling gullies, or planting steep or erodible land to grass and trees; it means drainage if the land is too wet, and irrigation if it is too dry. It means addition of fertilizers and organic matter
to soil which is impoverished of these constituents. It is all these, and whatever else needs to be done to keep the soil... permanently productive.*

CAUSES OF SOIL EROSION

Soil erosion is the movement of soil from one place to another by the action of water or wind.

Water erosion starts when beating raindrops strike bare soil and churn it into flowing mud. The muddy water tries to soak downward through the natural cracks in the soil but cannot do so because the mud seals the cracks. There is no other place for the muddy water to go but to flow over the surface of the soil, scouring rills and gullies as it moves down the slope towards the small streams (nalas) and rivers. The scouring and erosive action of the muddy water continues as long as the amount of water is great and the slopes are steep.

As soon as the volume of water is lessened and the slopes become more gentle, a large part of the mud (silt) settles out and is deposited in the bottoms of nalas and in the quiet waters of lakes and reservoirs. As a result, the fertile top soil is lost from the bare fields and poorly managed grasslands and forests, nalas and river beds are choked with sediment; and the useful life of lakes and reservoirs is greatly reduced.

Wind erosion starts when bare sandy soil becomes dry and high winds roll the sand grains over each other, resulting in shifting sand dunes. During dust storms the finer particles of silt may be picked up by the wind and carried for miles. The results are a depletion of the soil, a covering up of good farm land by worthless sand, and menacing dust storms.

KINDS OF SOIL EROSION†

Water and wind moving across the surface of the soil always carry away some of the soil.

If the erosion processes remove top-soil only as rapidly as top-soil is formed from the parent material beneath, no harm results. This is geological erosion. But man has cut too much jungle, grazed the grasses excessively, and ploughed the land too often. These activities have laid bare the formerly protected soil and exposed it to beating raindrops and angry winds. The result was a removal of the top-soil faster than it was being made. This is man-made erosion and may be classified into water erosion and wind erosion.

**WATER EROSION**

Water erodes soil mainly in two ways:
1. By the violent splash of the falling raindrop on bare soil.
2. By the scouring action of soil-laden water moving down the slopes.

Falling raindrops splash soil in the same manner that a rock will splash in a pool of water. Raindrops fall at a speed of about twenty miles per hour. A single raindrop may splash wet soil as much as two feet high and five feet from the spot where the raindrop hits. Continuous bombardment in a rainstorm by thousands of raindrops causes damage by beating the bare soil into flowing mud. This flowing mud moves into and seals the worm holes, root channels, cracks, and larger soil pores. Movement of water downward into the soil is thus retarded. This means that during rain, as less water enters the soil more of the rainfall moves over the surface, carrying soil particles with it.

Movement of soil by raindrop splash erosion is the primary cause of sheet erosion. By sheet erosion is meant the removal of soil in a more or less continuous, thin sheet over the surface of the soil. This type of erosion is usually so slow that the cultivator is seldom conscious of its existence.

*Rill erosion* takes place when run-off waters laden with splash erosion sediment concentrate in many channels to form streamlets. Such streamlets cut incisions into the face of the earth, just as a cat claws the back of your hand and leaves scratches (Plate XLIII).

Greater concentrations of soil-laden water will move even larger amounts of soil, soon resulting in gully erosion. Gullies often start along bullock cart tracks, livestock trails, footpaths, or burrows of animals. Gully erosion is much more spectacular than either sheet or rill erosion. Continuous exposure to beating raindrops and to
the cutting action of muddy water produces deeper and deeper gullies, thus completely destroying the land for any productive use.

WIND EROSION

Along sandy seashores, sand dunes are evidence of geological wind erosion. Further inland, wind erosion is evidence of poor land use. Sandy soils from which the vegetative cover has been over-cut, over-grazed, or over-ploughed soon dry out and are subject to blowing by the wind.

When the original grass sod was ploughed in preparation for growing farm crops, many grass roots bound the soil particles together. As the roots decayed and the soil surface became dry, sandy soils were shifted about by the wind, especially during droughts which were accompanied by high winds.

As the wind increases in drying power and velocity, deeper layers of soil are “sucked” dry. Water which formerly helped to bind the soil particles together is lost rapidly by evaporation. The result is a sorting action of the wind which:

1. Picks up the finer and more fertile silt particles and moves them many miles as clouds of dust;
2. Rolls and hops coarser sand particles and certain clay granules along near the surface. These particles lodge against clumps of grass, crop residues or fence rows, and momentarily come to rest.

RESULTS OF SOIL EROSION

Erosion causes a loss of productive top-soil, a deposition of infertile sand on productive fields, a silting of reservoirs, and a lowering of the ground-water table. Each kind of damage will be briefly discussed.

1. Washing away of productive soil. The top-soil is the most important soil layer for crop growth because most of the plant roots are in this layer. When the top-soil has been washed away, the sub-soil is less fertile and more cloddy — making it both more difficult and more expensive to raise satisfactory farm crops.
2. **Deposition of sand on productive fields.** In the downstream areas there is always a danger of the fertile fields being made unproductive by being covered with coarse material brought down the hill by running water. In areas of wind erosion, infertile sand dunes frequently cover productive soil and make it useless for further crop production.

3. **S muling of lakes and reservoirs.** Reservoirs are constructed to store the rainwater for later use for drinking, the generation of electricity or for irrigation. In the catchment (watershed) area, if soil erosion is allowed to go unchecked, the reservoirs and lakes become filled with soil, thus reducing their storage capacity and their useful life.

4. **Lowering of the underground water-table.** As the surface run-off increases, the quantity of water available for entering the soil is decreased. Less water moving downward by percolation means a smaller supply of water to replenish the ground-water in wells. With less water in wells, irrigation is reduced, and crop yields decline (Plate XLIV).

**CONTROL OF WATER EROSION**

The soil is most susceptible to erosion when the fields are bare of vegetation. Soils low in organic matter, low in fertility, and poor in soil structure are more easily eroded than those high in organic matter, fertile, and having a desirable soil structure.

When grasses and legumes secure a foothold, the soil is held in place by the network of roots. Old roots die and new ones take their place. A part of the roots and a part of the tops from grasses and legumes remain to form organic matter in the soil. This improves the organic matter status, the physical condition of the soil and ultimately increases soil fertility. Thus the soil is protected from beating raindrops and erosive action of surface water by being covered with grasses and legumes, both living and dead. Because of these characteristics, grasses and legumes are some of the best agents in controlling soil erosion.

Soil erosion caused by running water can be effectively controlled by increasing soil fertility, using sod-forming crops, contour

cultivation, strip cropping, contour bunding, and by the reclamation of gullies.

INCREASING SOIL FERTILITY

Good root growth and protective cover reduce the harmful dispersive action of beating raindrops. The more fertile the soil, the more luxuriant the plant growth and the better the soil is protected against soil erosion.

One of the best ways of increasing soil fertility is to first have the soil tested. Based upon these tests, fertilizer recommendations will be made, which, if followed, will result in larger crop yields with a minimum expenditure for fertilizer. The final result will be higher crop yields as well as more effective erosion control.

USING SOD-FORMING CROPS

Sod-like crops, such as grasses, *sannhemp*, lucerne, berseem clover, or groundnut offer excellent soil protection against erosion by water. Such crops are effective primarily because they provide a cushion against which the raindrops break their fall and thus gently soak into the soil. Such crops also effectively protect the soil against erosive winds because of their binding action.

The denser the vegetation the more effective is the cushioning effect. Close-growing crops also help to control erosion by providing root channels through which water moves downwards more freely. In addition, plant roots aid in making a desirable soil structure which does not “melt” during rain. A final reason why crops aid in soil erosion control is that crops encourage the growth of earthworms and other desirable forms of soil life. Because of the holes they make these animals help to keep the soil open and receptive to raindrops.

To be effective in controlling erosion, the vegetation must be very dense at the time of the greatest erosion hazard. For example, at the Research Station in Sholapur, Maharashtra State, most of the water erosion occurs when the soil is bare during the monsoon period of August and September. Crops that are close-growing and luxuriant during this period are therefore ideal to use in the control of water erosion. Two such crops that are effective in the 24-inch rainfall belt of the Sholapur District are groundnut and wild hulga
(Atylosia scarabaeoides). Wild hulga is a leguminous vine which is native to the region (Plate XLV).

The use of sod-forming crops in a cropping system are necessary for effective control of soil erosion. An example may be cited from the results of ten years of research at Sholapur. The order of effectiveness of the cropping systems in controlling soil erosion were as follows, from the most to the least:

Native grasses, not cut
Groundnut
Fallow (no crop)
Native grasses (cut)
Bajra — tur (kharif) (Summer)
Jowar (rabi) (Winter)

It may be noted that rabi jowar, the most common cropping system in the area, is the least effective in controlling erosion because it does not grow during the monsoon period of August and September when most of the erosion occurs.

CONTOUR CULTIVATION

All tillage operations and the sowing of crops should be done at right-angles to the slope of the land. Contour tillage helps in creating obstructions to the flow of water above every furrow and in a more uniform distribution of water. The result is more infiltration of water, less run-off and erosion, more water in the soil available for plant growth, and higher crop yields. For example, in 1953 at the research station in Rehman Khera, Lucknow District, Uttar Pradesh, sugar cane planted on rows up and down the slope resulted in five times more runoff water and twelve times more soil erosion than a similar plot where the rows were on the contour. In addition, the sugar cane yields were two and a half times greater when grown on contoured rows (Plate XLVI).

STRIP CROPPING

Strip cropping consists of growing erosion-permitting and erosion-resisting crops alternately in strips across the slope and on the approximate contour. In this system, the crops such as groundnut and soya bean are included as erosion-resisting crops, and jowar and
Pl. XXXVII. Desert Soils are formed in arid regions and are often quite productive when irrigated. This soil was developed under 15 inches of annual rainfall in Gujarat State. [Courtesy: George Flinger].

Pl. XXXVIII. Saline and alkali soils occur in semi-arid and arid regions and are not productive unless reclaimed. [Courtesy: H. R. Arakeri].
Pl. XXXIX. Most of India's grasslands have been overgrazed until their productivity has been almost destroyed. When the productive grasses are gone the results are soil erosion and a greater loss of water by runoff. [Courtesy: H. R. ARAKERI].

Pl. XL. One way to improve overgrazed grasslands is to regulate grazing and to build contour trenches (bunds) for the purpose of encouraging more rainwater to move into the soil. [Courtesy: H. R. ARAKERI].
bajra as erosion-permitting crops. They should be grown in alternate strips so that soil that has been eroded from the erosion-permitting crops will be caught by the strip of erosion-resisting crops.

At the Soil Conservation Research Station, Sholapur, Maharashtra State, strip cropping bajra and tur (both erosion-permitting crops) with groundnut (an erosion-resisting crop) reduced the soil erosion losses to approximately half and has given an additional yield of about five hundred pounds of groundnut pods per acre (Plate XLVII).

**CONTOUR BUNDING**

Contour bunding is very effective in checking erosion in fields. If breaching is to be avoided the bunds should be built with a gentle fall along their water channels. Waste weirs (outlets) should always be provided to avoid breaching. In Maharashtra State, large-scale bunding works have been carried out. Bunding has been moderately successful in sandy and loamy soils but not successful in deep black clay soils. In low rainfall areas approximately a twenty-five per cent increase in crop yields can be expected following bunding (Plate XLVIII).

One of the greatest difficulties with the use of bunds is that they often break (breach). A broken bund is worse than no bund at all because of the erosive action of the water that has been concentrated behind the bund. Bunds may breach for any of the following reasons:

1. The rainfall may come with a greater intensity than that for which the bunds were designed;
2. The soil in a low place in the bund may become saturated and the bund therefore weakened;
3. The intentional breaching of the bund by ryots (cultivators) to drain stagnant water;
4. Rat and other rodent holes in the bund;
5. Cattle, sheep, or goat trails across the bund;
6. The crossing of the bund with bullock carts, automobiles, or lorries.
7. Ploughing too close to the bund and thus weakening it;
8. Lack of periodic maintenance of the bunds (Figure 78).
Fig. 78. Bunds will be maintained properly only when the villagers make them and understand the useful purpose they serve in soil and water conservation. [Courtesy: Roy L. Donahue].

RECLAMATION OF GULLIES

Gully control is necessary in order to prevent complete destruction of cultivated lands and grasslands. In the first place, water now flowing into the gully should be diverted by means of a graded bund built above the head of the gully. The second step is to build several obstructions in the gully such as sod, brush or rock dams (Figures 79 to 81 and Plate XLIX). Next, the steep sides and head of the gully should be sloped and the loose soil put above the dams. Some type of vegetation such as fast-growing trees, grasses, or vines, should be planted in the loose soil above the dams and around the head of the gully. The vegetation should be protected from livestock. If the soil is not fertile, manure, compost, or commercial fertilizers must be added to increase the growth of the vegetation. When the vegetation has become well-established, the diversion bund at the head of the gully can be broken to allow the water to flow down the protected gully.
Fig. 79. Gully control with the aid of a loose rock dam. The rocks should extend a foot or more into the embankment and the centre of the dam must be the lowest part to permit water to flow over the stones and not around the ends of the dam. [Redrawn from: USDA Handbook No. 61, 1954].

Fig. 80. Gully control by means of sod strips across the gully. The centre of the sod strips should always be low for water to flow over them. [Redrawn from: USDA Handbook No. 61, 1954].
CONTROL OF WIND EROSION*

A large part of the present desert in Rajasthan was once a fertile land irrigated by many rivers. Because of the continuous destruction of the trees, shrubs, and grasses, a large area of land once held in place by vegetation is now a desert where dry winds often blow sand about frequently covering buildings and railway lines.

The Western and Northern Railways and the Desert Afforestation and Soil Conservation Station at Jodhpur, Rajasthan,† developed a

† In 1959, renamed the Arid Zone Research Station.
scheme for stabilizing the shifting sand along the railway track. In 1954 several kinds of trees and shrubs were planted, and the area was fenced with a five-foot high thorn brush fence to keep stray animals from destroying the vegetation before it became established. Brush was also laid on the surface of the soil in lines four feet apart and at right angles to the prevailing dry-season winds.

Trees and shrubs which were planted with success were:

_ Jand (khejri) (Prosopis spicigera), mesquite (Prosopis juliflora), babul (kikar) (Acacia arabica), tamarix (Tamarix articulata), neem (Azadirachta indica), pipal (Ficus religiosa), kumat (Acacia senegal), ber (Zizyphus jujuba), phog (Calligonum polygonoides), anwal (Cassia articulata), and khimp (Leptadenia spartium) (Plate L)._

The average cost of fencing, laying brush, and planting trees and shrubs was Rs. 2,500 per mile per year for the first two years. The maintenance cost for each year thereafter was estimated at Rs. 1,000 per mile. The cost of establishing trees and shrubs along the railway to prevent the sand from covering the track averaged less than half of the cost of removing the sand from the track. In addition, the trees and shrubs now serve as a source of fodder and fuel.

**PRACTICAL RESULTS OF SOIL AND WATER CONSERVATION**

Near Patiala in Punjab, soil conservation measures were started in 1936 and by 1947, about 400,000 acres of land had been properly treated. The conservation measures included:

1. Controlled grazing by livestock;
2. Planting trees;
3. Contour trenching on the gentle slopes;
4. Check dams in the gullies, _nalas_and streams.

As a result of the conservation practices, the water table, which had been previously falling by about nine inches a year, was now rising by about six inches a year. Wells which had gone dry were now supplied with water. Soil erosion sediments which had been choking the rivers and reservoirs, now remained on the hillsides where they produced useful trees, grasses and farm crops.*

"Dry Farming" is a term used to indicate a system of crop production without irrigation in areas of low rainfall. Usually such areas in India receive from 20 to 40 inches of rainfall a year.

The main problem in producing rain-fed crops in semi-arid regions is that of conserving the precious rainfall. An associated problem is one of controlling soil erosion. Both of these problems are related because the less the total rainfall received, the more uncertain and uneven it is received. Both torrential rains and droughts at irregular intervals are common in semi-arid regions where dry farming methods are practised.

Recommended practices in a successful dry farming system of agriculture include the following:

1. Selection of the proper land for different dry crops; for example, a deep, black soil, rich in humus for jowar (Figure 82);
2. Contour bunding to control rainwater run-off and to reduce erosion;
3. Contour cultivation to absorb more rainwater and to reduce erosion;
4. Use of seed of adapted crop varieties;
5. Adoption of a lower seed rate per acre and a wider spacing of crops;
6. Manuring, composting, and fertilizing to improve soil structure, increase infiltration of water and to supply plant food;
7. Practising contour strip-cropping by growing erosion-resisting crops such as groundnut and erosion-permitting crops such as jowar in alternate strips to check run-off water and soil loss;
8. Fallowing and rotating crops such as cereal crops and legumes one year and no crop the second year to increase soil moisture and fertility.

In 1957 the Desert Afforestation and Soil Conservation Station was established at Jodhpur, Rajasthan. With United Nations assistance the station was strengthened in 1959 and renamed the Arid...

Zone Research Institute. Many problems of dry farming are investigated.

Intensive research on dry farming and soil conservation has been conducted at Sholapur in Maharashtra State, Hagari, Bijapur, and Raichur in Mysore State, and Rohtak in Punjab, under a coordinated scheme for dry farming research sanctioned by the Indian Council of Agricultural Research during the years 1933–43. In Maharashtra State, work has been continued even after the termination of the scheme and valuable data have been collected. Similar research in dry farming has also been undertaken at Viswa Bharati in West Bengal, Saurashtra in Gujarat and in Vindhya Pradesh (now in Madhya Pradesh).

**SUMMARY**

There is barely enough productive land in India to provide adequate food and fodder. Approximately two of every three acres have been impoverished by erosion. Geological erosion cannot be stopped but man-made water and wind erosion is within man's control.

Water erosion may be controlled by increasing soil fertility, using sod-forming crops, contour cultivation, strip cropping, contour
bunding, and gully reclamation. Wind erosion may be controlled by laying brush on the surface of the soil and planting adapted trees. Dry farming refers to a system of farming without irrigation in areas of low rainfall. Contour bunding, selection of erosion-resisting and drought-resisting crops, and contour strip-cropping are the recommended measures for dry farming regions.

QUESTIONS

1. How serious is erosion in India?
2. Define soil conservation.
3. Describe in detail one good control measure for soil erosion.
4. How may wind erosion be controlled?
5. What are the practices recommended for the dry farming regions?

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Chapter 11

TILLAGE AND WEED CONTROL

The primary reasons for tilling the soil are to obtain a good seed bed for the growth of crop plants, to control weeds, and, to some extent, to control insects and diseases. A good seed bed is one that will permit the seeds of the planted crop to germinate, grow, and produce the maximum yield. A desirable seed and plant bed is one that is moist, finely granular, firm, and at least three feet deep to a restrictive layer such as a hard layer or bedrock.

Weeds and certain insects and diseases may be controlled by timely tillage. To effectively control weeds by tillage, the plough or the harrow must be used when the weeds are no more than one inch high.

Many insects live either in the soil, in plant residues, or in weeds. The stem borers, grasshoppers, and cut-worms, all live in the soil during a part of their life cycle. Similarly, some of the disease-causing organisms live on weeds and plant residues. Tillage operations destroy the weeds which serve as host plants of certain insects and diseases; as a result of weed destruction, many insects and diseases are also destroyed. Tillage exposes the soil and plant residues to the drying action of the sun and the wind, resulting in the destruction of certain insects and diseases. By tillage, insects are exposed to the attack of birds and are thus destroyed.

PLoughING

Primitive man first developed a plough to stir the soil (Figure 83). A modern plough opens and pulverizes the soil and covers plant residues; as a result the physical, chemical, and biological properties of the soil are improved. For these reasons, ploughing is considered necessary, although it is realized that it is the most labour-consuming and expensive tillage operation on the farm, accounting for about one-third of the cost of growing a crop. In recent times, however, it has been demonstrated that on some soils ploughing is not necessary before every crop.

The question of whether the land should be ploughed prior to each crop has to be decided after taking into consideration the
Fig. 83. Primitive man tilled the soil the best way he could for the purpose of raising more food per acre. [Courtesy: H. R. Akere].
TILLAGE AND WEED CONTROL

previous crop, the crop to be grown, the number and kinds of weeds, the soil, and the climate.

New and uncultivated land cannot be satisfactorily brought under cultivation without ploughing. If the previous crop was sugar cane, lucerne, or any other crop that forms a heavy stubble or sod, the land cannot be prepared for most crops that follow without ploughing (Plate LI). Similarly, to prepare land after the harvest of thick stands of jowar or maize, ploughing is considered necessary to destroy the stubble. After the harvest of crops such as pulses, bajra, Irish potatoes, cotton, or groundnut, the land can usually be prepared for the next crop without ploughing (Plate LII).

The crop for which the land is to be prepared also determines to a great extent whether ploughing should be done, and if so, to what depth. Some crops require a loose seed bed and others require a firm seed bed. Some of the crops remain in the soil for a long time and others for only a short period. For crops such as sugar cane or lucerne which remain in the soil for a long time and are irrigated, it is essential that the land be ploughed to a good depth. For root crops such as ginger, turmeric, sweet potato, and Irish potato, a loose seed bed is required and therefore ploughing is usually a necessity. In the process of preparing land for irrigation, the soil must be ploughed many times. For dry-land crops, if the land is not infested with weeds it may be prepared without ploughing. Crops such as bajra, wheat, and jowar, require a firm seed bed, and therefore ploughing may not be necessary.

Ploughing, especially deep ploughing, is often necessary for the control of certain deep-rooted weeds such as kans grass. But recent experiments in the U.S.A. and in India have demonstrated that with the proper use of chemical weed-killers, ploughing and cultivation are not needed as often. Many successful crops of maize in the U.S.A. have been produced with only one ploughing and one cultivation each year.

Deep, black, clay (cotton) soils that crack deeply are said to plough themselves. Therefore, in such soils it has been observed that ploughing may not be necessary every year. Even in the medium-textured black soils such as loams, experiments at Poona (Maharashtra State) have shown that ploughing may not be necessary every year if the land is not infested with weeds.

Poorly drained, fine-textured soils such as clays, need ploughing to improve the aeration. In such soils, the availability of nitrogen,
Fig. 84. Deep ploughing to control deep-rooted weeds such as *kans* grass, and deep ploughing to deepen the seed and plant bed are possible only with the use of a wheel tractor (*above*) or crawler tractor (*below*).

*Above: Courtesy: Ford Motor Co.*

*Below: Courtesy: Caterpillar Tractor Co.*
phosphorus, and potash may increase as a result of ploughing. In coarse, sandy soils, ploughing may not be necessary to improve soil tilth. In arid regions, ploughing may actually be harmful because it hastens the loss of soil moisture by evaporation.

Some soils in India have responded to deep ploughing. The results of an experiment conducted from 1948 to 1958 at the Anand Agricultural Institute in Gujarat State, showed that the yield of bajra was increased by thirty-five per cent by tractor-ploughing 14 inches deep, as against ploughing with the common Indian wooden (desi) plough to a depth of four inches (Figure 84 and Plate LIII).

Experiments in many semi-arid regions of the world have shown that it is better to leave crop residues mixed with the surface soil rather than to turn them under. Crop residues reduce water and wind erosion, prevent the destruction of desirable soil structure due to beating raindrops, and reduce the loss of surface run-off water. Therefore, loosening the soil without any turning action, and mixing crop residues and weeds with the surface soil are recommended for many semi-arid zones. However, in the humid areas the results of experiments conducted in the United States of America and in India show that ploughing with a mouldboard plough gives better yields of maize as compared to other methods of preparatory tillage (Figures 85 and 86).

**PREPARING THE SEED BED**

The seed bed is usually prepared by ploughing, crushing the clods, levelling the land, compacting, and harrowing.

To get the maximum benefit from ploughing, it should be done just after the harvest of the previous crop. This is the best time for the operation because the plough pulls easier, very few clods are formed, the residues of the previous crop are destroyed, and the tilth of some soils is improved because the soil is exposed to the sun’s heat. Some lands may get hard immediately after the harvest of the crop; such lands should be ploughed after the first rains have been received.

Ploughing leaves the land cloddy, loose, and uneven; and therefore not in proper tilth to receive the seeds of crop plants. To bring the soil to a good tilth, it is necessary to work the soil with a number of other tillage implements. In short, the objectives of tillage after ploughing is to prepare a good seed bed that is firm underneath
with a loose, friable, fine-granular structure on the surface. Such seed beds resist washing away of soil, permit easy penetration of rainwater, and do not form a hard surface crust after a rain. A well-prepared seed bed facilitates quick germination of seed and provides a good medium for the growth of plant roots.

Clod crushing is not always necessary. If the land is ploughed when the moisture condition is optimum, very few clods are formed. Where rain-fed crops are to be grown, the fields are ploughed and left undisturbed until rain is received; this practice softens and breaks the clods. Clod crushing is a big job when crops are raised in off-seasons. If irrigation water is plentiful, the cloddy land may be irrigated, allowed to partially dry and the clods that are softened by the water may be crushed by running a heavy plank or a blade harrow over the soil.

Land levelling is one of the occasional land development operations and not an operation that is necessary every year. Farmers of irrigated and paddy tracts must be particular about the level of the land. When the level is not as required, land levelling is carried out after ploughing with a bullock-drawn buckscraper to ensure an even distribution of rain and irrigation water, to avoid the death
Fig. 86. Common desi ploughs that have been designed and used in various regions in India. [Redrawn from: RAMIAH and SRIVASTAVA].
of plants due to stagnation of water in low-lying areas, and to reduce
soil erosion and the breaching of bunds.
Sometimes the soil may be loosened too much by excessive
tillage; the result is excessive aeration and a loss of soil moisture.
It is necessary to compact such loose soils. The small-seeded crops
such as *sesamum*, *bajra*, and the millets require firm seed beds.
Under conditions in India, soil compaction is usually accomplished
by a beating rain. For that reason artificial compaction of soils may
not be necessary except in rare instances. If artificial compaction
is necessary it can be done by an ordinary single or double plank.

Harrowing serves many purposes. It breaks clods, smoothes the
seed bed, destroys germinating weeds, compacts the sub-soil, and
leaves the surface soil loose and friable. Harrowing is usually done
with the use of a blade harrow. By harrowing at the proper time,
a loose, friable, and well-aerated seed bed is made. In dry tracts
and in deep black soils, the blade harrow and spike-tooth harrows
are often the only implements used for preparing the seed bed
(Figure 87 and Plate LIV).

**INTER-CULTIVATION**

A thorough cultivation should always be made before sowing a
crop and continued until the spread of the crop prevents further
growth of weeds. The cultivation before the complete germination of
the crop plants is mainly to break the crust. This encourages
germination of the seed and destroys the germinating weeds.

There has been some controversy in recent years in regard to the
objectives of inter-cultivation. In earlier years it was thought that
inter-cultivation reduced evaporation of soil moisture due to the
creation of a dust mulch on the surface. In recent years, however,
it has been shown that inter-cultivation is required mainly for
controlling weeds. Soil moisture is conserved primarily through the
reduction in weeds and less transpiration of water because of fewer
weeds.

In addition to controlling weeds, inter-cultivation is responsible
for other benefits such as increasing the infiltration of water and
better aeration. Soil that has been compacted by the rains can be
loosened by proper cultivation and thus aeration is increased,
desirable micro-organisms multiply faster, and the availability of
plant nutrients is increased (Plate LV).
Pl. XLII. For many years the tribal farmers in certain parts of India have cleared the land and built bunds, as shown here, with no technical guidance. Now the Departments of Agriculture are helping them.

[Courtesy: C. P. RAJU].

Pl. XLII. The States and the Central Government in India are helping to educate farmers to appreciate the value of soil and water conservation.

[Courtesy: ANDREW RENSHAW].
Pl. XLIII. Rill erosion is formed by rain water on unprotected slopes when the rows run up and down the slope. [Courtesy: ROY L. DONAHUE].
Fig. 87. Spike-tooth harrows are commonly used prior to broadcast sowing of seeds and after sowing to cover the seeds.


[Redrawn from: RAMIAH and SRIVASTAVA].
Under certain circumstances, inter-cultivation is done with the objective of reducing the moisture content of the soil. For example, in some of the cotton fields of Mysore State, cultivation is practised to reduce the soil moisture and thus arrest the vegetative growth of the crop in order to encourage flowering and fruiting.

**FREQUENCY OF INTER-CULTIVATION**

There is no fixed rule to determine the number of inter-cultivations that should be given for a crop. One thing is certain: The number should be the minimum that is required to control weeds and to keep the soil in proper tilth (Plate LVI). Too much inter-cultivation leads to a breakdown in the physical condition of the soil instead of resulting in the improvement of the tilth.

The other factors which determine the frequency of inter-cultivation are the weeds, soil type, crop, and climate. If there are many weeds, the soil should be cultivated more frequently. Soils that have a good physical condition need cultivation less frequently. Soils that are like dust when dry become easily compacted when it rains, and therefore they should be cultivated after nearly every rain. Some crops require inter-cultivation for a longer time than others. For instance, in broadly-spaced crops such as chillies, sugar cane, cotton, and tobacco, inter-cultivation must be continued for a long period; in other crops like wheat, maize, jowar and bajra — which cover the soil in a short period — only a few inter-cultivations are necessary. For groundnut, no inter-cultivation is advisable after flowering; this crop needs only about two inter-cultivations.

Due to beating rains, the soil structure is destroyed; therefore inter-cultivation must be given more frequently. Because of frequent rains, the weed trouble increases and more inter-cultivations are necessary to control them.

**DEPTH OF INTER-CULTIVATION**

The depth to which the soil should be inter-cultivated depends upon crop growth and weed growth. The crops that are young and have not become well-established should not be cultivated deeply because there is danger of uprooting the plants. Neither should well-established plants be cultivated deeply for fear of pruning too many roots and thus reducing crop yields.
TILLAGE AND WEED CONTROL

DAMAGE CAUSED BY WEEDS

A weed is a plant out of place. Weeds cause loss to the farmer and to his crops by reducing crop yields, by competing with crops for light, soil moisture, and nutrients; by increasing the cost of cultivation; lowering the quality of crops; harbouring insects and diseases; and by increasing the cost of maintaining irrigation and drainage channels (Plate LVII).

Weeds usually grow faster than the crop plants and thus shade them and deprive them of full sunlight, water, and plant nutrients. The seasonal weeds with broad leaves are the most effective in shading the crops. The crops which grow slowly, especially in the beginning, are damaged by weeds more than fast growing crops. *Nilwar jowar* for fodder grows rapidly and is therefore not usually damaged by weeds. Weeds in cotton are always a problem because the young cotton plants develop slowly. Losses due to shading are more common in humid regions and during monsoon rains when weeds grow more rapidly and opportunities for removing them are restricted because the soil is often too wet for inter-cultivation.

Moisture lost by transpiration through weeds is often much greater than water lost by evaporation, surface run-off, or deep seepage. The only way to avoid losses of water by transpiration through weeds is to control the weeds by practising clean cultivation. A few farmers feel that it is a blight on their good record to permit even one weed to grow among their crops. If this attitude would spread to all farmers in India, crop production could be increased from 10 to 25 per cent by proper weed control (Plate LVIII).

A deficiency of nutrients in the soil is one of the major factors limiting crop production. Available nutrients in the soil are taken up first by the weeds, since they have a stronger root system. Very little nutrients are left for the crop plants. It is a common experience among farmers to report that following an application of fertilizer the weeds are stimulated more than the crop plants. The answer to the problem lies in:

1. Placing the fertilizer close enough to the crop plants to permit them to feed on the fertilizer before weeds get it; and,
2. Keeping all weeds from growing large enough to compete with crop plants.
There is plenty of evidence to show that most tillage operations are done to control weeds. All seed-bed preparations such as ploughing, discing, harrowing, smoothing, planking, and compacting, are necessary to control weeds as well as to prepare a good seed-bed. In addition to these cultural operations, much hand-weeding must be done to destroy weeds.

While harvesting the crop plants, many weeds and weed seeds are also harvested. This means a lowered quality of produce or a higher labour cost in separating the weeds from the crop plants. Weed seeds, especially of *landga* (Cockle bur), lower the quality of wool and mohair from sheep and goats (Plate LIX).

Whenever the population of weeds is high, the trouble from pests and diseases is often great because insects and diseases usually live a part of their life cycle on weeds. Clean inter-cultivation therefore helps in reducing the damage caused by insects and diseases. For instance, weeds around paddy bunds harbour the gall fly, and when the weeds are destroyed the gall fly damage to rice is reduced. The mites that cause the curly leaf disease of potato and chillies may live on weeds which commonly grow on the sides of bunds and in waste areas. Similarly, a number of virus and bacteria live on weeds in the off-season and attack the crop plants during the regular cropping season.

Weeds growing in irrigation and drainage channels reduce the flow of water. This causes a reduction in the capacity of the channel to carry water. Keeping weeds out of the channels is a big, costly practice for both the farmers and the Government; but it must be done to increase the capacity of the channels and to reduce the spread of weed seeds.

**PREVENTING THE SPREAD OF WEEDS**

The introduction of weeds can be largely prevented by adopting the following measures:

1. Using seed that is free from weed seeds;
2. Producing and using manure and compost free from viable weed seeds;
3. Cutting the weeds along irrigation and drainage channels, roadsides, *nala*s, and waste areas before they produce seed.
Weed seeds are almost always mixed with the seeds of crop plants. To prevent such introduction in some countries, seed laws are enforced that prohibit the sale of certain seeds of crop plants that contain more than a certain percentage of specific noxious weeds. Seeds of crop plants can be certified if the conditions laid down in the laws are satisfied. The agents selling the seeds must tag each bag with a printed label that must specify the percentage of noxious weeds. Periodic seed sampling and testing ensures the farmers against violations of the seed laws.

In 1919 the International Crop Improvement Association was organized. The purpose of this private association is to assist in promoting the production, identification, and distribution of high quality seed of superior varieties that are approved by the state and national research stations. All countries in the world would gain by joining and participating in an association of this kind, but so far India is not a member.

There is also an International Seed Testing Association which prescribes purity standards for all field crop and vegetable seeds. In India there are at present no seed laws and therefore no check on the introduction of new weed seeds along with the crop seeds, except routine quarantine measures supervised by customs officials at the ports of entry. To assist the farmers in obtaining high quality seed, the Indian Agricultural Research Institute, New Delhi, and the State Departments of agriculture have established seed testing laboratories. Information on how to have your seed tested may be obtained by writing to the Institute or to your State Department of Agriculture.

Seeds taken in by the animals along with the fodder eaten may pass through the animal undigested and become the source of introduction of weeds through the manure. Secondly, the straw used as bedding, usually adds weed seeds to the manure. If the manure or compost is well decomposed, the viability of weed seeds is likely to be less, due to the effect of heating during decomposition. Manure that is not handled and stored properly is likely to contain viable seeds and thus become a source of introduction in the cultivated areas. This source can be reduced by using manure and compost that has properly decomposed. The third source of weed seeds is through the weeds growing in the manure and compost yard and on the heaps themselves. Therefore, all weeds growing in the manure yard and on the manure and compost heaps and pits should be removed before they bear seed.
Irrigation channels, drainage ditches, bunds, roadsides, and waste areas are always covered with weeds. If the weeds are cut before they bear seed, this will control their spread. The weeds when cut can be used for fodder, green manuring, or for bedding for cattle. The Government is now encouraging farmers to plant useful grasses and legumes on bunds and waste areas to replace useless weeds.

MECHANICAL METHODS TO CONTROL WEED

Hand-weeding, tillage, and burning are the main mechanical methods of weed control.

In most farm areas in India, labour to pull weeds by hand can usually be employed at a daily wage of Re. 1.00 to Rs. 2.00. For this reason, hand-weeding at present is the most common method of controlling weeds. A sickle, *khurpi*, or some type of improved hoe are the common implements used in hand-weeding (Plate LX).

Ploughing is an effective method of reducing the number of weeds because many of the small weeds are uprooted. Harrowing is another efficient method of killing the small weeds. Similarly, timely inter-cultivation with an adapted hoe is very effective in controlling the weeds. Tillage operations control annual weeds and shallow-rooted perennial weeds by eradicating them before they produce seeds. However, the perennial weeds must be disturbed more often to prevent further rooting and sprouting until the vegetative parts die. The objective in controlling deep-rooted perennial weeds by tillage operations is to destroy the top growth frequently and thereby exhaust the food reserves in the roots; however, not all perennial weeds can be controlled by tillage.

The primary objective in burning the surface of seed beds before raising seedlings is to kill the weed seeds. Burning is quite effective if it is done very slowly, but quick burning is not effective in controlling weeds. Burning green weeds with flame-throwers before they form seeds has been employed to control weeds in some uncultivated areas. This method has also been successfully employed in cotton, maize, and sugar cane in the United States of America. The flame is thrown near the base of the crop plants; this burns the tender weeds, leaving the stems of the less sensitive crop plants
uninjured. The underground parts of some weeds however may remain undamaged and such weeds may start growing again. In India, destroying weeds by burning them, except on tobacco nursery beds, is not a very common practice.

CROPPING SYSTEMS TO CONTROL WEEDS

Some crops are good competitors of weeds while others help in increasing the intensity of weeds. For instance, *nilwar jowar* for fodder, *sannhemp*, and sweet potato, can compete satisfactorily with weeds because they become established quickly and grow rapidly. These crops are even more effective in controlling weeds if care is taken to establish them properly, supply an adequate quantity of fertilizers for good growth, and obtain a thick stand by using heavier than usual seeding rates.

A cropping system that includes crops such as potato, chillies, cotton, tobacco, and groundnut effectively controls weeds for the succeeding crop due to the frequent inter-cultivation of the soil. On the other hand, the vegetable crops and most other irrigated crops, give more opportunities for the multiplication and spread of weeds.

Heavily irrigated crops are also associated with specific weeds. Continuous cropping with the same cropping system will usually lead to infestation with certain perennial weeds. In such cases it is better to change the crops year after year. A suitable cropping system should be adopted, which includes clean-cultivated, quick-growing, and dense sod-like crops in order to control the several kinds of weeds.

CHEMICALS TO CONTROL WEEDS

Although many chemical weed killers have been tried in India, so far only 2, 4-D has proved most effective.

About fifteen years ago, 2, 4-D was first used as a selective weed killer. By “selective” is meant that if used according to directions it will kill broad-leaved weeds but not narrow-leaved weeds or narrow-leaved, grass-like crops. For example, broad-leaved weeds in a grass lawn, wheat field, or sugar cane field would be killed by 2, 4-D; but the grass, wheat, and sugar cane would not be injured.
Being cheap, effective, easy to apply in solution and not harmful to man or animals, makes 2, 4-D a very popular weed killer. The common forms of 2, 4-D are metallic salts, amine salts, and esters. Their relative effectiveness is in the order named, from lowest to highest.

The recommended dosage of 2, 4-D will vary with the chemical form, the kind of weeds, the kind of crop, the stage of growth of the crop and the weeds, and the weather conditions at the time of application. The usual rates of 2, 4-D are approximately one-fourth to two pounds acid equivalent per acre. The results of some of the experiments conducted at the Poona Agricultural College Farm, Maharashtra State, indicate that by using 2, 4-D before the crop plants come up, weeds can be controlled in sugar cane, potato, ginger, and suran (Plate LXI). The application of 2, 4-D at the rate of 1.5 pounds of acid equivalent per acre in eighty gallons of water, first five days after planting and next twenty-five days after planting, gave a 90 per cent control of weeds for a six-week period. The cost was about Rs. 15.00 per acre.

Users of 2, 4-D should always follow the manufacturer’s directions to get the best results. The following precautions must be taken:

1. Use only the recommended quantities—an over-dose may kill the crop;
2. Do not spray when the wind velocity is high, especially when susceptible crops such as cotton, bhendi, and tomato are nearby;
3. The containers used for 2, 4-D should never be used for spraying or dusting fungicides or insecticides because under farm conditions it is not possible to wash out all 2, 4-D residues from a sprayer or duster;
4. Do not store 2, 4-D near fungicides and insecticides for fear they will be mistakenly used for each other.

CONTROL OF LAVALA
(Nut grass) (Cyperus species)

One of the most noxious perennial weed of many parts of India, especially of irrigated tracts, is lavala (nut grass). The above ground part of lavala consists of a rosette of leaves occurring in ranks of three, and in cross-section the stems are not flat like a grass but have three corners. The underground parts consist of rhizomes, on the
Pl. XLIV. As protective vegetation is removed from a catchment (watershed), more rainwater flows off the surface and less moves into the soil. The result is a lowering of the level of water in wells. [Courtesy: C. P. RAJU].

Pl. XLV. *Hulga* is a wild legume that is excellent as a cover for the soil to reduce soil erosion, especially in the blacklands of Central Maharashtra State. [Courtesy: ROY L. DONAHUE].
Pl. XLVI. Contour cultivation results in more water entering the soil for use by growing crops. [Courtesy: H. R. ARAKERI].

Pl. XLVII. Strip-cropping with erosion-resistant crops such as groundnut (centre) and erosion-permitting crops such as bajra or jowar is a recommended practice. [Courtesy: H. R. ARAKERI].
Pl. XLVIII. Freshly made bunds may be planted to some crop such as castor (shown here) until they become covered with grass.  
(Courtesy: Roy L. Donahue).

Pl. XLIX. Gully control is simpler when stones are readily available for building dams. The centre of the dam should always be the lowest part of the dam so that water will flow over the stones and not around the ends of the dam. (Courtesy: H. R. Arakeri).
Pl. L. An effective wind-break in Rajasthan, consisting of *neem* (large trees) and *babul* (smaller trees). *[Courtesy: Mahendra Prakash]*.

Pl. LI. When the previous crop was sugar cane, as shown here, the land must be ploughed in preparation for planting another crop.  
*[Courtesy: Roy L. Donahue]*.
ends of which are formed nuts, and roots. The nuts are white and succulent when young and turn reddish-brown and finally black with age. There are two types of nuts, one type which comes up to establish above ground parts and the second which goes down deep to form new nuts. The growing season is usually the kharif (summer) but it starts growing in most places in India whenever the moisture conditions are satisfactory.

Lavala propagates mainly by nuts. The propagation by seeds is also important even though only about two per cent of the seeds are viable. The nut is the quickest means of propagation. It has been observed that within twenty days after the establishment of leaves, a new nut is formed and this new nut germinates and establishes new leaves within the next twenty days. The majority of the rhizomes and nuts occur in the top six-inch layer of the soil, although the depth depends upon the soil type. The nuts develop deeply in loam soils and shallower in clay soils (Figure 88).

A number of methods have been tried to control lavala. Of all the methods tried, ploughing with a two-bullock iron plough at intervals of fifteen days during its vegetative growth has been found

![Diagram of Lavala plant](image)

Fig. 88. Lavala (nut grass) plant is a very troublesome weed because of its method of reproduction by “nuts” at intervals on the roots.

[Courtesy : H. R. Arakeri].
to be quite successful. In some areas, where labour is cheap and mechanical power is not available, *lavala* is controlled by turning lumps of soil to a depth of six inches with the aid of an iron bar, thus exposing the rhizomes and nuts to the drying action of the sun and wind (Plate LXII). Similarly, growing cover crops such as carrot, or *nilwar jowar* for fodder have been effective in keeping this weed under control.

Spraying with 2, 4-D in the form of a sodium or amine salt at the rate of two pounds of acid equivalent per acre is effective in killing the above ground growth and about fifty per cent of the nuts to a depth of six inches. To bring *lavala* under control it is advisable to adopt a good cropping plan with as few irrigated crops as possible, and to include cover crops such as *nilwar jowar* for fodder, carrot, chillies, and *brinjal*.

**CONTROL OF DUB GRASS**

(*Bermuda-grass, hariali, Cynodon dactylon*)

*Dub* grass is a low-growing grass that occurs commonly over most of India. It is particularly abundant on moist fertile soils along roadways and paths as well as on crop land.

The grass is valuable as a fodder and as a lawn grass, but on crop land it is called a weed because it is not wanted there.

*Dub* grass propagates vegetatively from surface creeping stems, shallow root stocks (rhizomes), and from seed (Figure 15, page 59). Economical control of *dub* grass in India consists of deep ploughing at the beginning of the hot and dry period, followed by frequent and shallow cultivation. During wet periods, however, uprooting and removing *dub* grass from the field is necessary to control it.

**SUMMARY**

Tilling the soil is done primarily to provide a good seed bed for crops and to control weeds. To some extent, tilling also aids in the control of certain insects and diseases. Ploughing the soil is the most expensive tillage operation; for that reason it should be kept to a minimum. Some fields do not require ploughing every year. Inter-cultivation should be done as shallow as possible and only often enough to control weeds.

A weed is a plant out of place. Weeds always reduce crop yields and should be removed when small. Hand-weeding, inter-cultivation,
and burning are the principal mechanical methods of weed control. Sowing such dense-growing crops as nilwar jowar, sananhemp, and sweet potato will aid in controlling certain weeds by smothering them. In recent years, chemicals to control weeds, such as 2, 4-D have become popular.

Lavala (nut grass) is a very troublesome weed that may be controlled by deep ploughing or deep digging by hand during the hot, dry season, or by spraying with 2, 4-D. The same control measures are used for dub grass except that it does not now appear to be economical to use 2, 4-D.

QUESTIONS

1. What are the primary reasons for tillage.
2. Name the conditions under which ploughing is necessary for seed-bed preparation.
3. Under what conditions is ploughing not necessary.
4. How is lavala controlled? Dub grass?
5. What precautions should be observed in the use of 2, 4-D.

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Chapter 12

FERTILIZERS, MANURES, AND GREEN MANURES

The reason India cannot grow enough food for her people is primarily because her crop yields per acre and production per animal are the lowest in the world. There are many reasons for low yields, including the lack of proper application of scientific methods, drought, wet weather, insufficient irrigation water, poor seed, diseases, insects, weedy fields, and infertile soils. This chapter deals with infertile soils and how to make them more productive.

Every soil in India can be made more productive by the proper application of fertilizers, manures, and green manures. Some soils require only nitrogen fertilizer, others only phosphorus; but most crops on nearly all soils respond to a combination of nitrogen and phosphorus, such as ammonium sulphate plus superphosphate. Certain soils also respond to applications of potassium fertilizer (Figures 89 and 90).

Animal manures supply organic matter to keep the soil in good tilth, as well as to supply many of the essential elements for plant growth. Green manures are sometimes grown to help maintain good tilth. They do not add new supplies of essential elements to soil except legumes that add nitrogen to the soil; all green manures do, however, make more available some of the existing elements in the soil.

ESSENTIAL ELEMENTS FOR PLANTS

Plant growth cannot take place without the presence of sixteen elements. These elements and their source are given in Table 12.1, page 192.

It can be seen that plants obtain carbon, hydrogen, and oxygen from air and water; and that from soil, fertilizers, and manures, plants obtain the other thirteen essential nutrient elements. The primary nutrients are nitrogen, phosphorus, and potassium. Plants use these three elements in large amounts; for this reason they are supplied by all complete fertilizers. The secondary nutrients are calcium, magnesium, and sulphur; they are used in second largest amounts by plants. The micro-nutrients are so named because they
are used only in small quantities by plants. The micro-nutrients are iron, zinc, boron, copper, manganese, molybdenum, and chlorine.

In order to grow, plants must have all of the sixteen essential elements in an available form every day. Plants use large amounts of some elements and only very small amounts of other elements. Nitrogen, for example, is absorbed by plants in large quantities, while copper is used only in trace amounts. To make the problem even more complicated, any plant such as cotton requires varying amounts of essential elements at different stages of its growth. For instance, in the seedling stage a cotton plant requires only a small amount of all sixteen elements; during the period of rapid growth the plant needs larger amounts of all elements and especially
more nitrogen; finally, during the fruiting stage the plant needs more phosphorus because phosphorus is concentrated in the seed.

The storehouse (godown) of essential minerals in most soils is so empty that the use of fertilizers, manures, and composts is necessary to boost crop yields.

The godown of the sixteen essential elements contains different amounts of each element. At any one time, plant growth is limited by the one element that is in the shortest relative supply. For example, if five units of nitrogen are required by jowar during a week and only three units are available, the shortage of nitrogen will limit crop yields (Figure 90). The solution to the problem of increasing crop yields is to try to determine what element is holding down crop yields and to add it as a fertilizer. To estimate the fertilizer requirement more accurately, a soil sample should be sent for testing to the nearest soil testing laboratory.*

KINDS OF NITROGEN FERTILIZERS

The most common kinds of nitrogen fertilizers in India are ammonium sulphate, calcium ammonium nitrate, ammonium

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* See Chapter 8, pages 111–13, for further information on soil testing, including the location of the soil testing laboratories in India.
### TABLE 12.1. ESSENTIAL NUTRIENT ELEMENTS FOR PLANT GROWTH AND THEIR SOURCES

<table>
<thead>
<tr>
<th>From Air and Water</th>
<th>From Soil, Fertilizers, and Manures</th>
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<tbody>
<tr>
<td><strong>Primary nutrients</strong></td>
<td><strong>Secondary nutrients</strong></td>
</tr>
<tr>
<td>Carbon</td>
<td>Nitrogen*</td>
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<tr>
<td>Hydrogen</td>
<td>Phosphorus</td>
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<td>Oxygen</td>
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*Legume plants can obtain a part of their nitrogen from the air; all other plants obtain nitrogen only from the soil.

Sulphate nitrate, urea, and such organic materials as oil cakes, by-products of slaughter houses, fish meal, bird manures, and sewage.

Ammonium sulphate is by far the most common of the nitrogen fertilizers, and is manufactured in India. It contains about 20.6 per cent nitrogen.

Calcium ammonium nitrate contains 20.6 per cent nitrogen. It is made by first manufacturing ammonium nitrate and then adding enough calcium carbonate (limestone) to make the fertilizer neutral; that is, neither acid nor alkaline. India has a plant at Nangal and one at Rourkela to produce calcium ammonium nitrate.

Ammonium sulphate nitrate contains 26 per cent nitrogen. Production of this fertilizer has started at Sindri, Bihar State.

Urea is the most concentrated of the solid nitrogenous fertilizers, containing 45 per cent nitrogen. In addition to its use on the soil, urea may be sprayed on the foliage of plants and is absorbed by the plant through the leaves. The other nitrogenous fertilizers cannot be applied in this way because they burn the leaves. Urea is now being manufactured in India.

Other nitrogenous fertilizers that are sometimes available in India are ammonium chloride — 24 per cent nitrogen; sodium nitrate — 16 per cent nitrogen; calcium nitrate — 15 per cent nitrogen; potassium nitrate — 10 per cent nitrogen; calcium cyanamide — 20
Pl. LII. After a crop of groundnut, as shown here, the land can usually be prepared for the next crop without ploughing. [Courtesy: Roy L. Donahue].

Pl. LIII. Deep ploughing encourages plant roots to grow deeply for water and plant nutrients. [Courtesy: U.S. Soil Conservation Service].
Pl. LIV. In black clay soils, a good seed bed may be prepared following a crop of wheat by the use of only the blade harrow (*bakhar*).

*Above:* The *bakhar* tilted to observe the bottom.  
*Below:* The *bakhar* in operation in wheat stubble.  

*Courtesy: ROY L. DONAHUE.*
Pl. LV. Soils that have been compacted by rains must be loosened by proper inter-cultivation, as is the situation with young cotton shown here. [Courtesy: Acco Press, Houston, Texas, U.S.A.].

Pl. LVI. This soyabean crop needs inter-cultivation to improve soil tilth. [Courtesy: B. H. VANDERFORD, Mississippi State Univ., U.S.A.].
Pl. LVII. Weeds in an irrigation channel should be destroyed, because they slow the movement of water as well as produce seed that are carried by water to infest the fields. [Courtesy: H. R. ARAKERI].

Pl. LVIII. On a research station where new varieties of jowar are being developed for Indian farmers, weeds are being kept under control with the use of long-handled, American-type hoes. [Courtesy: ROY L. DONAHUE].
per cent nitrogen; anhydrous ammonia — 82 per cent nitrogen; and ammonium phosphate — up to 21 per cent nitrogen.

Oilcakes are used as a fertilizer in large quantities in India. The principal oilcakes used are groundnut cake — about 7.3 per cent nitrogen; castor cake — 4.3 per cent nitrogen; and neem cake — 5.2 per cent nitrogen. Other oilcakes used are cotton-seed, safflower, coconut, linseed, niger, rape-seed, and sesame.

Slaughterhouse refuse usually consists of a mixture of dried blood, meat scrap, and small bones. Its content of nitrogen may vary from 5 to 10 per cent.

Fish meal, containing 7 per cent nitrogen, consists of the refuse that remains after the extraction of oil from fish, or from whole fish that are in excess of demand for human food.

Bird manure, often called bird guano or bat guano, contains up to 16 per cent nitrogen. In India, bat manure is collected in certain caves where bats roost and is sold as a fertilizer.

Sewage is used in a few places in India as a fertilizer. Sometimes the sewage is treated in open vats and then applied in irrigation water. At other places, night soil (human excrement) is used after composting in pits.

APPLYING NITROGEN FERTILIZERS

The chemical fertilizers such as ammonium sulphate, calcium ammonium nitrate, ammonium sulphate nitrate, and urea are completely water soluble. This means that when placed in moist soil the chemical fertilizers will dissolve in the soil solution and move with the soil water.* The oil cakes and other organic materials will not move from their point of placement.

Nitrogen fertilizers are often broadcast on the surface of a ploughed field and harrowed into the surface. This method is satisfactory with the organic fertilizers but is not recommended for use with the chemical fertilizers. Neither should the chemical nitrogen fertilizers be placed with the seed at the time of sowing; to do so will injure the seedlings (Figure 91).

* The only exception to this general rule of movement is in the case of all ammonium compounds. While the ammonium is completely water soluble, it is held on the surfaces of the clay and humus particles from which it does not move. Under conditions of a warm, moist soil, bacteria soon change the ammonium into the nitrate form which then moves freely in the soil solution.
For row crops, the chemical nitrogen fertilizers can be applied in a furrow and mixed with the soil a day or two before planting. It can also be applied to one side of the seed and slightly below seed level with the aid of a seeder. A desi plough can easily be adapted to apply the fertilizer in the recommended location. Two bamboo tubes each topped with a funnel can be attached to the plough. The opening for the fertilizer in the bottom of the desi plough should be about two inches to one side and in front of the opening for the seed. Thus, the fertilizer will be placed deeper and to one side of the seed (Plates LXIII and LXIV).

Two facts must be kept in mind regarding the use of chemical nitrogen fertilizers:

1. There is no good storehouse for nitrogen in the soil;
2. Plants quickly absorb the fertilizer that is applied.

The only logical conclusion is to apply chemical nitrogen fertilizers two or three times during the growing season to any one crop.

Experiments on rice in India, the United States of America, Japan, and in Egypt have shown that ammonium sulphate should
be placed at a depth of two to four inches under the surface of the soil to obtain the maximum yield of rice. Sometimes fifty per cent more rice is produced when the ammonium sulphate or other ammonium form of nitrogen is placed at the recommended depth in the rice field.

The explanation for this increased efficiency of ammonium nitrogen is that the surface quarter inch of soil in rice fields permits chemical and biological oxidation. The oxidizing layer aids in the transformation of the ammonium to nitrate nitrogen and then to gaseous nitrogen that escapes into the atmosphere. When ammonium nitrogen is placed at a depth of two to four inches, it stays in the ammonium form for use by the rice plant and is not lost into the atmosphere.

RESPONSE TO NITROGEN FERTILIZERS

Results of extensive trials conducted throughout India in cultivator’s fields are summarized as follows.

The best response with nitrogen fertilizer on rice was obtained on old alluvial soils, with an increase over the control plots of 859 pounds of paddy (unhulled rice). In decreasing order, the responses on other soils were: black soil, red soil, red gravelly soil, and a mixture of red and black soil. The least response with nitrogen fertilizer on rice was obtained on coastal alluvium, deltaic and saline soils, new alluvium, laterite, and on red and yellow soils. The average increase in paddy yield over the control plots, as a result of applying 150 pounds of ammonium sulphate per acre was 514 pounds of grain.

At a cost of Re. 0.15 per pound of ammonium sulphate and a value of Re. 0.12 per pound of rice, Rs. 22.50 (150 × 0.15) invested in fertilizer returned Rs. 61.68 (514 × 0.12) in rice. This is a return of Rs. 2.74 in rice for each rupee invested in ammonium sulphate.

The increased yield of bajra following the application of 150 pounds of ammonium sulphate per acre averaged 155 pounds per acre. Ragi yields were increased by an average of 412 pounds per acre, and wheat 289 pounds, following an application of 150 pounds per acre of ammonium sulphate.

While nitrogen fertilizer alone can be expected to increase the yields of most crops in India, when superphosphate is added along with the nitrogen the yields are usually increased even more. For example, on the average, the yield of rice was increased by 514 pounds
per acre following the application of 150 pounds of ammonium sulphate. In the same series of experiments, when 200 pounds of superphosphate was applied in addition to 150 pounds of ammonium sulphate, the yield of rice was increased to 789 pounds or an additional 275 pounds per acre due to the superphosphate.

With bajra, 150 pounds of ammonium sulphate increased yields by 155 pounds; adding 200 pounds of superphosphate to the nitrogen gave a total increase of 363 pounds, or an additional 208 pounds per acre due to the superphosphate.

One hundred and fifty pounds of ammonium sulphate on ragi increased yields by 412 pounds. When 200 pounds of superphosphate was added to the ammonium sulphate, the yield was increased to 693 pounds, or an additional 281 pounds per acre due to the superphosphate.

From these experiments and many more conducted throughout India, on the average, five pounds of ammonium sulphate can be expected to produce eight more pounds of wheat. At Re. 0.15 per pound of ammonium sulphate, the five pounds would cost Re. 0.75. With wheat valued at Re. 0.17 per pound, the increase of eight pounds would be equal to a return of Rs. 1.36. Thus, Re. 0.75 spent for ammonium sulphate could be expected to return wheat valued at Rs. 1.36.

Urea is a new nitrogen fertilizer in India that is more than twice as concentrated as common ammonium sulphate. Urea is the cheapest per pound of actual nitrogen. Recent experiments in India have shown that, pound for pound of nitrogen, urea is as effective as ammonium sulphate on wheat and sugar cane. Urea on rice, however, is slightly less effective than ammonium sulphate.

Demonstrations on fertilizing irrigated wheat and rice were conducted all over India during the rabi (winter) season of 1955–56. On the average, an application of 150 pounds of ammonium sulphate per acre resulted in an increase in wheat valued at Rs. 27.00 above the cost of the fertilizer. The same amount of ammonium sulphate on rice resulted in an increase in rice valued at Rs. 30.00 above the cost of the fertilizer.

Under these conditions, when ammonium sulphate is in short supply, it would bring more profit to the farmer when applied on rice than when used on wheat.*

KINDS OF PHOSPHORUS FERTILIZERS

Almost all of the phosphorus fertilizer used in India is sixteen per cent superphosphate. To a lesser extent, rock phosphate, bone meal, and basic slag are used.

Most of the superphosphate used in India is made in India by treating ground rock phosphate from North Africa with sulphuric acid. The acid treatment makes the phosphorus much more readily available to the farmers’ crops. Rock phosphate, ground animal bones, and basic slag are a good source of phosphorus but they are not as readily available on the market as superphosphate.

APPLYING PHOSPHORUS FERTILIZERS

For all practical purposes, superphosphate does not move in the soil from the point of application. The only conclusion is therefore to place the fertilizer in moist soil near the seed. Superphosphate can be drilled along with the seed if that is the easiest method of application. Unlike the chemical nitrogen fertilizers, superphosphate does not injure the germinating seed.

Another fact to keep in mind is that superphosphate in contact with the soil soon becomes less available to the plants. This means that it should never be applied broadcast on the surface of the soil; superphosphate must be applied in a concentrated band near the seed.

To further reduce the “tie-up” of phosphorus by the soil, the superphosphate should be mixed with compost, manure, or oil-cakes before it is applied.

RESPONSE TO PHOSPHORUS FERTILIZER

Demonstrations on an all-India basis were conducted during the kharif (summer) season of 1954–55, using a uniform application of 190 pounds of superphosphate per acre on rice. The value of the increased yield of rice was Rs. 12.00 per acre above the cost of the fertilizer.*

A series of India-wide demonstrations were conducted during the rabi (winter) season of 1955–56, using a uniform application of

190 pounds of superphosphate on both irrigated wheat and rice. The value of the increased yield of wheat from the fertilized plots was Rs. 18.00 above the cost of the fertilizer; the value of the increased yield of rice was Rs. 23.00 more than the cost of the fertilizer.*

While it is economical to add superphosphate to both wheat and rice, during periods of a short supply of fertilizer, a farmer would make more profit if he used the superphosphate on his rice field.

In Pusa, Bihar, over a 15-year period, wheat yields were 93 per cent higher and the profit per acre per year was Rs. 13.00, following annual applications of 250 pounds of superphosphate per acre.

While many crops on many Indian soils respond to applications of superphosphate, a soil test should be made to determine the need for superphosphate before applying it.

**POTASSIUM FERTILIZERS**

The two main sources of potassium fertilizers are:

1. *Muriate of potash* (potassium chloride), containing 60 per cent \( \text{K}_2\text{O} \);
2. *Sulphate of potash* (potassium sulphate), containing 48 per cent \( \text{K}_2\text{O} \).

Wood ash contains up to five per cent potash \( (\text{K}_2\text{O}) \) as well as 20 to 50 per cent lime. Wood ashes are used to some extent as a source of both potassium and lime.

The potassium in muriate of potash, sulphate of potash, and in wood ashes is readily soluble in water. This means that the potassium fertilizers must not be applied close to seeds or seedlings because of the danger of "burning". Just as weeds can be killed by applying common table salt, so also potassium fertilizers will kill all plants when they are applied close to them. In this way the nitrogen and potassium fertilizers are the same, that is, neither should be applied in large quantities close to a germinating seed or a tender plant.

Indian soils are more plentifully supplied with potassium than with nitrogen and phosphorus. However, as crop yields per acre increase, more soils will be depleted of available potassium by crop

removal. Also as a wider variety of crops are grown in soils in high rainfall regions, more response to potassium fertilizers can be expected.

For example, in Champaran District, Bihar, a combination of 200 pounds of ammonium sulphate plus 600 pounds of superphosphate plus 135 pounds of muriate of potash per acre resulted in an extra yield of 2.2 tons of sugar cane and a profit of Rs. 59 per acre that was due to the potassium fertilizer. With the same amount of ammonium sulphate and superphosphate, increasing the muriate of potash to 270 pounds per acre resulted in 4.5 more tons of sugar cane and a profit of Rs. 117 per acre.

Coconuts respond to applications of potassium fertilizers. Approximately two pounds of muriate of potash per tree can be expected to increase the yield of coconuts and to increase the resistance of the tree to certain diseases.*

Arecanut also responds to potassium fertilizer in combination with nitrogen and phosphorus. The general recommendation is 600 pounds of ammonium sulphate, 300 pounds of superphosphate, and 300 pounds of muriate of potash per acre per year.†

In South India, the common recommendation for mature tea plantations is 600 pounds of ammonium sulphate, 200 pounds of superphosphate, and 100 pounds of muriate of potash per acre per year.‡

Coffee, tapioca, and potato, usually respond to applications of potassium fertilizer. To determine accurately how much potassium fertilizer to apply to any soil for a particular crop, a soil test must first be made.

SECONDARY AND MINOR ELEMENTS

The secondary elements are calcium, magnesium, and sulphur.

Calcium and sometimes magnesium may be added to the soil as burned or ground limestone. Wood ashes and cow dung ashes are both good sources of calcium and magnesium, as well as of potassium.

* John, C. M., *Coconut Cultivation*, The Indian Central Coconut Committee, Indian Council of Agricultural Research, New Delhi, 1955.
† *How to Cultivate Arecanut Successfully*, Indian Central Arecanut Committee, Indian Council of Agricultural Research, New Delhi.
Calcium and magnesium are usually needed on soils in India which are high-lying, well-drained, and which receive more than about 40 inches of rainfall a year. This means that the soils in the following locations may require lime for the maximum production of crops: Kerala, Western Ghats of Mysore and Maharashtra States, the seacoast of Orissa and West Bengal, Assam, Northern Bihar and Uttar Pradesh, and Kashmir.

Sulphur is sometimes used in India as the elemental, yellow powder, but more commonly sulphur is supplied to the soil as gypsum (calcium sulphate). Gypsum is used in India to reclaim black alkali soils. (See Chapter 8, pages 114, 115.)

The minor elements include copper, boron, manganese, iron, zinc, molybdenum, and chlorine. Under a low level of crop production per acre, adequate minor elements are usually supplied from the decomposition of soil organic matter and from the minerals in the soil. To obtain higher yields per acre, however, a greater demand for major, secondary, and minor elements is made from the soil. Since the supply of available minor elements in the soil is so variable, the response of plants to an application of the minor elements also varies.

For rice production, soil applications of copper gave yield increases of 35 to 85 per cent in parts of Maharashtra State. Zinc sulphate that was sprayed on rice plants near Coimbatore gave yield increases of 10 to 28 per cent.

Wheat yields have been increased near New Delhi by foliar and soil applications of copper, zinc, and manganese. At both Bangalore (Mysore State) and New Delhi, copper increased the yield of jowar. Cotton yields in Madhya Pradesh and Gujarat have been increased by applications of manganese, zinc, and boron.*

In Rajasthan, zinc applications increased the yield of barley and gram each by 14 per cent. Zinc and iron each slightly increased the yield of wheat.

Many citrus orchards throughout India often show a deficiency of nitrogen, calcium, magnesium, or one of the trace elements, zinc, copper, iron, or boron. To overcome these deficiencies, the following mixture is recommended per acre for use as a spray on the leaves of citrus trees:

Pl. LIX. Weeds in waste areas and along bunds and irrigation channels should be cut before they bear seed. The use of a sickle is the most common method of hand-weeding in India. [Courtesy: Roy L. Donahue].
Pl. LXI. Five days after sugar cane was planted and before it emerged, the rows on the left were sprayed with 2, 4-D. Note absence of weeds. On the right, no 2, 4-D was used. Note the abundance of weeds. [Courtesy: H. R. Arakeri].

Pl. LXII. Where a tractor and mould-board plough are not available and 2, 4-D is too expensive, soil infested with lavula (nut grass) can be turned over by hand labour to expose the nuts to the killing action of the drying sun. [Courtesy: Roy L. Donahue].
Pl. LXIII. Broadcasting fertilizer on the surface of the soil, as shown by white dots, increases the growth of the crop but also hastens weed growth. [Courtesy: Robert Engle].

Pl. LXIV. A desi plough adapted for seeding and fertilizing in one operation. The seed comes out the opening on the right while fertilizer comes out the opening on the left. Seed and fertilizer, especially nitrogen, should not be sown in mixture because of the danger of fertilizer killing the seedlings. [Courtesy: Andrew Renshaw].
Pl. LXV. This tomato plant was grown in a large clay pot in which lumps of farmyard manure were buried. Note how the roots of tomato grew into the manure and formed many small roots. [Courtesy: A. R. Midgeley, University of Vermont, U.S.A.].

Pl. LXVI. Town refuse makes excellent compost (Mysore State). [Courtesy: H. R. ARAKERI].
FERTILIZERS AND MANURES

<table>
<thead>
<tr>
<th>Material</th>
<th>Pounds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zinc sulphate</td>
<td>5</td>
</tr>
<tr>
<td>Copper sulphate</td>
<td>3</td>
</tr>
<tr>
<td>Magnesium sulphate</td>
<td>2</td>
</tr>
<tr>
<td>Ferrous sulphate</td>
<td>2</td>
</tr>
<tr>
<td>Boric acid or borax</td>
<td>1</td>
</tr>
<tr>
<td>Lime, burned</td>
<td>9</td>
</tr>
<tr>
<td>Urea</td>
<td>10</td>
</tr>
<tr>
<td>Water</td>
<td>100 gallons*</td>
</tr>
</tbody>
</table>

FARMYARD MANURE, OILSEED CAKES, AND COMPOST

Farmyard manure consists of animal dung, urine, and bedding such as straw. The oilseed cakes commonly used as a fertilizer in India are groundnut, castor, neem and cotton seed. These oilseed cakes are about five times richer in nitrogen, two and a half times richer in phosphorus, and two times richer in potassium than ordinary Indian farmyard manure.† The composition of compost varies widely, depending upon the composition of the materials from which it is made (Plates LXV and LXVI).

Farmyard manure will increase plant growth to a greater extent when it is applied to the soil when fresh. When this cannot be done, it should be stored either in a pit or a heap. In areas receiving less than 30 inches of rainfall per year, the pit method is recommended; in more humid areas, the heap method is recommended (Figures 92 and 93).

The pit method of storing farmyard manure until it can be applied to the soil, consists of digging a pit about six feet wide, three feet deep, and as long as necessary, to hold all of the manure. The bottom of the pit should be covered with straw. Manure should be added to the pit each day and covered with a thin layer of clay soil. No surface water should be allowed to enter the pit. The manure may be used any time the field is ready to receive it.

* Venkataratnam L., “Proper Spacing in Citrus Orchards” Kisan, Volume VI, No. 2, September 1959, Hyderabad, Andhra Pradesh, India.
† The oilcakes mentioned contain on the average, 5·2% nitrogen (N), 1·5% phosphorus (P₂O₅), and 1·4% potassium (K₂O); whereas farmyard manure in India, without bedding, averages 1·0% nitrogen (N), 0·6% phosphorus (P₂O₅), and 0·7% potassium (K₂O).
Fig. 92. In regions that receive less than 30 inches of annual rainfall, the pit method of storing farmyard manure is satisfactory. [Redrawn from: ARAKERI]

The heap method consists of selecting a well-drained spot, adding each day’s production of manure in such a way as to have a circular heap about six feet in diameter and when the heap is about six feet high, plastering the top with mud so that the rain-water will not leach away the plant nutrients. The manure is ready for use when it is needed.

Satisfactory compost may be made by digging a pit about six feet wide, three feet deep, and as long as necessary to hold the organic material to be used. A six inch layer of tree leaves, straw, town refuse, or sugar cane refuse is then added to the pit, trampled firm, and a two inch layer of farmyard manure is added and covered by about one inch of soil. The filling continues until the pile is about two feet above ground level. The top of the pile should then be covered with six inches of soil. In about four months the compost is ready for use and compares favourably with farmyard manure.
The oilcakes may be used in the same way as farmyard manure or compost but less is required per acre because oilcakes are richer in plant nutrients.

A comparison was made of the increase in the yield of wheat at Pusa, Bihar, following an application of farmyard manure, rape cake, and ammonium sulphate. In the fifteen year experiment, the same amount of nitrogen (N) was applied per acre per year on one plot that received only ammonium sulphate, another plot that received only rape cake, and a third plot that received only farmyard manure. A fourth plot did not receive any fertilizer or manure and therefore served as a control for comparison.

The ammonium sulphate increased the yield of wheat 7 per cent more than the control, while the oilcake increased yields 93 per cent, and the farmyard manure 141 per cent more than the control.

Fig. 93. In regions receiving more than 30 inches of annual rainfall, the heap method of storing farmyard manure is satisfactory. [Redrawn from: Donahue].
GREEN MANURING AND GREEN-LEAF
MANURING

Crops that are grown for the purpose of adding organic matter to the soil are known as green manuring crops. Green-leaf manuring consists of gathering green leaves from one location and adding them to the soil in another location. In both kinds of manuring, the organic material should be worked into the soil while it is young and before it becomes hard and woody so that it will readily decompose. After the application of the organic material to the soil, several weeks should be allowed for decomposition before the field is seeded to a crop.

In the permanent manurial and rotation experiments conducted at Pusa, Bihar State, since 1908, it has been observed that the lowest yields have been made on plots that have been continuously under cereal crops. Any introduction of legumes in the cropping system, as a pulse and green manure crop, brought marked increases in the yield of the cereal crop, particularly when a phosphatic fertilizer application was made to the legume (Figure 94).

The most common green manure crops are sannhemp, dhaincha, sesbania, moth, urid, mung, pillipesara, guar, senji, berseem clover, methra, khesari, pea, and lentil (Figure 95).

The common plants that are used for green-leaf manuring are glyricidia, dhaincha, wild ferns, forest tree leaves, guar, wild indigo, sannhemp, tea prunings, sea weeds, and common upland weeds. Approximately 5,000 pounds of green-leaf per acre will usually give the maximum increases in yields of the following crops (Plates LXVII to LXIX).

In addition to the use of green manure and green-leaf crops, crop residues are a good source of organic matter for the soil (Plate LXX).

SUMMARY

Sixteen elements are required by all crop plants for their growth. Nitrogen and phosphorus are the two essential elements that most often limit crop production in India.

Ammonium sulphate is now the most popular nitrogenous fertilizer in India. None of the nitrogenous or potassic fertilizers should be applied with the seed or close to small plants because of the hazard of burning the plants.
GREEN MANURE WITH PHOSPHATE FERTILIZER INCREASES YIELDS OF FOLLOWING CROPS

YIELDS WITH NO GREEN MANURE, NO PHOSPHATE

YIELDS FOLLOWING GREEN MANURE AND PHOSPHATE.

INCREASE IN YIELD%

PADDY IN BIHAR

96%

PADDY IN MADRAS

66%

WHEAT IN BIHAR

327%

WHEAT IN M.PRADESH

20%

WHEAT IN U.P.

53%

Fig. 94. Green manure crops with superphosphate fertilizer increased the yields of rice in Madras and Bihar and wheat in Uttar Pradesh, Bihar, and Madhya Pradesh. [Redrawn from: ICAR Pamphlet No. 4].
Fig. 95. *Pillipesara* (*Phaseolus trilobus*) is a good green-manuring crop for use in rotation with rice, and also a good green fodder for cattle. *Left*: young branch; *Right*: mature fruiting branch. [*Courtesy*: \textit{ROY L. DONAHUE}].
FERTILIZERS AND MANURES

The most common fertilizer containing phosphorus is 16 per cent superphosphate. It can be applied with the seed or near the seed at the time of sowing. Potassium chloride is the most common carrier of potassium fertilizer.

Farmyard manure is a good organic fertilizer but it is seldom available in adequate quantities. Compost and oilseed cakes are used when sufficient manure is not available.

QUESTIONS

1. Name the sixteen elements necessary for plant growth.
2. Describe three common sources of nitrogenous fertilizers.
3. What response may be expected with the use of ammonium sulphate on rice growing on old alluvial soils?
4. How may it be determined whether a crop will respond to an application of superphosphate?
5. Describe one desirable method of storing farmyard manure until it is ready for use on the field.

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Chapter 13

IRRIGATION AND DRAINAGE

IRRIGATION

The word “irrigation” means the application of water to the soil for the purpose of increasing the growth of plants. Farmers in India have been irrigating their crops for more than two thousand years. For one reason or another, however, most of the methods used have not been very efficient. To increase the acreage and yield per acre of crops under irrigation, the following ten recommendations are given:

1. Water facilities. Increase the number and quality of canals, wells, and tanks in order to increase the supply of water available for irrigation.
2. Losses of water. Reduce the losses of water from the source of supply to the crops in the field.
3. Water lifts. Select the method of water lift that is adapted to the most efficient source of power, the soil and the crop.
4. Methods of Irrigation. Select a method of irrigation that is adapted to the supply of water, soil, crop, and the slope of the land.
5. Water application. Apply the recommended amount of water at the proper intervals.
6. Multiple cropping. Raise two or three crops a year on the same land when irrigation water is available.
7. Crop varieties. The best crop varieties will produce perhaps twice as much as the poorest varieties.
8. Adequate fertilization. Plants contain 75 per cent or more of water and about 5 per cent of minerals. When crops are irrigated, their demand for fertilizer increases and must be supplied in the form of more manure and more commercial fertilizers.
9. Tillage practices. Irrigation water always increases the number of weeds which, if not destroyed, will rob the crop plants of both water and soil fertility.
10. Crop protection. Increased crop yields as a result of irrigation will be of no value to the farmer if the crops are destroyed by insects, diseases, birds, rodents, or stray animals.

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Above: Pl. LXVII. Dhaincha is the second most popular green-manure crop in India. It will grow on soils that are too salty, too wet, or too dry for sanhemp. [Courtesy: Roy L. Donahue].

Pl. LXVIII. Burying sanhemp, India's most popular green-manure crop. A furrow is opened with a mould-board plough, sanhemp is pulled and placed in the furrow and is covered the next time around with the plough. [Courtesy: Roy L. Donahue].
Pl. LXIX. Ploughing in a green-manure crop of pillipesara (a legume) to enrich the soil. [Courtesy: Roy L. Donahue].

Pl. LXX. These crop residues will be used for fuel but as many residues as possible should be left on the soil to supply organic matter. [Courtesy: Roy L. Donahue].
Pl. LXXI. Irrigation facilities can be increased by building a dam across a river. [Courtesy : H. R. ARAKERA].

Pl. LXXII. Farm ponds (tanks) rank third as a source of water for irrigation. Many more tanks are now being built in India. The farmers are lifting water with a swinging shovel. [Courtesy : FRANK SHUMAN].
Pl. LXXIII. An example of losses of irrigation water from a canal by seepage through sandy and stony soil. Such canals should be lined with clay (Madhya Pradesh). [Courtesy: Roy L. Donahue].

Pl. LXXIV. Tobacco yields were increased by nine per cent due to the straw applied on the surface of the soil at the right. The increase in yield was no doubt due to the reduction in water lost from the soil by surface evaporation (Andhra Pradesh). [Courtesy: Roy L. Donahue].
IRRIGATION AND DRAINAGE

The first five items mentioned will be discussed in the following pages; the last five are covered in Volume II.

WATER FACILITIES

India has more total water than any other major country in the world; yet water shortage is her main problem. The temperatures in India are suitable for year-round cropping, but the distribution of the rainfall is not satisfactory. Approximately 75 per cent of the annual rainfall received over most of India comes within a period of four months or less, from June to September. The unfavourable distribution of rainfall usually means that without irrigation water, only one rainfed crop can be grown. A second and third crop in any one year must be grown almost entirely with the aid of irrigation water from rivers, wells, canals or tanks.

India irrigates approximately one-fourth of the total land irrigated in the world. In 1953–54, the acreage irrigated in India was 53.5 million acres; while the total acreage irrigated in 1960–61 is estimated at 87 million acres. In 1951 it was estimated that only 8.5 per cent of India’s river waters were being used for irrigation; for 1961 the estimate is 19 per cent.*

Irrigation water in India is supplied mainly from rivers through canals, and from wells, and tanks. The State ranking first in irrigated acreage is Uttar Pradesh, with 12.5 million acres, or more than 23 per cent of the total for India. Punjab ranks second, followed in order by Andhra Pradesh, Madras, Bihar, Gujarat, and Maharashtra. All other States report more than one million acres irrigated except Jammu and Kashmir, and Kerala.

India is rapidly increasing the amount of water for irrigation by the construction of large dams, and by assisting in the construction of more wells, tanks, and canals (Plates LXXI and LXXII).

LOSSES OF WATER

The bulletin on “Better Use Of Land” by the Ministry of Community Development states that: “In many irrigated areas, half of the water diverted from the rivers and streams is lost in conveyance

* It has been estimated that if all of the water now flowing annually in India’s rivers were spread out evenly over all of India, it would cover the entire surface of India to a depth of about 20 inches.
and half of the water given to the fields is lost before it gets to the roots of the plants." This means that only one-fourth of the irrigation water is used by farm crops. Can these losses be reduced? Irrigation experts say that many of the losses of water can be avoided by applying the information in this chapter.

Irrigation water is lost in the following ways (Figure 96):

1. Evaporation losses from an open water surface, such as a river or a reservoir;
2. Seepage losses through the soil while water is being conveyed from the source to the field;
3. Field losses, which include over-irrigation, transpiration through weeds, and evaporation from the surface of the soil. Each of these kinds of losses of water and practices to reduce the losses will be discussed briefly.

**EVAPORATION LOSSES**

The loss of water by evaporation from rivers and tanks (reservoirs) is very high. For example, in Central India at Nizamsagar, Andhra Pradesh, the average annual loss of water by evaporation is 5.5 feet.

High temperatures, strong winds, and low humidity (moisture in the air) are the primary factors influencing surface evaporation of water. Since evaporation is controlled by climatic factors that cannot be changed by man, most people think that such losses cannot be avoided. This is not true.

Evaporation takes place only from the surface of the water. The solution to the problem of reducing evaporation losses is to reduce the surface area of water. For any given volume of water, the deeper the reservoir, the less the surface area. For example, if a water-tight container had inside dimensions of 1 foot by 1 foot and was 1 foot deep, it would hold 1 cubic foot of water and have 1 square foot of water exposed to the atmosphere for evaporation. If, however, another container were 0.5 foot wide, 1 foot long and 2 feet deep, the volume of water would also be 1 cubic foot but the area of water exposed for evaporation would be only 0.5 square foot, and the evaporation losses would be only half as much as in the former case. In a similar manner, the deeper the reservoir, the less the water surface exposed to the atmosphere and the less the evaporation for a given volume of water.
Fig. 96. When monsoon rains come the water is never still but continues to move in what is called the water cycle. [Redrawn from: Soil Conservation Service].
SEEPAGE LOSSES

An enormous quantity of water is lost in conveying water from the main canals to the fields. These losses occur due to leakages through breaches in the canals or through holes made by animals, or by seepage through porous soil. The losses are the greatest when canals are made in rocky or sandy soils; in such soils the canals should be lined with clay to reduce seepage losses (Plate LXXIII). The aquatic (water) plants growing in the canals slow the movement of water and therefore reduce the water capacity of the channel. In addition, weeds growing in the channel are responsible for a great loss of water by transpiration. When irrigation water lost as seepage is considered excessive, the canals can be lined with clay.

FIELD LOSSES

When a farmer pays for water on the basis of acreage of specified crops irrigated, he is inclined to apply too much water, causing water to be wasted, an excessively high water table, and possible salt injury. The result is reduced crop yields.

If a farmer is in a canal irrigation district in Maharashtra State, he pays Rs. 120 per acre per year for water for sugar cane or banana; Rs. 60 per acre per year for fruit trees or lucerne; Rs. 32 per acre for eight months of vegetables; and Rs. 13 per acre each for kharif and rabi rice.

Since a farmer pays only on an acre basis and not on a volume basis,* there is no incentive to use the correct amount of irrigation water. Since it costs the same, a farmer is inclined to use too much water at each application. The solution to the problem is to measure the irrigation water and charge the farmers only for the actual volume of water used, as is done in several western countries.

When weeds are allowed to grow in an irrigated field, they absorb large amounts of water that could be used by the crop plants. The problem can be solved by a vigorous and continuous campaign to kill all weeds by tillage, hoeing, pulling, or by the use of a chemical weed killer.

*On a volume basis, water is frequently measured by acre-inches, or acre-feet. An acre-inch is a volume equal to one acre in area (43,560 square feet) and one inch deep; while an acre-foot is equal to one acre in area and one foot deep.
Water in irrigated fields is also lost by evaporation from the surface of the moist soil. Such losses can be reduced by encouraging the crop plants to grow as rapidly as possible to shade the soil, and by providing some type of organic mulch on the surface of the soil. For instance, at the Central Tobacco Research Institute, Rajahmundry, Andhra Pradesh, mulching Virginia tobacco with three cart-loads of rice straw per acre increased the yield of tobacco by nine per cent. The increased yield of tobacco was probably due to the higher available moisture because of less loss by evaporation from the surface of the soil (Plate LXXIV).

WATER LIFTS

From canals the water usually flows by gravity to irrigate the fields; but when water is obtained from wells or tanks, some kind of water lift is necessary. Water lifts may be powered by men, bullocks, or mechanical power such as oil engines with pumps or electric motors with pumps.

WATER LIFTS POWERED BY MEN

The common water lifts that are powered by human labour are the swinging basket, swinging shovel, piccotah, and the Archimedian screw.

The swinging basket water lift usually consists of a fibre basket or metal can, with a capacity of two to three gallons, which is fastened on each side by two ropes about six feet long. Two men stand about eight feet apart, hold one rope in each hand, and together lower the basket in the water and then swing it two or three feet high and dump it. The water thus raised is used to irrigate crops at a higher level. When water must be lifted four to six feet, two men will lift the water to one level and another team with a second swinging basket will lift the same water another two or three feet (Figure 97).

The swinging shovel consists of a hollowed-out trunk of a palm tree six to eight feet long and closed on one end (iron troughs are sometimes used). The closed end is dipped into the water by means of a rope attached to a counterweighted log which is mounted on a forked support (fulcrum). Usually one man stands in the water in front of the shovel and operates the shovel up and down, lifting the water one or two feet (Figure 98).
Fig. 97. A swinging basket is adapted for water lifts of two to three feet.

[Courtesy: AGRICULTURAL COLLEGE, BAPATLA, A. P.].
Fig. 98. With the swinging shovel one man is able to lift about 2,000 gallons of water to a height of three feet. [Courtesy: AGRICULTURAL COLLEGE, BAPATLA, A. P.].
Piccotah water lift is designed to lift water to a greater height than by any of the other man-operated water lift, sometimes as much as 20 feet. The lift consists of a strong log laid across a high fulcrum. The water bucket is attached to the horizontal log by means of a bamboo pole or a rope. Two or more men walk back and forth on top of the horizontal log, while another man guides the bucket. The men on the log walk towards the fulcrum to lower the water bucket; when the bucket is full they walk along the log away from the water, thus raising the bucket full of water to the surface of the soil where it is dumped into an irrigation channel (Figure 99).

The Archimedian screw is hollow, usually about a foot in diameter, and may be made of wood or metal. On top is a handle that is turned by one man. Inside the hollow “screw” is a set of baffles that resemble an ordinary metal screw made for screwing into wood. These baffles elevate the water as the “screw” is turned on its central axle. Water is usually elevated about 2 feet with this device (Figure 100).

WATER LIFTS POWERED BY BULLOCKS

The most common water lifts that are powered by bullocks are the mhote and the Persian wheel.

The mhote bucket is made of either metal or leather and holds about 50 gallons. On the bottom of the bucket is a leather spout which is operated by a separate rope attached to the yoke of the bullocks. A second and stronger rope is fastened to the top of the bucket and runs over a pulley and then to the bullock yoke.

To raise the bucket from the well, the bullocks pull the two ropes at the same time, one lifting the bucket and the other keeping the leather spout tight against the side of the bucket until the bucket reaches the top, at which time the second rope pulls the leather spout open and the water flows into a trough and then into an irrigation ditch. The bullocks then back up to lower the bucket in the well and the operation is repeated (Figure 101).

The Persian wheel consists of one large gear wheel mounted on the side of the well near the bottom and another of the same kind mounted at ground level. Running over these two wheels is a continuous chain, similar to a bicycle chain, on which are attached small buckets about two feet apart. In the centre of the top gear
Pl. LXXV. Furrow irrigation is a very efficient method and is adapted to row crops such as sugar cane and maize. [Courtesy: H. R. ARAKERI].

Pl. LXXVI. The border method of irrigation permits a very careful control of irrigation water and is adapted to close-growing crops such as wheat. [Courtesy: VICTOR SURFACE].
Pl. LXXVII. Wild flooding is a very common but also a very wasteful method of using water. [Courtesy: ROY L. DONAHUE].

Pl. LXXVIII. It is time to stop irrigating when the soil is soft to within about three inches of the pre-determined depth, say two feet. [Courtesy: VICTOR SURFACE].
Fig. 99. Of the human-powered water lifts, the *piccotah* is able to lift water to the greatest height. [Courtesy: AGRICULTURAL COLLEGE, BAPATLA, A. P.]
FIG. 100. The Archimedean screw is the most efficient water lift operated by one man. The cut-a-way section shows the “screw” baffles on the inside of the cylinder, extending the full length of the tube. [Courtesy: AGRICULTURAL COLLEGE, BAPATLA, A. P.]
Fig. 101. The *mhote* is probably the most common water lift in India.

*Courtesy: Agricultural College, Bapatla, A. P.***
wheel is attached an axle which extends about 15 feet along the surface of the ground, with a gear fastened on the end. Another gear meshes with this one and is fastened to a shaft that extends at right angles and upward about 3 feet. A pole is fastened at right angles to this upright shaft and is pulled by bullocks walking in a circular motion. As the bullocks pull the pole around, the gear wheel turns, the continuous chain with buckets attached move upward on one side full of water. As soon as the water is discharged at the surface, the empty buckets continue to move downward on the chain to again become full of water (Figure 102).

WATER LIFTS POWERED MECHANICALLY

The common water lifts which are power operated include oil engines with pumps and electric motors with pumps.

Oil engines used for pumping irrigation water are commonly from 5 to 10 horse-power, with pumps 2 to 4 inches in size. Such equipment may irrigate from 1 to 2 acres a day. One of the greatest sources of waste in establishing an oil engine and pump for irrigation is that the engine or pump may not be the right size; that is, too large or too small to do the work required. Another common source of waste of power is to pump the water to a higher level than is necessary to irrigate the field (Figure 103).

Because of their economy, electric motors are rapidly replacing oil engines in villages where electricity is available. The purchase of the right kind and size of motor is a highly complicated problem which your nearest Agricultural Officer will be willing to discuss with you. Most State departments of agriculture offer loans to farmers for the purchase of oil engines or electric motors with pump sets.

METHODS OF IRRIGATION

As one travels over India and observes the methods of irrigation being used, the same question continues to be asked: Is there not a more efficient way to use India's scarce water? The selection of the most suitable irrigation method for each field, carefully applied, will contribute greatly toward increasing crop yields, make more efficient use of scarce water, and thereby help to raise the standard of living of everyone.
Fig. 102. The Persian wheel is the most efficient of the bullock-operated water lifts but the initial cost is fairly high. [Courtesy: AGRICULTURAL COLLEGE, BAPATLA, A. P.]
Fig. 103. Oil engines and pumps are becoming more popular with farmers who can afford the high initial investment. [Courtesy: AGRICULTURAL COLLEGE, BAPATLA, A. P.].
IRRIGATION AND DRAINAGE

The irrigation methods discussed here are: *basin*, *furrow*, *border*, *sprinkler*, and *wild flooding*. Each of these methods will be discussed along with their adaptations.

**BASIN IRRIGATION**

The basin method of irrigation is popular all over the world. The common method of irrigating rice is an example of the basin method. Citrus orchards, lucerne, berseem and other clovers, and some cereals such as wheat are usually irrigated by some modification of the basin method.

Basin irrigation is dependent upon the establishment of nearly level areas of land surrounded by bunds, from a few inches to several feet in height, to retain the desired depth of water. Each basin is then flooded in turn and the water allowed to soak into the soil. In the case of rice culture, the desired level of water is retained by the bunds, and it is essential that water standing in rice fields be at about the same depth. Land with a slope no more than 0.2 per cent within each basin is necessary to accomplish this objective.

At the Tharsa Citrus Research Garden, Nagpur District, Maharashtra State, it was found that each mature tree required 150 gallons of water at each irrigation and 26 irrigations during an eight-month period. The system used was the basin method of irrigation, with each basin approximately 12 by 12 feet square making a total application of 50 acre-inches of irrigation water (Figure 104).

**FURROW IRRIGATION**

The main objective in furrow irrigation is to direct the water between two rows of a crop and permit it to soak downward to the roots of the plants.

On slopes of about one,* furrow irrigation with straight rows is quite successful. On steeper slopes, the furrows should be laid out on the approximate contour to reduce the hazard of erosion and to achieve uniform water penetration. The length of each run is determined by soil permeability and by the steepness of the slope. On permeable soils such as sands, the runs must be shorter than

* A slope of one per cent means a rise or fall of 1 foot for each 100 feet of horizontal distance.
Fig. 104. The basin method of irrigation is ideal for citrus gardens (shown here) and for paddy fields. [Redrawn from: Donahue].

those on less permeable soils such as clays. On slopes less than 1 per cent the furrow runs can be longer, and on steeper slopes the runs must be shorter than the average.

As a rule, if it takes four hours to add sufficient water to a furrow, the water should be turned into the furrow in such volume that it will flow to the end of the furrow in one hour (one-fourth of the elapsed time). In this way, water will soak into the soil at a fairly uniform rate all along the furrows and result in uniform crop growth (Plate LXXV).

BORDER IRRIGATION

The border method of irrigation consists of levelling strips of land, building earth bunds about 1 foot high along the edges of the
Pl. LXXIX. Every field that is irrigated must have a drainage system, as shown here by the clay pipes in the foreground that have been placed at the end of a run that is being irrigated by the border system. [Courtesy: Victor Surface].
strips, and irrigating one area at a time by flooding with a thin sheet of water. Wheat, lucerne, berseem clover, and other close-growing crops are especially suited to the border system of irrigation.

The width of each strip between two bunds is so designed as to permit the available head of water to flow evenly at a depth of 2 to 3 inches. A common width of strips varies from 20 to 50 feet, depending upon the volume of water available for irrigation. The length of each run must be adjusted to get fairly uniform penetration of water into the soil over the full length of the run. The length may thus be 100 feet for sandy loam soils and 500 feet for clay soils.

In 1956, lucerne was being irrigated by the border method at the Agricultural College Farm, Nagpur, Maharashtra State. Best results were obtained when the strip was 20 feet wide, 150 feet long, and with a grade of 0.5 per cent. The border irrigation system at Nagpur takes only half as much water as did the former wild flooding method (Plate LXXVI).

SPRINKLER IRRIGATION

The sprinkler irrigation system consists of pumping water through a pipe and through rotating nozzles so as to apply water to the soil in a manner similar to that received by natural rainfall.

Sandy soils that are difficult to irrigate because they absorb water too rapidly can be readily irrigated by a sprinkler system. This system likewise is ideal in helping a close-growing crop such as wheat or lucerne to germinate uniformly. There is no better system than sprinkler irrigation to apply water uniformly on steep or hilly land. Moreover, this method is well adapted to shallow soils that lie over bedrock or a hardpan. In some countries, nitrogen and potash fertilizers may be successfully applied to crops by introducing a solution of these fertilizers into the sprinkler irrigation system.

WILD FLOODING

Wild flooding is the oldest, most common, and most primitive method of irrigation; it is also the least efficient in the use of water. It has been estimated that with wild flooding only about 10 per cent of the irrigation water at its source is actually consumed by the plants. The other 90 per cent is lost as run-off, deep seepage, and evaporation. Moreover, crops growing in the low spots in the field
are drowned, while crops on mounds and ridges are under-irrigated. As a result, crop growth is not uniform and the average yields are low.

Wild flooding consists of opening a water channel so that water can flow freely in all directions. Men with shovels or similar implements "tease" the water over the field with a small ditch here or a small bund there to try to get uniform distribution.

Although primitive and inefficient, wild flooding is still popular in areas where there is an abundance of water to spread on low-value-per-acre crops. Many enlightened farmers would change to a more efficient method of irrigation if they had the technical assistance and a small loan for the purpose (Plate LXXVII).

WATER APPLICATION

Applying irrigation water is both a science and an art. It is a science because a scientist with expensive and delicate instruments can determine quite accurately when it is time to apply irrigation water and how much to apply.

The cultivator, however, cannot do this. The best he can do is to learn as much of the practical science as possible and then to use his judgment (art) in making decisions.

WHEN TO START IRRIGATING

When plants need more water, they usually wilt. If this happens over the entire field, it is probable that the final yields have already been reduced, even though water is applied immediately. One good way to determine when to start irrigating is to observe the initial wilting of plants growing on the driest part of the field.

WHEN TO STOP IRRIGATING

To determine when to stop irrigating, walk into the field where water has just been applied and push a stick or iron rod into the soil. The probe will push easily into the wet soil but will be very hard to push in dry soil. Probe the soil several times over the field to get the average depth of water penetration. Stop irrigating when the moisture has penetrated to within about 3 inches of the
desired depth. After the irrigation water has been stopped, the water will gradually seep down the last 3 inches to wet the soil to the predetermined depth, usually to a depth of one to two feet (Plate LXXVIII).

DRRAINAGE

On many farms, wet soils are often the most fertile soils. But because the soils are too wet for a part of the year (unless used for rice production) they produce only a fraction of their potential yield. When adequately drained, wet soils may produce abundant crops. Drainage means the removal of surplus water from a field to make the conditions more favourable for the growth of crop plants.

A wet soil is likely to be compact or dense. Plant roots cannot spread easily through a compact soil. For this reason, the use of manure or fertilizer on a compact soil that requires drainage is a waste of time and money.

After a wet soil is drained, it can be worked sooner after a rain. Seeds germinate faster and a better stand is obtained. On a well-drained soil, plants are freer from insects and diseases. On soils in need of drainage, plants may drown out after a rain. Moreover, with a well-drained soil there are fewer crops lost at harvest time because of wet soil.

A properly drained field will not have wet spots and can therefore be farmed more efficiently because the entire field can be ploughed, planted, and cultivated at the same time. A bigger as well as a more uniform yield is obtained over the entire field when all wet areas are adequately drained.

Crops planted on lands which need drainage often "burn out" during a drought. A soil that is nearly saturated at planting time will restrict root development to the surface of the soil. Later, when droughts come, the water table falls below the root zone and the crop gets too little moisture. In well-drained land, however, the roots go down deeper; thus they can draw on deeper moisture and the plants are better able to withstand periods of drought (Figure 105).

Proper drainage is required in irrigated fields to remove excess water. In areas where salt accumulation is a problem, drainage is necessary to leach out the harmful salts.
DRAINAGE SYSTEMS

Land can be drained by tile drains or by open ditches. Open ditches occupy valuable crop land; are usually hard to cross with farm implements and they choke up with weeds and silt and should be cleaned several times a year. Unless the open ditches are deep they drain only the soil surface; but their first cost is less than the tile drainage. For compact clay soils in humid areas, surface drainage by open ditches is usually necessary because water will not move downward fast enough.

Tile drains, on the other hand, waste no land and do not interfere with farm operations. They need little care once they are installed. Since they drain the pores of the soil, the roots of crops are more extensive. But tile drains require more cash outlay in the beginning, and they are not effective in some compact, clay soils.

Only conditions in the area involved can determine the kind of drainage needed and the method of doing the work. What is good in one place may not be good in another. The soil, the slope of the land, the crops raised, and the value of the land must all be considered. An adequate drainage system often involves a number of farms, sometimes a whole watershed (catchment area). In such
cases it is better to plan the drainage system on an area basis rather than farm by farm.

The first thing to determine is whether the land can produce enough additional crops to make it worthwhile to install a drainage system; for drainage is expensive. The next step is to decide whether to use the open drainage or the tile drainage system.

**Tile Drainage**

*Tile drainage* consists of digging a narrow trench, placing short sections of tile end-to-end at the bottom, and covering the tile with earth to the original level. The joint between each two sections of tile serves as a place where drainage water may enter the drainage system.

The satisfactory layout of a tile drainage system requires considerable planning and experience. Often an unschooled but experienced labourer will have better "luck" than a recent college graduate with many handbooks. The best job can be done, however, with both formal schooling and "schooling by doing". Technical assistance in the layout and installation of a tile drainage system can usually be obtained from the Department of Agriculture in each State.

A tile drainage system will be satisfactory for a century or more if properly planned, adequately constructed, and carefully maintained. The depth and spacing to lay the lines of tile will vary with the crops grown and the type of soil. Soils with slow downward movement of water should have shallower placings of the lines of tile and the lines should be laid closer together. Drainage to be established for lucerne or orchards needs a depth of tile of about 4 feet. Maize needs intermediate depths and the grasses and small grains such as wheat can get along best with the tile lines placed about 2 feet deep.

Spacings may vary from 40 to 300 feet between lines of tile, depending upon the soil drainage capacity. In clay and clay loam soils, the depth of the tile should not exceed 3 feet and the spacing between lines should not be more than 70 feet. Tile lines in silt loam soils can be placed 4 feet deep and 100 feet apart. The respective maximum depth and spacing of lines recommended in sandy soils is 4.5 feet and 300 feet. In all saline soils the tile should be deeper.
Outlets for tile lines should be screened to prevent rodents from plugging them. Outlets should also be encased in cement, with a suitable apron to prevent undercutting by flowing water. Also the last 10 feet of tile back from the outlet should be cemented at the joints. Other tiles in the lines are placed end-to-end and with no cement, to permit water to seep between each two sections of tile. In some silty soils, before burying the tile it is desirable to lay a handful of grass across the top of the line of tiles where they join. This material is to reduce the amount of silt flowing into the tile system until the loose soil becomes settled around the tiles.

**SURFACE DRAINAGE**

Surface drains may consist of open ditches that are laid out by eye, leading from one wet spot to another, and finally into a *nala* or river. This is often called the *natural system*. Often such a drainage system is too steep in some places and causes erosion, or it does not have sufficient grade to discharge the excess water fast enough.

The surface drainage system may also consist of a ditch at the base of a slope to divert excess water from the field above. This drainage system is sometimes called the *diversion system*.

The *gridiron system* of drainage is an open-ditch method of drainage. The pattern of ditches is regular, resembling the lines on graph paper. The method is adapted to land which has a uniform slope.

Field ditches for surface drains may be either narrow with nearly vertical sides, or V-shaped with straight side slopes. V-shaped ditches have the advantage of being easier to cross with large machinery. Narrow ditches are most common where large machinery is not used.

Land occupied by narrow, steep-sided ditches cannot be cultivated. Where many of them are required, a considerable area is lost to cultivation. Neither can large V-shaped ditches be cultivated; but many can be planted to grass and the grass cut for fodder. Where very closely-spaced field drains are needed, V-shaped ditches can be made very shallow and broad and the sides of the ditches cultivated with the rest of the field.

In level areas, a collecting ditch may need to be installed along one side of the field and shallow V-shaped ditches constructed to
discharge into the collecting ditch. The field ditches should be laid out parallel and spaced 50 to 150 feet or more apart as required by the soil, surface conditions, and crops to be grown. They should be 12 to 24 inches deep, depending upon the depth of the collecting ditch.

Farming operations should be parallel to the field ditches. In ploughing with a mould-board plough, back furrows should be established midway between the ditches, and all furrows turned toward the middle. This will give each "land" a slight crown and will keep the ditches open. If this practice is followed for several years, the land acquires a considerable crown. Therefore, it is best not to use this system where land should be kept as level as possible. This is especially true where field drains supplement tile drains in the same field.

The area that a ditch will drain satisfactorily depends on how quickly water runs into it, its size, its grade, and its irregularity. The irregularity is affected both by the roughness of the ditch section and the debris and vegetation in the ditch. How quickly water runs into the ditch depends on how much rain falls, the slope of the land, the condition of the soil, and the plant cover. Field ditches and outlet ditches to drain up to 600 acres of gently sloping land should be large enough to remove from \( \frac{1}{2} \) to 3 inches of water in 24 hours depending upon the conditions described above.

Flowing water has power to erode drainage channels as well as land surfaces. In many cases, it is practicable to keep the water in the drainage ditch at a low velocity by constructing the ditch in sections having less fall than the natural slope and connecting those sections with vertical drop spillways.

**DRAINAGE FOR IRRIGATION SYSTEMS**

During the early years of irrigation, the main concern was to obtain an adequate water supply. Little concern was given to the quality of the water or whether irrigation practices resulted in water-logged and salty soils.

Soils become water-logged and salty upon irrigation because adequate drainage is not installed. *Every field that is irrigated must also have a suitable drainage system* (Plate LXXIX).

The major sources of excess water that must be removed by artificial drainage are deep percolation losses on irrigated lands and
seepage losses from reservoirs and canals. On most irrigation projects, deep percolation losses of water from channels is one of the main causes of a water-logged soil. There is a tendency for many engineers to place all of the blame on the farmer by accusing him of over-irrigating. While this is true in many cases, the fact remains that a high water table may develop even under the best of irrigation practices. The lateral movement of unconfined or free ground water and the upward flow of confined water from an artesian aquifer (water-bearing bed) are often minor sources of excess water. In either or both cases the origin of this water may be seepage losses from canals or deep percolation losses from irrigated lands. Efficient water application on the higher lands will often reduce the need for drainage on the lower lands. In fact, good irrigation practices throughout an irrigation project are essential if drainage problems are to be kept to a minimum. No one can doubt the fact that irrigation and drainage must go hand in hand.

The relationship between salinity and drainage must be clearly understood. Salts in the irrigation water, in the soil, or in shallow ground water, increase the need for drainage. In other words, the depth to the water table must be such that the upward flow of salty ground water into the plant root zone is either reduced or eliminated.

**SUMMARY**

India appears to have adequate water but it is not well distributed. Increasing storage facilities for water to be used for irrigation is a very important assignment that India is now carrying out. Reducing the losses of water, utilizing more efficient methods of lifting water, and applying the correct amount of water, can all assist in increasing production of crops with a given amount of water. Selling irrigation water to farmers on a volume basis instead of crop-wise per acre will encourage a more efficient use of water.

The *wild-flooding* method of irrigation is very wasteful of water. This method should be replaced by the *basin, furrow, border* or *sprinkler* method. Applying the correct amount of irrigation water can be accomplished after a study of the suggestions offered in this chapter and the application of good judgement.

All irrigation systems should have a drainage system surveyed and established at the same time. Drainage systems may be any one of several kinds of tile drains or open drains.
IRRIGATION AND DRAINAGE

QUESTIONS

1. How can losses of irrigation water be reduced?
2. Which irrigation method is least efficient? Why is it so popular? What can be done to eliminate it?
3. How may a farmer judge when to start irrigating?
4. When should a farmer stop irrigating?
5. Why should every irrigated field have a drainage system?

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Appendix A

CONVERSION FACTORS*

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<tr>
<td>1 metre</td>
<td>1.09361 yards</td>
</tr>
<tr>
<td>1 kilometre</td>
<td>0.62137 mile</td>
</tr>
</tbody>
</table>

## Conversion Factors—Contd.

<table>
<thead>
<tr>
<th>British Units</th>
<th>Metric Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>144 square inches = 1 square foot</td>
<td>100 square millimetres (sq mm) = 1 square centimetre (sq cm)</td>
</tr>
<tr>
<td>9 square feet = 1 square yard</td>
<td>100 square centimetres = 1 square decimetre</td>
</tr>
<tr>
<td>4,840 square yards = 1 acre</td>
<td>100 square decimetres (1 sq m = 10,000 sq cm)</td>
</tr>
<tr>
<td>640 acres = 1 square mile</td>
<td>100 square metres = 1 are or 1 square dekametre</td>
</tr>
<tr>
<td></td>
<td>100 ares = 1 hectare or 1 square hectometre</td>
</tr>
<tr>
<td></td>
<td>100 hectares = 1 square kilometre</td>
</tr>
</tbody>
</table>

### Conversion Factors

- 1 square inch = 6.4516 square centimetres (exact)
- 1 square foot = 9.2903 square decimetres
- 1 square yard = 0.83613 square metre
- 1 acre = 0.404686 hectare
- 1 square mile = 2.58999 square kilometres
- 1 square centimetre = 0.155000 square inch
- 1 square metre = 1.19599 square yards
- 1 hectare = 2.47105 acres
- 1 square kilometre = 0.386101 square mile
## Weight

### Basic Units of Weight

<table>
<thead>
<tr>
<th>British Units</th>
<th>Metric Units</th>
<th>Indian Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>16 drams</td>
<td>10 milligrams (mg) = 1 centigram</td>
<td>80 tolas = 1 seer</td>
</tr>
<tr>
<td>16 ounces</td>
<td>10 centigrams = 1 decigram</td>
<td>40 seers = 1 maund</td>
</tr>
<tr>
<td>28 pounds</td>
<td>10 decigrams = 1 gram (1 g = 1000 mg)</td>
<td></td>
</tr>
<tr>
<td>4 quarters</td>
<td>10 grams = 1 dekagram</td>
<td></td>
</tr>
<tr>
<td>20 hundred-weights</td>
<td>10 dekagrams = 1 hectogram</td>
<td></td>
</tr>
<tr>
<td></td>
<td>10 hectograms = 1 kilogram (1 kg = 1000 g)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>10 kilograms = 1 myriogram</td>
<td></td>
</tr>
<tr>
<td></td>
<td>10 myriograms = 1 quintal</td>
<td></td>
</tr>
<tr>
<td></td>
<td>10 quintals = 1 metric tonne</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(1 tonne = 1000 kg)</td>
</tr>
</tbody>
</table>

### Conversion Factors

1 gram = 0.0352740 ounce = 0.085735 tola
1 kilogram = 2.20462 pounds = 1.07169 seers
1 metric tonne = 0.98420 ton = 26.7923 maunds

1 ounce = 28.3495 grams
1 pound = 0.4535924 kilogram
1 ton = 1.01605 metric tonnes

9 pounds = 350 tolas (exact)
### CONVERSION FACTORS—Contd.

#### Capacity

<table>
<thead>
<tr>
<th>British Units</th>
<th>Metric Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 gills</td>
<td>10 millilitres (ml) = 1 centilitre</td>
</tr>
<tr>
<td>2 pints</td>
<td>10 centilitres = 1 decilitre</td>
</tr>
<tr>
<td>4 quarts</td>
<td>10 decilitres = 1 litre</td>
</tr>
<tr>
<td></td>
<td>(1 litre = 1,000 ml)</td>
</tr>
<tr>
<td></td>
<td>10 litres = 1 dekalitre</td>
</tr>
<tr>
<td></td>
<td>10 dekalitres = 1 hectolitre</td>
</tr>
<tr>
<td></td>
<td>10 hectolitres = 1 kilolitre</td>
</tr>
</tbody>
</table>

#### Conversion Factors

<table>
<thead>
<tr>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 pint</td>
<td>= 0.56824 litre</td>
</tr>
<tr>
<td>1 quart</td>
<td>= 1.13649 litres</td>
</tr>
<tr>
<td>1 gallon (Imperial)</td>
<td>= 4.54596 litres</td>
</tr>
<tr>
<td>1 litre</td>
<td>= 1.75980 pints</td>
</tr>
<tr>
<td>1 litre</td>
<td>= 8.87990 quart</td>
</tr>
<tr>
<td>1 litre</td>
<td>= 0.219976 gallon (Imperial)</td>
</tr>
</tbody>
</table>

**Note:** In addition to British Imperial gallon, gallon as recognized in the United States of America is also used in India. The conversion factors for gallons (U.S.) to litres and gallons (Imperial) are:

1 gallon (U.S.) = 3.78533 litres
                   = 0.83268 gallon (Imperial)
**CONVERSION FACTORS—Contd.**

**THERMOMETER SCALES**

Degrees Fahrenheit to Degrees Centigrade*

<table>
<thead>
<tr>
<th>Fahrenheit</th>
<th>Centigrade</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-17.2</td>
</tr>
<tr>
<td>2</td>
<td>-16.7</td>
</tr>
<tr>
<td>3</td>
<td>-16.1</td>
</tr>
<tr>
<td>4</td>
<td>-15.6</td>
</tr>
<tr>
<td>5</td>
<td>-15.0</td>
</tr>
<tr>
<td>6</td>
<td>-14.4</td>
</tr>
<tr>
<td>7</td>
<td>-13.9</td>
</tr>
<tr>
<td>8</td>
<td>-13.3</td>
</tr>
<tr>
<td>9</td>
<td>-12.8</td>
</tr>
<tr>
<td>10</td>
<td>-12.2</td>
</tr>
<tr>
<td>20</td>
<td>-6.7</td>
</tr>
<tr>
<td>30</td>
<td>-1.1</td>
</tr>
<tr>
<td>40</td>
<td>+4.4</td>
</tr>
<tr>
<td>50</td>
<td>+10.0</td>
</tr>
<tr>
<td>60</td>
<td>+15.6</td>
</tr>
<tr>
<td>70</td>
<td>+21.1</td>
</tr>
<tr>
<td>80</td>
<td>+26.7</td>
</tr>
<tr>
<td>90</td>
<td>+32.2</td>
</tr>
<tr>
<td>100</td>
<td>+37.8</td>
</tr>
<tr>
<td>200</td>
<td>+93.3</td>
</tr>
<tr>
<td>300</td>
<td>+148.9</td>
</tr>
<tr>
<td>400</td>
<td>+204.4</td>
</tr>
<tr>
<td>500</td>
<td>+260.0</td>
</tr>
</tbody>
</table>

* To convert degrees Fahrenheit to degrees Centigrade, subtract 32 from the °F and multiply by 5/9. For example:

\[ ^{\circ}C = \frac{5}{9} (^{\circ}F - 32) \]  
When F = 50, F - 32 = 18, \( \frac{5}{9} \times 18 = 10^\circ C \).
CONVERSION FACTORS—Concl.

THERMOMETER SCALES

Degrees Centigrade to Degrees Fahrenheit*

<table>
<thead>
<tr>
<th>Centigrade</th>
<th>Fahrenheit</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>32.0</td>
</tr>
<tr>
<td>1</td>
<td>33.8</td>
</tr>
<tr>
<td>2</td>
<td>35.6</td>
</tr>
<tr>
<td>3</td>
<td>37.4</td>
</tr>
<tr>
<td>4</td>
<td>39.2</td>
</tr>
<tr>
<td>5</td>
<td>41.0</td>
</tr>
<tr>
<td>6</td>
<td>42.8</td>
</tr>
<tr>
<td>7</td>
<td>44.6</td>
</tr>
<tr>
<td>8</td>
<td>46.4</td>
</tr>
<tr>
<td>9</td>
<td>48.2</td>
</tr>
<tr>
<td>10</td>
<td>50.0</td>
</tr>
<tr>
<td>20</td>
<td>68.0</td>
</tr>
<tr>
<td>30</td>
<td>86.0</td>
</tr>
<tr>
<td>40</td>
<td>104.0</td>
</tr>
<tr>
<td>50</td>
<td>122.0</td>
</tr>
<tr>
<td>60</td>
<td>140.0</td>
</tr>
<tr>
<td>70</td>
<td>158.0</td>
</tr>
<tr>
<td>80</td>
<td>176.0</td>
</tr>
<tr>
<td>90</td>
<td>194.0</td>
</tr>
<tr>
<td>100</td>
<td>212.0</td>
</tr>
<tr>
<td>200</td>
<td>392.0</td>
</tr>
<tr>
<td>300</td>
<td>572.0</td>
</tr>
<tr>
<td>400</td>
<td>752.0</td>
</tr>
<tr>
<td>500</td>
<td>932.0</td>
</tr>
</tbody>
</table>

* To convert degrees Centigrade to degrees Fahrenheit, multiply the °C by 9/5 and add 32. For example:

  *F = 9/5°C + 32. When C = 50, 9/5 × 50 = 90, plus 32 = 122.0°F.
Appendix B

GLOSSARY OF INDIAN AND TECHNICAL WORDS WITH THEIR SCIENTIFIC NAMES AND ENGLISH EQUIVALENTS

ABUTILON: *Abutilon indicum*. Indian Mallow; Kanghi (Hindi); Japa-Petari (Bengali).


AILANTHUS: *Ailanthus* sp. “Tree of Gods”.

ALMOND: *Prunus amygdalus*. Badam (India).

AMLA (Hindi): Emblic Myrobalan; *Phyllanthus emblica*.

ANWAL (India): *Cassia auriculata*.

APPLE: *Pyrus malus*; Seb (India).

Babul: *Keekar* (India), *Acacia arabica*.

Bajra (India): Bulrush Millet, *Pennisetum typhoides*.

BANANA: Kela (Hindi), *Musa paradisiaca*.

BARLEY: Jau (Hindi), *Hordeum vulgare*.

BEANS belong to the Family of Papilionaceae in Leguminosae Natural Order:

- Broad Bean: *Raj Mah* (Punjabi), *Vicia faba*.
- Cluster Bean: Guara (Hindi), *Cyamopsis psoraloides*.
- Country Bean: Hyacinth Bean, *Dolichos lablab*.
- Double Bean: Rawan (Punjabi), *Phaseolus lunatus*.
- French Bean: Jungli Sem (Hindi), Frans Bean, *Phaseolus vulgaris*.
- Kidney Bean: Moth (India), *Phaseolus aconitifolius*.
- Lima Bean: Rawan (Hindi), *Phaseolus limensis*.
- Soya Bean: Soyabeen (India), *Glycine max*; *G. hispida*.

BEET: *Beta vulgaris*; Chakander (India).

BEETLES: Coleopterous insects.

BEGONIA: Elephant Ear Plant; *Begonia* sp.

BER (India): *Zizyphus jujuba*; Jujube.

BERSEEM (India): Egyptian Clover, *Trifolium alexandrinum*.

BHARAT KRISHAK SAMAJ (Hindi): Farmers Forum of India.

BHENDI (Hindi): Lady's Finger; *Hibiscus esculentus*; *Abelmoschus esculentus*.

BIRDS: *Aves*.

BITTER GOURD: Karela (India), *Benincasa hispida*.

BREAD FRUIT: Khadel (Hindi), *Artocarpus incisa*.


BROCCOLI: A cabbage-like garden vegetable with loose, green, leafy edible flower panicles.

BRYOPHYLLUM: Sprout-Leaf Plant; Zakhm-i-Hayat (India), *Bryophyllum pinnatum*.

BUTTERFLIES: Lepidopterous insects.

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CABBAGE: *Bandgobhi* (Hindi), *Brassica oleracea* var. *capitata*.

CALOTROPIS: *Ak*; *Madar* (India), *Calotropis gigantea*; *C. procera*.

CAMPHOR: A solid volatile oil obtained by steam distillation of wood of the camphor tree (*Cinnamomum camphora*); *Mushkkafoor*; *Kapur* (Hindi).

CARDAMOM: *Amomum aromaticum*, *Chhoti Khushbudar ilaichi* (Hindi); *A. subulatum*, *Bari Ilaichi* (Hindi); *Elettaria cardamomum*.

CARROT: *Gajar* (Hindi), *Daucus carota*.

CASHEWNUT: *Kaju* (Punjabi), *Anacardium occidentale*.

CASTOR: *Arind* (Hindi), *Ricinus communis*.

CASUARINA: Beef Wood Tree; Swamp Oak; *Jhau* (Hindi), *Casuarina equisetifolia*.

CAULIFLOWER: *Pulogobhi* (Hindi), *Brassica oleracea*.

CHICORY: *Kashni* (Hindi), *Cichorum intybus*.

CHILLIES: *Lal Mirch* (Hindi), *Capsicum annuum*; *C. frutescens*.

CINCHONA: Quinine; *sinkona* (Punjabi), *Cinchona officinalis*.

CINNAMON: Spicy bark of a laurel; *Dalchini* (Hindi), *Cinnamomum zeylanicum*.

CLOVES: Flower-buds of Clove Tree; *Laung* (Hindi), *Syzygium aromaticum*.

CLOVERS:

- Bur Clover: *Lusan* (Punjabi), *Medicago hispida*.
- Egyptian Clover: Berseem, *Trifolium alexandrinum*.
- Indian Clover: *Senji* (Punjabi), *Melilotus parviflora*.
- Lucerne: *Lusan* (Hindi), *Medicago sativa*.
- Persian Clover: *Shaftal* or *Shatala* (Punjabi), *Trifolium rusatunatum*.

COCOA: *Coco* (Punjabi), *Theobroma cacao*.

COCONUT: *Naryal* (Hindi), *Cocos nucifera*.

COFFEE: *Kafi* (Punjabi), *Coffee arabica*.

COLOCASIA: *Colocasia antiquorum*.

CONIFERS: Gymnosperm (naked-seeded plants).

CORIANDER: *Dhana* (India), *Coriandrum sativum*.

COTTON: *Kapas* (India), *Gossypium herbaceum*.

CUCUMBER: *Kheera* (Punjabi), *Cucumis sativus*.

CUSTARD APPLE: *Seetaphhal* (Hindi); *Sharifa* (India), *Anona squamosa*.

CYCADS: Gymnosperm (Naked-seeded plants).

DAHLIA: *Dahlia* sp. A tuber-rooted perennial.

DATE PALM: *Khajur* (India), *Phoenix dactylifera*.

Desi (India): Native; indigenous.

Dhaincha (India): *Sesbania aculata*. A green manure crop.

EARTHWORMS: *Gandoya* (Punjabi), *Pheritima posthuma* (Commonest Indian earthworm).

ELEPHANT FOOT: *Ziminkand* (India), *Amorphophallus campanulatus*.

ELEPHANT GRASS: *Hathi Ghah* (Punjabi), *Pennisetum purpureum*.


EUCALYPTUS: *Junklattar* (Punjabi), *Eucalyptus globulus*. Yields Eucalyptus Oil.

FLAX: The fibres of the plant *Linum* sp. (Linseed) that are woven into linen cloth.
Gaon (Hindi): Village.
Gaon Sabha (Hindi): Village organisation.
Garlic: Thom (Punjabi), Lesan (India), Allium sativa.
Geranium: Crane’s Bill; Geranium sp. (many kinds). With showy flowers.
Ghee (Hindi): Clarified Butter; Butter Oil.
Ginger: Adrak (India), Zingiber officinale.
Goiitre: An iodine deficiency disease in which glands of the neck of the animal enlarge and the eyes bulge out.
Gourd: Ghiaitori and Kali tori (Hindi), Luffa aegyptica.
Gram (Hindi): Village.
Grass: Channa (India); Chhola (Punjabi); Kadalai (South India); Cicer arietinum; Bengal Gram.
Grape: Angur (India), Vitis vinifera.
Groundnut: Peanut; Mungphali (India), Arachis hypogaea.
Guar (India): Field Vetch; Cluster Bean; Cyamopsis psoralioides; C. tetragonoloba.
Guinea Grass: Gini ghah (Punjabi), Panicum maximum.
Gur (Hindi): Crude brown sugar in lumps made by heat evaporation of water from sugar cane juice.
Gypsum: Calcium sulphate—CaSO4.

Hariali (India): Bermuda Grass, Cynodon dactylon.

Hemp:

Cannabis indica: Bhang; Ganja (Hindi).
Indian Hemp: Crotalaria juncea, Sannhemp.
Manila Hemp: Ravenala sp., Hemp of Commerce.
Sisal Hemp: Agave sisalana, Seesal (India).
Bowstring Hemp: Cordyline sp.

Henna: Mehndi (India), Lawsonia inermis. Used as a hair dye.
Hibiscus: Madras or Deccan Hemp, Hibiscus cannabinus.

Honey Bee:

Rock Bee or the Giant Bee of India: Apis dorsata.
Indian Bee: Apis mellifica-indica.
The Little Bee or the Flower Bee: Apis florea.
The Dammar Bee or the Mosquito Bee: Tragona sp. and Melipona Bees.

Huloa, Wild: Atylosia scarabaeoides.

Hyacinth Bean: Dolichos lablab.

Indigo: Neel (Hindi), Indigofera tinctoria.
Insects: Class Insecta (Arthropoda), with 3 pairs of legs.

Jack Fruit: Kathal (Punjabi), Artocarpus integrifolia.
Jand (Hindi): Khejri (Rajasthan), Prosopis spicigera.
Jasmine: Yielding flowers of great fragrance:

Night Jasmine: Nyctanthes sp., Harshingar (Hindi).
Queen of the night: Cestrum sp., Hasnahan (Hindi); Rat ki Rani (India).
APPENDIX B

Cape Jasmine: Gardenia sp., Gandharaj (Hindi).
Bela (Hindi): Jasminum sambac, Jasmine.

JOHNSON GRASS: Sorghum halepense.
Jowar (Hindi): Great Millet, Andropogon sorghum.
JUTE: Patsan (India): Corchorus capsularis; C. olitorius.

KALE (Hindi): A cabbage-like plant with open curled leaves; Bundhgbobhi; Brassica oleracea acephala.
Kankan (India): Small limestone; Murrum (India).
Kharif (India): Summer crops.
Khesari (India): Chickling Vetch, Lathyrus sativus.
Khimp (India): Leptadenia spartium.
Khurpi (Punjabi): Hand Hoe.
Krishak Sabha (Hindi): A Farm Organisation.
Krishak Samaj (Hindi): Farmers Forum.
Kulthi (India): Horse Gram, Dolichos uniflorus; D. biflorus.
Kumat (India): Acacia senegal.

Landga (India): Cockle Bur, Xanthium sp.
Lavala (India): Nut Grass, Cyperus sp.
LAVENDER: Lavandula sp., Yields lavender oil (perfume).
LEMON: Nimbu (India), Citrus limonia.
LENTIL: Massur or Massar (India), Lens esculenta; L. culinaris.
LETTUCE: Salad (India), Lactuca sativa.
LUCERNE: Lusan (Punjabi); Alfalfa, Medicago sativa.

MAHOGANY: Swietenia mahogani (Spanish); Khaya ivorensis (African).
MAIZE: Makki (India); Zea mays.
MANGO: Am or Amb (India), Mangifera indica.
MESQUITE: Prosopis juliflora.
Methra (India): Fenugreek, Trigonella foenugraecum.

Mhote (India): A water-lifting contrivance in which a large leather bucket is hauled up and down the well by bullocks or camels walking on a sloping ramp nearby. The bucket is pulled up by ropes, one end of which is tied to the bucket and the other to the bullock’s yoke. The rope moves on a wooden pulley (Charsa).

MILLETS:

Barnyard Millet: Echinochloa colona var. frumentosa. Swank (Hindi).
Bullrush Millet: Pearl Millet, Pennisetum typhoides, Bajra (Hindi).
Common Millet: Panicum miliaecum, Chaena (Hindi).
Finger Millet: Eleusine coracana, Ragi (South India).
Great Millet (Sorghum): Andropogon sorghum; Sorghum vulgare, Jowar (Hindi).
Italian Millet: Setaria italica, Kangni (Punjabi).
Little Millet: Panicum miliare, Swank (India).

MINT: Mentha piperita; M. arvensis, Poodina (Hindi).
Moth (India): Kidney Bean, Phaseolus aconitifolius.
MULBERRY: *Shahtoot or Toot* (India), *Morus alba.*  

**Nala** (Hindi): Drain.  
**Napier Grass:** *Napier Ghah* (Punjabi), *Pennisetum purpureum.*  
**Nasturtium:** Water-cress, *Tropaeolum sp.*; *Nasturtium officinale.*  
**Neem** (India): *Azadirachta indica.*  
**Niger:** *Kala Til* (India): *Guizotia abyssinica.*  
**Nutmeg:** *Jaiphal* (Hindi), *Myristica laurifolia*; *M. fragrans.*

**Oats:** *Jawi* (India), *Avena sativa.*  
**Onion:** *Piaz* (India), *Ganda* (Punjabi), *Allium cepa.*  
**Orange:** *Santra* (Punjabi); *Narangi* (India), *Citrus reticulata.*

**Palm**s belong to Palmaeae Natural Order:  
Betelnut Palm: *Areca catechu,* Arecanut: *Supari* (Hindi).  
Bottle Palm: *Oreodoxa regia.*  
Cabbage Palm: *Areca oleracea.*  
Double Coconut Palm: *Lodoicea sp.; Cocos nucifera; Naryal* (Hindi).  
Edible Date Palm: *Phoenix dactylifera,* *Khajur* (India).  
Ivory Palm: *Phytelaphus sp., Zalacca beccarii.*  
Oil Palm: *Elaeis guineensis sp., Hyphaene sp.*  
Nipa Palm: *Nipa fruticosa; Golpata* (Bengali).  
Palmyra Palm: *Borassus flabellifer; Tar* (Hindi).  
Sago Palm: *Fishtail Palm, Metroxylon rumphii; Caryota sp.*  
Sugar Palm: *Arenga saccharifera.*  
Talipot Palm: *Corypha sp.*  
Toddy Palm: *Caryota urens.*  
Wild Date Palm: *Phoenix sylvestris, Khajur* (India).

**Palm sugar:** A palm yielding toddy (Palm wine) from which sugar is made.  
Panchayat: (Hindi) A system of local self-government of the villages.  
Panchayat Samiti (Hindi): Council of representatives of the village Panchayat in a Development Block.  

**Papaya:** *Carica papaya; Papita* (India).  
Pea (Field): *Pisum arvense; P. sativum, Muttar* (India); Garden Pea.  
Pear: *Pyrus communis; Nashpati* (India).  
Peepal (India): *Ficus religiosa.*  
Pepper (Black): *Piper nigrum; Kali Mirch* (India).  
Persian Wheel: The water is lifted in it in a series of small buckets fixed on an endless belt which moves on a vertical wheel. The bullocks walking in a circle turn the drum through a bevel of gears. *Rehat* (India).  

**Phog:** *Calligonum polygonoides.*  
**Piccottah:** A contrivance for lifting water in which a wooden beam is mounted in a see-saw fashion on a vertical pillar fixed near a well. A bucket with a long rope is tied to one end of the beam and the other end is counter-balanced with a heavy stone. *Dhindri* (Punjab).
PINE: *Pinus* sp. (Conifers); *P. Khasya*; *P. sylvestris*; *P. longifolia*; *P. excelsa*. Pine-nut is *Chilghaza* (India).

PINEAPPLE: *Ananas sativa*; *Ananas* (India).

POPPY: *Papaver somniferum*; *Post* (India).

POTATO: *Solanum tuberosum*; *Alu*.

PUMPKIN: *Cucurbita pepo*; *C. moschata*; *Halwa Kaddu* (Punjab); *Kashiphal* (Hindi).

**Rabi** (India): Winter crops.

**Ragi** (India): *Eleusine coracana*; Finger Millet.

**Rice** (Paddy-Unhulled Rice): *Oryza sativa*; *Chawal Dhan* (Hindi).

**Rose**: *Rosa damascena*; Damask or Bussora Rose; *Gulab* (India).

**RYOTS** (India): Farmers; Cultivators.

**Sabha** (Hindi): Organisation.

**SAFFLOWER**: *Carthamus tinctorius*, *Kusum* (Hindi); *Jungli Kesar* (Punjab).

**Sal** (India): *Shorea robusta*.

**Sandal** (India): *Santalum album*.

**SANNHEMP**: *Crotalaria juncea*; *Sann* (Hindi).

**Senji** (India): *Melilotus parviflora*; Indian Clover.

**SESAMUM**: *Sesamum indicum*; *Gingelly*; *Til* (India).

**SESBANIA**: *Sesbania cannabina*; *Dhaíncha* (India).

**Shaftal** (India): *Trifolium rusupinatum*; *Shatala* (Punjab); Persian Clover.

**SNAKE GOURD**: *Trichosanthes anguina*; *Chhachhinda* (Punjab).

**SPINACH**: *Spinacia oleracea*; *Palak* (India).

**SQUASH**: *Sechium edule*; Indian Squash Melon; *Tinda* (India).

**STERCULIA**: *Sterculia alata*.

**SUDAN GRASS**: *Sorghum sudanensis*; *Sudan Ghah* (Punjab).

**SUGARBEET**: *Beta vulgaris*.

**SUGAR CANE**: *Saccharum officinarum*; *Ganna* (Hindi); *Kamad* (Punjab).

**SUNFLOWER**: *Helianthus annuus*; *Surajmukhi* (Hindi).

**SWEET POTATO**: *Ipomea batatas*; *Shakarkandi* (India).

**Taluk** (India): Sub-division of a district.

**TAMARIX**: *Tamarix articulata*; *Ban-jhau* (Hindi).

**TAPIOCA**: *Manihot utilissima*; *M. esculenta*; *Tapioca* (Hindi).

**TEA**: *Camellia thea*; *C. sinensis*; *Chai* (India).

**TEAK**: *Tectona grandis*; *Sagwan* (India).

**TOBACCO**: *Nicotiana tabacum*; *Tambaku* (India).

**TOMATO**: *Lycopersicum esculentum*; *Tamatar* (India).

**Tur** (India): *Cajanus indicus*; Pigeon Pea; *Arhar* (Hindi).

**TURMERIC**: *Curcuma longa*; *Haldi* (India).

**TURNIP**: *Brassica campestris* var. *rapa*; *B. rapa*; *Shalgham* (India); *Gonglu* (Punjab).

**Urid** (India): *Phaseolus mungo* var. *radiatus*; *Urad* (India); *Manh* (Punjab).

**Vedic** (India): Of the time of *Vedas*, the four holy books of the Hindus.
WALNUT: *Aleurites moluccana*; *Akhort* (India).

WASPS: Hymenopterous Insects (Many varieties)—Family *Vespidae*.

WATER MELON: *Citrullus vulgaris*; *Tarbuz* (India); *Hadwana* (Punjab).

WHEAT: *Triticum sativum*; *T. aestivum*; *Gandam* (India); *Gehun* (India); *Kanak* (Punjab).

Yam (India): *Dioscorea alata*; *D. bulbifera*; *Ratalu* (India).

Yuvak Krishak Sangh (Hindi): Young Farmers' Association.

Yuvak Mandal (Hindi): A Youth Club.

*Zemindari System* (India): A system of collecting rent or revenue from farmers or tenants by government through certain agents.

*Zilla Parishad* (India): It is the apex of the *Panchayat* organisations at the district level.
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