Elementary Tropical Agriculture

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ELEMENTARY TROPICAL AGRICULTURE

PREFACE

IF the immense, potential agricultural wealth of West Africa is to be extensively developed, it is essential that West African youths should be encouraged to adopt agriculture as a profession, for the unhealthiness of the climate must militate against the direct exploitation of this industry by Europeans.

It appears to me that the best method of removing the antipathy to agriculture exhibited by the majority of educated natives is to introduce agriculture as a specific subject in West African schools.

Although this book is primarily intended for use in connection with the study of the principles of agriculture in West African schools, it is hoped that it will also prove useful for a similar purpose in other tropical countries.

It likewise should be of service to tropical planters, and especially to those who have not had the opportunity of studying these principles prior to taking up tropical planting.

To Sir Daniel Morris, K.C.M.G., lately Commissioner of Agriculture for the West Indies, I am greatly indebted for suggesting alterations in my original manuscript, and also to Mr A. D. Peacock, B.Sc., lately Entomologist, Department of Agriculture, Southern Nigeria, for preparing the diagrams.

W. H. JOHNSON.

14th April 1913.

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INTRODUCTORY

mportance of agriculture in the tropics is well ...rated by the numerous commercial commodities hat are manufactured from the crops produced by armers in these regions. Cotton is extensively employed for making clothes; cocoa, coffee, and ea supply the most largely used beverages. Other mportant articles produced by the tropical farmer are rubber, sugar, tobacco, various spices, condiments, fibres, drugs, and large quantities of seeds, such as ground nut, coco nut, and sesamum, from which oil is extracted for the manufacture of soap, candles, etc.

The word agriculture is derived from two Latin words, *ager*—a field, and *cultura*—cultivation. It, however, has a far wider meaning, for it embraces all factors which affect the production of crops. To ... ultural operations in a profitable manner, ... know what

The soil and atmosphere are of primary importance for it is from them that plants obtain their food. The farmer should therefore know how soils are formed, how plants obtain their food, and what they feed upon; also why certain soils are suitable for particular crops, and why soil becomes exhausted or worn out, and how to renovate it. The cause of disease in plants and the best means of both preventing and attacking different diseases must also be studied by him. Briefly stated, it is not only necessary for him to know how to conduct various agricultural operations, but he must thoroughly understand why these operations are performed.

In the same way it is necessary that work in the school garden should be supplemented with instruction in the principles of agriculture. The practical work in the school garden must not, however, be neglected, for it is there that many of the theories expounded in the class-room may be substantiated by ocular demonstration. Agricultural instruction should not be given with a view to make the pupils learn by heart a whole lot of theory, but to train their powers of observation and encourage them to take an intelligent interest in agricultural matters.

A properly managed school garden should provide a useful object lesson for farmers in the neighbourhood, and prove valuable by introducing new plants to outlying districts. The successful management of the school garden will be largely dependent upon the teacher's ability to excite and maintain his pupils' interest in it. Although it is advisable that they should carry out, as far as possible, the work themselves, it is important to avoid making this work unduly laborious or nauseating in any way. Much good can be done by encouraging pupils to form gardens of their own, at home or on their father's farms.

School gardens may be worked upon two different systems. In one, a piece of land is allotted to each pupil to cultivate upon a prescribed plan. In the second there is no allotment of land to individuals, but the work of the senior and junior pupils is differentiated. Until school gardening in West Africa is better understood, it is considered advisable that the second system should be adopted. For the same reason the scheme of operations should be limited to the cultivation of the more easily raised crops, and on no account should attempts be made to cultivate more land than can be maintained in first-class condition.

Records should be kept of all work performed, and special note-books should be issued to senior pupils for this purpose. Strict discipline must be insisted upon while work in the garden is being carried on. The pupils should be lined up, while two or three of the seniors distribute the necessary tools. Each pupil should have a task allotted to him, and he should not be allowed to leave it without the teacher's permission. When work is completed, all tools should be properly cleaned and then rubbed over with a little greasy substance, such as palm oil, to prevent their getting rusted. Each pupil should be held responsible for the condition of the tool allotted to him and for its safe return. Tool cleaning having been completed, the pupils should be again lined up, and not dismissed until all tools have been stored away in an orderly manner.

Oral instruction on all agricultural matters should be supplemented with object lessons. For example, when the different stages through which a particular insect passes is under discussion, the pupils should collect specimens of this insect and watch these changes proceed. Agricultural matters may be introduced with advantage in other lessons. Flowers and leaves make excellent models for drawing lessons. In testing the vitality of seeds the senior pupils should be requested to ascertain the rate per cent. of germination, both with regard to different kinds of seeds and during different periods.

PART I

THE SOIL AND PLANT LIFE

CHAPTER I

THE SOIL

Soil is the layer of earthy substance which is usually found upon the surface of the land. The primary sources of all food required by plants and animals are the soil and the atmosphere. It is necessary that the agricultural student should devote special attention to the soil. In order that he may do this in an intelligent manner he must know something about its origin and its peculiarities.

The Origin of Soil.—If the sides of a deep pit, from which rock has been removed, be examined it will be usually observed that above the rock is a layer of broken stones closely compacted together with finer material. Next to this is a layer with fewer and smaller stones. The surface layer, which is known as soil, is darker in colour and more loose or friable than the lower layers. If the stones and the rock be compared it will be found that they are similar in character. It is also often possible to trace a resemblance between the stones and the fine, gritty, soil particles. These particles have been formed from the rock which has been broken up through various causes. By removing the soil and exposing the sub-soil to

the air, the surface of the sub-soil is eventually converted into soil. Evidence of this process may be obtained by collecting some of the stones scattered about on the land. Some will be found quite hard but others may be broken by pressure

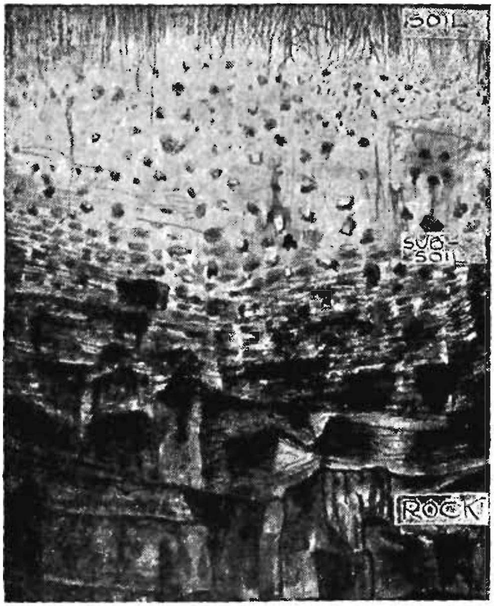
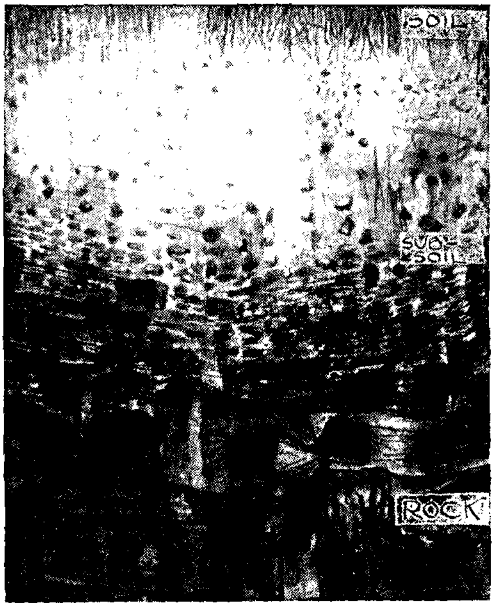


FIG. 1.—Rock, Sub-soil, and Soil.

in the hand. Some idea of the degree to which soil particles are reduced may be formed when it is stated that $2\frac{1}{2}$ oz. of soil have been estimated to contain two thousand million soil particles.

Factors Affecting Soil Formation. — In the breaking up of rocks by natural agencies the most active agent is water. As rain-water falls to the air, the surface of the sub-soil is eventually converted into soil. Evidence of this process may be obtained by collecting some of the stones scattered about on the land. Some will be found quite hard but others may be broken by pressure



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Factors Affecting Soil Formation. — In the breaking up of rocks by natural agencies the most active agent is water. As rain-water falls to the earth it dissolves a gas, to which we shall have to refer frequently, known as carbon dioxide or carbonic acid gas. Now although many of the substances of which rocks are composed are insoluble in pure water, they are soluble in water containing carbon dioxide. Of these substances, chalk or carbonate of lime is most readily soluble in water charged with carbon dioxide. Felspar, a mineral found in crystalline rocks, is attacked in a similar way, with the result that clay is formed.

The effects of running water in soil formation may be seen in any river bed. Channels are worn in the rocks, the banks of the river are washed away, and sharp-edged pieces of rock are ground against each other and converted into sand and pebbles. In West Africa the mangrove islands are excellent examples of the quantity of material brought down by rivers. So also are the stretches of rich, alluvial lands formed in a similar manner in the vicinity of the rivers.

There is an important difference between the physical action and the chemical action of water upon rocks. The material removed by physical action is held by the water in suspension. The material removed by chemical action is held by the water in solution.

An illustration of material held by water in suspension may be obtained by placing river water in a glass tumbler and allowing it to stand for a few hours. The suspended matter becomes deposited on the bottom of the tumbler in the form of a fine sediment.

Atmospheric Action.—The atmosphere and changes of temperature also influence soil formation. Atmospheric air is a mixture principally composed of nitrogen gas and oxygen gas, the former being four times more plentiful than the latter. As already mentioned carbon dioxide is also present, but in a very small proportion as compared with oxygen and nitrogen. We shall have cause to refer to these three gases frequently.

Oxygen is necessary for animal and vegetable life. It is by the assistance of this gas that all burning or combustion takes place. In the case of animals breathing it is taken into the lungs and the waste products from the blood are removed by what is equivalent to slow combustion. Oxygen is a very active gas and its effect on iron materials is everywhere in evidence by the rust which forms on them when they are exposed to the atmosphere. A metal affected in this manner is said to be oxidised, for its rusty appearance is due to the oxygen of the atmosphere combining with the metal. Iron and other constituents of certain rocks are also oxidised in this manner. By this process the breaking up (disintegration) of the rocks is promoted. The oxides thus produced become dissolved in rain water and thus assist in the formation of soil.

In temperate climates frost is an important factor in soil formation, but in the tropics this agent is absent except at very high altitudes. Variations of temperature, however, considerably assist in soil formation in the tropics. The intense heat from the sun during the day causes the rocks to expand, but when the temperature falls at night they contract. This constant expansion and contraction cracks the rocks; pieces flake off from the surface and in time become converted into soil.

The Action of Vegetation.—Vegetation also plays an important part in soil formation. The roots of tiny plants, such as mosses and lichens, which are often found growing on rocks, dissolve the softer parts of the rocks. By this means small particles of sand are liberated. In course of time these plants decay. Vegetable matter is then added to the sandy material liberated by their roots and the atmosphere. Food is thus provided for small hardy plants. These in their turn decay and provide food in a similar manner for still larger plants. Eventually pockets in the rock are formed in which sufficient soil gradually accumulates to support more strong-growing vegetation. The roots enter cracks in the rocks. As growth proceeds the roots expand and force the sides of the rock apart and still further aid in breaking up the rocks.

The enormous force exerted during the growth of roots may often be observed where a large tree has been allowed to grow near the stone or brick walls of a house. These walls are frequently split as the roots develop.

All plants which grow in the ground are constantly assisting to form soil. When a plant is carefully lifted from the ground, its rootlets are seen to be adhering to the tiny particles of stone upon which they are at work. This process, as well as the decay of vegetable matter, proceeds more rapidly in the tropics than in temperate climates. In the tropics vegetable growth is more vigorous and the period of growth is more extended as there is no frost to check it.

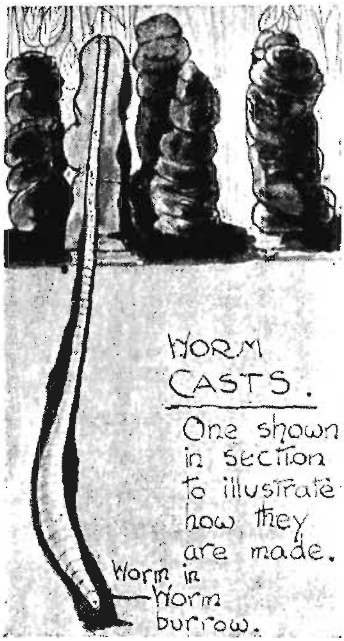

FIG. 2.

Earthworms.—In some parts of the tropics earthworms materially aid in soil formation. These creatures feed upon roots and decaying vegetable matter which they find in the soil. The castings or little heaps of soil, so commonly met with where earthworms occur, consist of very fine soil mixed with organic matter which has passed through the bodies of the earthworms, when making their burrows in the ground.

The student must clearly understand what is meant by the term organic matter, for it will be frequently alluded to in this book ; it means anything produced by or from living organisms, such as plants and animals.

Earthworms also enrich the soil by dragging leaves and other vegetable matter into their burrows. It is estimated that an acre of agricultural land in England contains 50,000 earthworms. Darwin, the great naturalist, considered that, in an ordinary English meadow, they brought to the surface fine soil, in the form of castings, at the rate of 15 tons per annum.

Soil Constituents.—The constituents of soils may be divided into two main groups. One group includes the inorganic or mineral constituents, and the other group the organic or vegetable and animal constituents. The principal constituents comprised in the inorganic group are clay and sand. Lime, in the form of limestone or carbonate of lime, is also generally present. Soils are often classified according to whether clay, sand, or gravel is most abundant in them.

Clay.—When moist the very minute particles of which clay is composed readily cohere to each other. In this condition it is sticky. It is due to this fact that many roads, which have clay on or near the surface, become slippery in wet weather. Moist clay is said to be plastic because it is capable of being moulded into any shape or form.

When rain falls upon clay it has little tendency to drain away; it is thus said to be impermeable to water. As water does not readily drain away from clay soils, they are said to be retentive of moisture.

Heavy and Light Soils.—Soils containing a large proportion of clay are, therefore, damp and cold, and sticky during wet weather. They are often described as heavy soils, while sandy soils are described as light soils. These terms are rather misleading, for it does not necessarily mean that a clay soil weighs more than a sandy soil. It frequently happens that a given quantity of clay soil weighs less than a similar quantity of sandy soil. A clay soil is said to be heavy because it is sticky or tenacious, and difficult to cultivate. A sandy soil is said to be light because it is more loose or open, and therefore more easily cultivated.

Sand.—The fine, gritty or glassy material commonly met with on the seashore, or by the roadside after heavy rain, is known as sand. If a small quantity be examined under a magnifying glass, it will be found to consist of small, water-worn pebbles similar in appearance to those found in gravel.

When sand is thrown into water it rapidly sinks. On the other hand, if sand be placed in a vessel and water be poured into the vessel, it rapidly sinks through the sand. Sand is not retentive of moisture. Unlike clay, moistened sand will not cohere, and if a small quantity be pressed in the hand the particles fall apart so soon as the pressure is removed.

These great differences between the properties of clay and sand should be carefully noted, for, as will be explained later, they are of considerable importance in agriculture.

Sandy Soils.—A sandy soil is of little value to the farmer. Its porous nature does not allow of sufficient water being retained to supply the needs of crops. It is also generally lacking in both the organic and inorganic elements required for the nutrition of plants.

It must not be supposed that sand is of no value in the soil. When it is present in reasonable proportions it improves the physical condition of the soil. It tends to convert heavy or stiff soils into a looser condition, thus rendering them more permeable to air and moisture. It makes cultivation more easy, and facilitates the development of the roots of plants.

Lime.—Nearly all soils contain lime. It is necessary to note the difference between lime and limestone. The latter is carbonate of lime and consists of carbon dioxide united with lime. Quicklime is obtained by burning limestone; the heat drives away the carbon dioxide and quicklime is left behind.

Quicklime is of great value in improving the fertility of soils. It renders clay soils more friable, and therefore more easy to cultivate. When such soils are deficient in lime it is necessary for the farmer to add it in order to improve their fertility.

Later we shall learn that a free circulation of air and moisture is necessary in any fertile soil. Now this does not take place so readily in a clay soil as in lighter soils. But when lime is applied to clay it increases the tendency which the tiny clay particles have to gather into masses. A freer circulation of both air and moisture is thus encouraged. When the tiny clay particles collect in this manner they are said to flocculate. Tillage operations also encourage clay soils to assume a flocculent condition.

Humus.—It has been already observed that the surface soil is darker coloured than the sub-soil. This coloration is largely due to the presence of humus. Humus consists mainly of decaying vegetable matter, but decaying animal matter is also frequently present. It is generally abundant on the ground in forests where it is formed by the decay of mosses and other small plants, leaves, and roots.

In West Africa large areas of land which are flooded each year during the rainy season are particularly rich in humus. If a hole be dug in such ground, the surface will be found to consist of a dark brown, spongy or peaty substance. This is principally composed of the remains of plants which have grown up and decayed, year after year, for a long period.

Humus is one of the most valuable components of soil. The substances formed from rocks are of little value to the farmer unless they be mixed with humus. When soil is described as being rich it is usually meant that it contains an abundance of humus. On the other hand, what is described as poor soil is understood to be lacking in humus.

Soil which is constantly cultivated, and to which no humus-forming substances are added, gradually becomes poorer as the original stock of humus disappears. This is one of the reasons why land, which has been cultivated for several years, is benefited by being allowed to "fallow," or is left uncultivated. Such land becomes rapidly covered with weeds. As these die and decay a new supply of humus is added to the soil.

It will thus be seen what a big mistake the farmer makes when he burns his vegetable refuse. Such material should be either dug into the ground or be piled into heaps to decay and then applied to the land.

The condition of the soil is improved in several ways by the presence of humus. It is able to hold more moisture than sand, consequently when it is present in sandy soils it prevents them from drying up too rapidly. It renders heavy clay soils more porous and encourages a freer circulation of air and moisture. Humus also contains valuable plant foods.

Moisture and Air in Soil.—By adopting suitable cultural methods and by drainage, the farmer is able to regulate the amount of moisture in his soil. Crops may suffer just as much from the soil containing too much moisture as from containing too little. A well-drained and properly cultivated soil is better able to sustain a crop during very dry weather than undrained, badly tilled soil.

The roots of plants grow down deeper into a soil which has been well drained and properly cultivated. Under such conditions, when the surface soil dries up, the roots are able to extract moisture from the soil below.

A great deal of the water which plants absorb from the soil is evaporated from their leaves in the form of water vapour. Frequently during very hot weather moisture is more quickly evaporated from the leaves than it is taken up from the soil by the roots. The leaves then assume that limp, drooping appearance so commonly seen in such plants as maize and cotton on a very hot day. If such plants be watched it will be observed that during the evening, as the heat becomes less intense and evaporation is consequently less rapid, the leaves reassume a firm, turgid appearance.

However well a soil is drained a certain quantity of water is retained by it after rain has fallen. A greater portion, however, remains behind in clay soils than in sandy soils. No matter how small are the particles of which a soil is composed, spaces exist between them. It is between these spaces that the water passes. In a well-drained soil they are generally filled with air, but, when rain falls, water takes the place of the air. As the water drains away the spaces again become filled with air.

For healthy root growth air is necessary as well as moisture. The presence of moisture in soil, after the surplus moisture has drained away, is principally due to the power which fluids have of rising above their level in fine tubes or pipes (capillary attraction).

Examples are frequently met with. Such porous substances as lump-sugar and blotting paper contain innumerable fine cavities. If the corner of a piece of lump-sugar be gently dipped into tea, the tea soon diffuses through the whole lump. Everyone is familiar with the manner in which ink travels through blotting paper as soon as the edge of the blotting paper touches the ink. It should be noted that when the sugar or the blotting paper is removed from the liquid that which has been absorbed does not drain away again.

The finer the tubes or cavities the greater is this power exerted. The more thoroughly a soil is tilled the finer does it become, and consequently the more delicate and therefore the more effective are the tubes in it.

Now let us consider what takes place in regard to soil moisture. The heat of the sun turns the moisture in the upper layers of the soil into water vapour, which is carried away in the air. This causes more water to rise from below to take its place. Obviously during long periods of dry weather there must come a time when the supplies of water below begin to diminish. Plants growing on such land must suffer for lack of moisture.

If steps be taken to check the loss of soil moisture by evaporation the water supply below would last much longer. This may be done by forming what is known as a dry-soil mulch on the surface, or by spreading on the land a layer of leaves, grass, or some similar substance.

A dry-soil mulch is formed by keeping the surface soil frequently stirred to a depth of two or three inches. This is done by raking, hoeing, or by passing an implement, known as a cultivator, over the land. The tubes are then broken and a layer of loose surface soil is formed. This contains many large air spaces through which moisture cannot readily pass by capillarity. A layer of leaves, grass, or farmyard manure has a similar effect and conveys the additional advantage of adding humus to the soil.

Demonstrations

In Part II. of this book instructions are given as to the manner in which a school garden should be made. When this work is being carried out it will be necessary to dig a trench for the hedge, and holes for various plants. Advantage should be taken of this work to dig deeper in order to demonstrate the character of the rock from which the soil has been formed. Note that the stones taken out of the trench or hole closely resemble the rock. Should stones be found which are quite different from the rock, they have been brought there and an attempt should be made to find out from whence they came. If the soil be very deep it would be advisable to examine the rock in some deep hole which has been dug in the neighbourhood.

Mechanical Analysis of Soil.—To ascertain the proportion of gravel, sand, and clay in the soil it is necessary to make what is known as a mechanical analysis of it. This may be done with approximate accuracy in the schoolroom. The apparatus necessary is as follows: a small set of metric weights and scales; three sieves with a mesh of $\frac{1}{50}$, $\frac{1}{25}$, and $\frac{1}{12}$ inch respectively; a glass beaker or a tumbler; a wooden stirring-rod and three or four soup plates.

Collect a heap of the soil to be tested and thoroughly mix it together. Weigh 100 grammes of this, place it in the glass vessel and pour water upon it. Place the sieve with a $\frac{1}{12}$-inch mesh over a soup plate. Then take the wooden rod, thoroughly stir the soil and water, and empty the mixture into the sieve. Pour water into the sieve and with the wooden stirring-rod agitate the stones and gritty material which remains in the sieve until they are quite clean. Put this sieve with its contents on one side. On a second soup plate place the $\frac{1}{25}$-inch-mesh sieve and empty into it the water and soil which passed through the first sieve. The water and fine material which passes through this sieve should be emptied into the sieve with the smallest mesh.

We now have three sieves containing grit and stones of various sizes and a soup plate containing muddy water. After the muddy water has stood for several minutes, a sandy sediment will settle on the bottom of the plate and the liquid may be poured away. Wash the sediment into the glass vessel and, after it has stood for several minutes, pour the water, which will probably be slightly muddy, into the soup plate. Continue this operation until the water poured away is quite clean.

Now thoroughly dry the materials contained in the three sieves and the glass, and then carefully weigh each separately. The material contained in the first, second, and third sieve, and in the glass may be described as coarse gravel, gravel, coarse sand, and sand respectively. The fine material taken away in the washing waters is silt and clay.

If we deduct the total weight of these four materials from the original weight of the sample of soil we obtain the weight of the silt and clay. It is now possible to ascertain the percentage of each material present in the sample of soil. This should serve as a lesson in arithmetic for senior scholars. It would be both interesting and useful to put the various materials into separate bottles and label them for future reference. The results obtained by this method are only approximately correct. Greater accuracy can, however, be secured by treating several samples of the soil in this manner and striking an average of the various weights obtained.

Lime.—When a strong acid is poured upon limestone or carbonate of lime, it bubbles up owing to the escape of carbon dioxide gas. Sea shells and the large snail shells so commonly met with in West Africa are rich in carbonate of lime. Lime juice contains citric acid. Crumble up some of these shells and place the small pieces in a plate. Squeeze a lime over them and note the effervescence which takes place. The acid separates the lime and the carbon dioxide, and the effervescence is due to the escape of carbon dioxide in the form of bubbles of gas. A similar effect may be produced by pouring strong vinegar on crumbled chalk. The white material used for writing on school black-boards is not chalk and must not be expected to give the desired results.

This method may be adopted to find out whether a particular soil contains lime. Thoroughly dry and powder a small sample of the soil to be tested, and pour a few drops of lime juice, vinegar, or strong acid upon it. If there be no lime in the soil effervescence will not take place. Pupils should be encouraged to collect samples of soil from various places to be tested in this manner. The results of these tests should be recorded for future reference.

Humus Combustible.—It is not a difficult matter to estimate approximately the amount of humus present in the soil. Collect a spadeful of dark surface soil, and thoroughly dry it. Weigh some of this dried soil and place it in an iron vessel or on an iron sheet over a fire. Notice that as the soil becomes heated it turns black but gradually changes to a light colour similar to the sub-soil. When it has been heated to a red heat for about an hour, or until no smoke is given off, place it on one side to cool. The burnt soil is then found to be a reddish colour. Again weigh it and the loss in weight represents the weight of the humus that it originally contained. The percentage of humus in the soil should now be worked out.

Moisture in Soils.—That heavy soils retain more moisture than light soils can be demonstrated as follows: Collect a sample of heavy soil and also one of a sandy soil. Thoroughly dry them and reduce them to a powdered state. Select a glass tumbler or some similar vessel, of equal size and weight for each sample. Weigh an equal quantity of each sample and put it into a separate glass. Shake and tap the glass to cause the contents to settle down firmly. More than sufficient water to cover the soil should now be poured into each glass and allowed to stand for twenty-four hours. Any water not held by the soil may then be poured away. If each vessel with its contents be now carefully weighed the quantity of water held by each sample can be ascertained.

To show that water drains away more rapidly from a light soil than from a heavy soil, prepare samples of sand and clay as before. Take two glass funnels and arrange a piece of muslin in the neck of each to prevent soil falling through. In one funnel place some of the sandy soil, and in the other an equal quantity of the clay soil. Pour a similar quantity of water into each funnel and notice that it drains away more rapidly through the sand.

Capillary attraction may be demonstrated in several different ways. Add a few drops of red or black ink to some water, and dip the corner of a thoroughly dry, clean piece of blotting paper into it. In a very short time the inky water will travel all over the sheet.

Take three glass tubes of similar size, and open at each end, such as small lamp chimneys. Place a piece of muslin over the bottom of each so that it will hold soil. Fill one tube with sand, one with good garden soil, and the third with clay. Weigh each tube with its contents and stand it in a saucer of water. Note the manner in which the water rises in the soil. The saucers should be kept supplied with water until it has risen to the surface of the soil in each case. If each tube be now weighed it will be found that the sand has absorbed most water and the clay least.

CHAPTER II

THE SEED

The Organs of Seeds.—It is by means of seeds that plants are principally propagated. But it is not always convenient to use seeds for this purpose. The different parts of which a seed is composed are most readily examined when germination has commenced. Obtain some young bean seedlings which are just showing above the ground, and also some beans which have been soaked in water for a few hours. Along one edge of the bean a black scar will be observed. This is the point where it was attached to its stalk and is termed the hilum. At one end of the hilum is a tiny cavity which is the micropyle. Now carefully remove the seed-coat or testa. It will then be found that the contents may be readily separated into two fleshy lobes or leaves. These are the cotyledons or seed-leaves.

The Rudimentary Plant. — Between the cotyledons is a tiny curled body. If this be examined with a magnifying glass, it will be found to consist of a tiny rudimentary root, the radicle, and a rudimentary bud, the plumule. If another seed be still more carefully opened it will be noticed that the radicle is turned towards the tiny cavity or micropyle in the seed-coat. The plumule, on the other hand, is turned inwards on the flat side of the cotyledons. The plumule, radicle, and cotyledons together represent the embryo or rudimentary plant.

The Cotyledons.—Now examine one of the small bean seedlings. It consists of two thick leaves between which there is a small bud with tiny

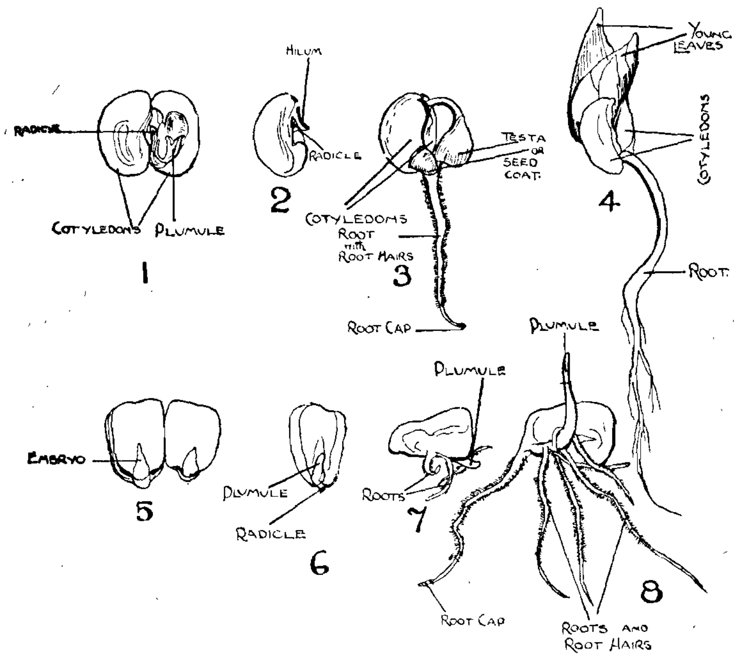

FIG. 3.—Development of Seedlings.
Cow Pea, 1-4 ; Maize, 5-8.

leaves. This is connected by a short stem with a small root. The thick leaves are the cotyledons, the bud has developed from the plumule and the root from the radicle.

All seeds do not have two cotyledons, some have only one. The seeds of all grasses, maize, Guinea corn, rice, and palms have but one cotyledon. The seeds of nearly all flowering plants agree in having either one or two cotyledons. They are accordingly divided up into two great classes (Monocotyledons and Dicotyledons). Later we shall discuss other characters which are peculiar to each class.

For comparison with the bean seed some grains of maize should be examined. After soaking some maize grains in water for several hours, it is possible to scrape off the thick coat and leave the seed bare. Note the embryo at the basal end of the seed. This may be readily separated. The remainder of the seed is composed of starchy material.

[The word grain is used here, for strictly speaking the maize grain is not a seed but a fruit, as explained in Chapter VII., "The Fruit."]

Plant Food in the Seed.—In the case of the bean and many other seeds, such as those of cocoa, lime, orange, and pumpkin, plant food is stored up in the cotyledons. The rudimentary plant feeds upon this until it is able to obtain its own food from the soil and the atmosphere. The young maize plant, on the other hand, feeds upon the starchy material previously referred to. In the seeds of coffee, castor oil, Guinea corn, and grasses, food material is likewise not stored up in the cotyledons, but in a separate part of the seed as in maize.

Germination.—Seeds will not germinate unless a suitable supply of heat, air, and moisture be present. There is a minimum temperature below which each kind of seed will not germinate, and also a maximum temperature above which germination will not take place. In the tropics there is almost invariably sufficient heat for germination to take place. Should the soil in which seeds are sown be too dry, or sufficient air be absent from the soil, germination is arrested.

Attention should be given to the behaviour of certain seeds upon germination. In the cow pea the stem just below the cotyledons forms a peculiar hook. This is the first indication above ground that germination has taken place. The cotyledons are still in the seed-coat underground.

As growth proceeds the hooked stem gradually pulls the seed-leaves, with the tiny bud enclosed, backwards out of the seed-coat. The stem then straightens itself and displays the cotyledons and bud to the light.

When gourd and melon seeds germinate the root appears first and forms a hook. As the root develops, the cotyledons enclosed in the seed-coat are forced out of the soil. The seed-coat splits in half and the tiny plant is exposed.

Seed Variations.—The peculiarities of different seeds should be closely studied by students. What a vast difference there is between the cocoanut, which is almost as large as a child's head, and the tiny seeds of tobacco.

Compare the hard coat of the seeds of the oil palm, Ceará rubber, and Canna with the soft seed-coats of pumpkin, okro, and orange.

Notice the great variation in the colour of the seed-coats of different seeds.

The exterior attachments of certain seeds should be also observed. Notice the fibrous covering of the cotton seed, the gummy mass in which the prickly seeds of the papaw are embedded; also, the peculiar glumes and bristle-like attachments to various grass seeds.

Students should be encouraged to collect and name seeds of the commonest wild and cultivated plants found in the district. Seeds of the most troublesome weeds should receive special attention. A most interesting collection can be made by placing some seeds of each kind in a bottle and labelling the bottle with the name of the seeds it contains. Certain seeds, such as those of cocoa and the Pará rubber tree, soon lose their vitality. Others, such as those of the Ceará rubber tree and various palms, may be kept in good condition for many months.

Demonstrations

Air and Moisture Necessary for Germination.—To prove that air and moisture are necessary for germination, select three wide-mouthed bottles and some dry seeds of maize, bean, or cotton. Thoroughly dry one of the bottles, place a few seeds inside, tightly cork it, and seal it with wax or thick palm oil. In the second bottle place some moist blotting paper before putting in the seeds and corking and sealing it. The third bottle should be treated similarly to the second, but it should be left uncorked. The seeds in bottle number one will not germinate, no moisture is present and only the air which was sealed up in the bottle. Moisture is present in bottle number two, but, as in number one, very little air. The seeds will possibly germinate and grow until they have used up all the air in the bottle. The seeds in bottle number three have both air and moisture, they will therefore germinate and grow satisfactorily.

Further, to demonstrate how necessary moisture is for germination, take several boxes, about 4 or 5 in. deep. Bore some holes, about $\frac{1}{2}$ in. in diameter, in the bottom of each, to allow water to drain away. Spread a layer of small stones over the bottom of each box and on this a thin layer of dry leaves, or dry grass chopped up fine to prevent soil falling through the drainage holes. Pass some soil through a sieve with holes $\frac{1}{4}$ in. in diameter. Fill some of the boxes with this soil, but, before filling the remainder, dry the sifted soil. Keep the boxes filled with dry soil and moist soil separate. Place the boxes under a shed, where they will be protected from rain. Sow a different kind of seed, such as maize, cotton, or bean, in a box of dry soil and also in a box of moist soil. See that the moist soil is maintained in this condition by watering it. This should be done with a water can fitted with a fine rose. The seeds in the boxes which are ...

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The young, healthy seedlings should be used for demonstrating the different parts of the seed previously referred to and the manner in which different seeds germinate. Attention should be drawn to the way in which the cotyledons in some cases and the seed-coat in others gradually shrink and shrivel. This is due to the young plant feeding upon the plant food stored therein. To show that the young plant develops from the embryo remove it from several seeds and note that no plant is produced as a consequence.

Drainage and Germination.—To show how necessary drainage is for healthy plant growth, take another seed box with no holes in the bottom. Fill this with soil and sow some seeds as before. Water the soil in this box daily. The seeds will probably germinate, but in course of time the soil will become sodden and sour-smelling. The seedlings will then turn yellow and die.

Depth to Sow Seeds.—Seeds sometimes fail to germinate properly because they are too deeply covered with soil; this is specially the case with small seeds. When sowing seeds it is usually sufficient to cover them to a depth equal to their average diameter. Before sowing very small seeds, the bed or box in which they are to be sown should be first raked smooth, and this should be then covered with a layer of finely sifted soil. Over this spread the seed thinly, and consolidate the soil around it by pressing it down with the palm of the hand, a piece of flat board, or the back of a spade. Sow the same kind of seed at different depths in the soil and note the results.

Seed Testing.—To obtain good crops it is necessary to raise strong, healthy, prolific plants.

Such plants cannot be raised if unripe or poor quality seed be sown, or if the seed be selected from weak plants or from plants which yield poor crops. It is often necessary to test the vitality of seeds. This may be done as follows: Cut two pieces of thick cloth or flannel the same size and shape as a plate. Soak them with water, and spread one of them over the plate. On this sow seeds of bean, maize, or cotton thinly, and cover them with the other piece of moist cloth. Now place over the whole a second plate of similar size and shape to the first. One hundred seeds is a convenient number to test at a time, for then the percentage which germinates is readily ascertained.

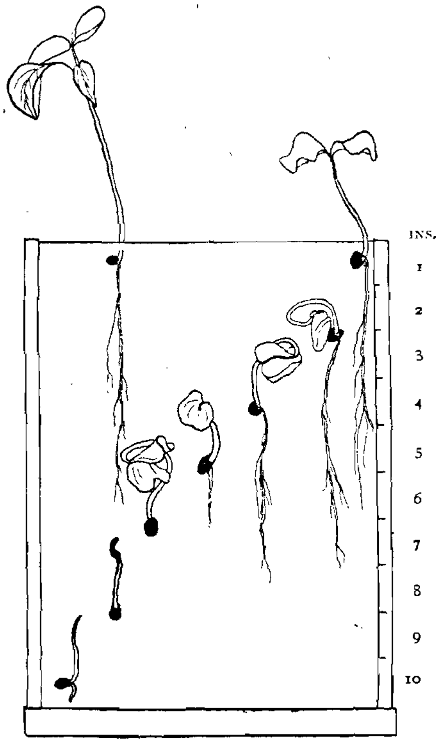

FIG. 4.—Germination Results from Cotton Seeds sown at Different Depths in a Glass Case filled with Soil.

If records be kept of the date different kinds of seeds are placed in the seed-tester, it will be found that certain seeds germinate within two or three days, but several weeks may elapse before other kinds germinate. A list should be made out showing the period required for the germination of each kind. As soon as germination commences the seeds should be examined daily, and those which have germinated should be counted and removed from the tester. In the case of seeds which take a long time to germinate it may be necessary to re-moisten the cloth. Great care should be exercised when testing very small seeds, to ensure that the cloth is not kept too wet.

Seedlings.—It is always advisable to sow more seeds than the number of plants required. This is because a certain number of the seeds will fail to germinate for various causes. Young, tender seedlings are also frequently attacked by insects, and die as a consequence. If too many seeds be sown, the seedlings are too densely crowded together and fail to grow properly. It is obvious that large plants require more space to grow in than smaller ones. The seeds of large plants must therefore be sown farther apart than those of small plants.

The mistake of allowing seedlings to grow too closely together may be easily illustrated. At the end of this book instructions are given regarding the distances apart to sow different kinds of seeds. In the case of one kind of seed, instead of sowing it at the distance recommended, sow it a quarter as far apart. All the seedlings in this bed will grow satisfactorily up to a certain stage, but then the plants which are too close together become weak and straggly, and in the end yield a poor crop. Larger crops are not necessarily obtained by closer planting.

CHAPTER III

THE ROOT

In the previous chapter we learned that flowering plants are divided up into two groups (Monocotyledons and Dicotyledons), in accordance as they have respectively one or two cotyledons. It was also stated that the plants belonging to these two groups have other characters which are common to one group or the other. An examination of the roots of the seedlings raised in the manner suggested in the preceding chapter will afford excellent material for the examination of young roots.

Fibrous and Tap Roots.—In the maize seedling the radicle does not elongate, but roots are formed from root-buds which arise from the undeveloped radicle. As a result a mass of fibrous roots is formed. Pull up some grasses and this type of root will be found in each case. Also compare the matted, fibrous roots of any palm with the roots of a large forest tree which has been blown down. Notice that in bean, cotton, and cocoa seedlings the radicle elongates and forms what is commonly termed the "tap-root."

Characters Peculiar to Roots.—It is necessary that the following characters peculiar to roots should be observed. They grow away from the light, and bear neither buds nor leaves. Certain plants, such as ginger, arrowroot, and Guinea corn, produce under ground both roots and stems. If the underground stems be examined, scale-like leaves will be found upon them. In the axils of these scales buds are produced.

Root-Hairs and their Functions.—If any seedling be carefully dug up, small particles of soil will be found adhering to its roots. Examine the part of the root to which the soil adheres, and a number of tiny, white hairs will be observed. These are known as root-hairs, and they will be readily seen on the seedlings raised in the seed-testing experiment. It is by means of these tiny hairs that the plant absorbs its food from the soil.

An examination of the roots of larger plants will show that root-hairs are only present on the very young roots. It is important that the student should bear this in mind. One often sees manures being applied close to the trunk of such trees as cocoa, rubber, and cola. This is obviously the wrong place to apply it, for investigation of the roots of these trees will show that the majority of the young roots are situated at some distance from the trunk.

When a plant, which is growing in dry, hard ground, is roughly pulled up, nearly all the tender root-hairs are broken off. It will thus be seen how necessary it is, when transplanting seedlings, to dig them up carefully from the ground, so as to destroy as few root-hairs as possible. A plant which has been robbed of its roots is unable to absorb food from the soil until new ones are formed.

The Root-Cap.—Notice that the root-hairs do not grow upon the tip of the root. This portion is quite bare and smooth. The tip is covered with a shield known as the root-cap. It is not easily found in some plants without the aid of a lens. The screw pine (*Pandanus*), which is so common in swampy places in West Africa, produces roots from the stem which grow downwards, and eventually enter the ground. The tips of these roots are covered with a conspicuous root-cap.

The root-cap of the screw pine will give the student a very good idea of what to look for, and what to expect to find, on the roots of plants where it is not so conspicuous. The object of the root-cap is to protect the young, tender root-tip as it penetrates the soil in search of food and moisture. It is from the region just behind the root-cap that growth takes place, and increases the length of the root. Older roots increase in thickness, but not in length.

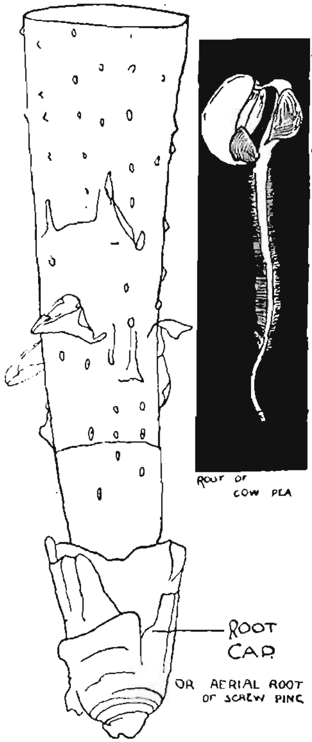

FIG. 5.—The Root-Cap.

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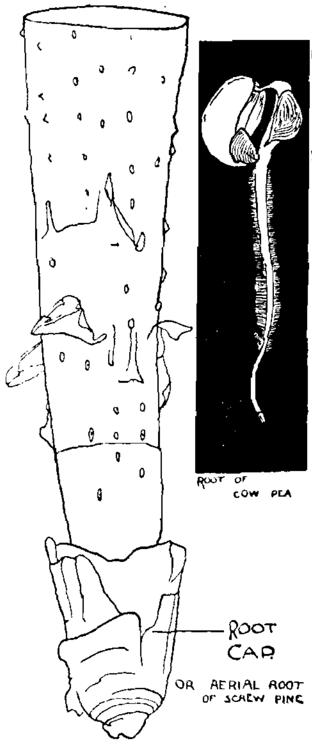


FIG. 5.—The Root-Cap.

Functions of Roots.—Anyone who has

attempted to pull even a small tree out of the ground knows how securely it is fastened there by its roots. One of the primary uses of roots is to fix the plant firmly in the ground. The young roots absorb water, with the food substances in solution, which plants obtain from the soil. Older roots do not absorb moisture, but they serve as a channel for conveying the material absorbed by the young roots to the stem and leaves of the plant.

Tuberous Roots.—The roots of certain plants *become thickened; they are then said to be tuberous.* In them starch is stored as reserve food material. Some of these are used by man as an article of food. Well known examples are cassava, sweet potato, and carrot. In order that thickened roots may not be confused with underground, thickened stems, such as yam, ginger, and arrowroot, bear in mind that roots do not produce buds or leaves.

Additional [Adventitious] Roots.—Any roots which do not originate by the direct elongation of the radicle may be described as additional. This term applies more generally to roots which arise from the stem and branches, such as those which are given off from the base of the stem of maize and Guinea corn. Other examples are the aerial roots, so called because they are produced in the air, of the screw pine, mangrove, fig tree, and various orchids.

The stems of certain plants, when separated from the parent, can be encouraged to produce roots. Advantage is taken of this characteristic to propagate them. Plants which may be readily propagated in this manner are cassava, sugar cane, purging nut, and sweet potato, and numerous ornamental plants.

Succulent leaves, like those of begonia, will produce buds and roots if they be placed on moist soil. The succulent leaves of Kalanchoe, a common medicinal plant in West Africa, will produce roots, buds, and even shoots when they are merely hung up in a shady place.

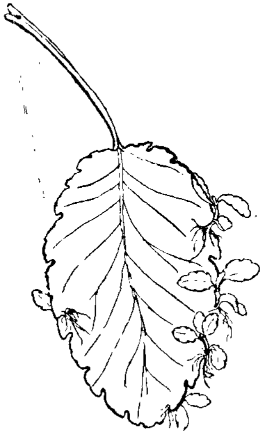


FIG. 6.—Shoots formed from a Kalanchoe Leaf hung up in the Shade.

Demonstrations

Gravitation Affects Roots.—The tendency of roots to grow downwards may be shown by the following means. Take a large glass jar, and on the bottom of this spread some moist sand. Select some seeds which have commenced to germinate. Insert a pin through each seed and fix them to a thin piece of wood, so that the radicle in each case points upwards. Place the wood inside the jar, and cover the jar with a piece of glass. In a short time the radicle will curve round until it points downwards. Now, change the position of the seeds so that each one points in a different direction, and the same thing happens.

Roots Attracted by Moisture.—In the last experiment the position taken up by the roots was largely influenced by the moisture at the bottom of the jar. To prove this, take an old piece of sacking about 2 ft. square and thoroughly saturate it with water. Select four sticks about 3 ft. long. Fix them in the ground in the form of a square, so that the piece of sacking can be tied by the corners to the tops of the sticks. Soak some maize, bean, or cotton seeds in water for about twelve hours, and spread them on the moist sacking. Cover the seeds with a thin layer of moist soil, and keep the soil moist by watering it from a water can with a rose attached.

In a few days, time the seeds will germinate, and the roots will penetrate through the sacking. They will not continue to grow downwards, but will travel along the moist sacking, and probably push back through it to the moist soil on the other side. This shows that the *tendency of roots* to grow downwards is overcome by the attraction which moisture has for them.

Growth of Roots.—That the growing region of roots is just behind the root-cap may be shown with little difficulty. Select some bean seedlings with nice straight roots about 2 in. long. After washing the roots lay each seedling alongside a ruler. By means of a fine camel-hair brush and Indian ink mark lines on the root $\frac{1}{8}$ in. apart, commencing from the tip and extending about $1\frac{1}{2}$ in. backwards. Place the seedlings between moist sheets of blotting paper, and keep them in a small, tight box or between two plates. After a day or two again place the seedlings alongside the ruler. It will then be seen that the distance between the marks nearest the tip of the root remains unchanged, that of those next is much greater, showing that growth has taken place. There is no difference in the distance between the marks made still further up the root. It will thus be seen that growth takes place just behind the root-cap, and this tends to force the root-cap through the soil.

Absorption of Water by Roots.—Cut down a banana stem close to the ground, and notice what takes place. Water exudes, and this continues for some time. It is obvious that this water can only come from the roots, and has been absorbed by them from the soil.

Roots Produced by Leaves.—Collect some leaves of Kalanchoe, string these on a piece of thread, and hang them in a shady place. After a few days buds will form at the edge of the leaf, generally near the veins. These buds may develop roots and even leaves at the expense of the material stored up in the original leaf. With a pen-knife make gashes across the veins on the back of some of these leaves. Lay them on some moist sand, so that the cut surfaces come in contact with the sand. In a short time new plants will develop from the points where the veins were severed.

Roots Produced by Stems.—Plants may be raised by taking off sections of the stem and inserting them in the soil. Obtain some boxes about 5 in. deep, and make some holes in the bottom. Spread a layer of small stones on the bottom of the box, and cover these with dry leaves or dry grass which has been chopped up into small pieces with a cutlass. Fill the box with fine soil, and press this down firmly.

Take off about 5 or 6 in. of the young stems of plants like Acalypha, Hibiscus, or croton. These should be firm and woody at the base. Be sure that your knife is sharp. Cut off the base of the stem cleanly just below a leaf, or where a leaf has fallen off. It will be found that roots are produced most readily from these points. Remove nearly all the foliage—the reason for this will be explained later—and the cutting is ready for inserting in the soil. Select a piece of stick slightly thicker than the stems of the cuttings. With this make a hole in the soil about 2 in. deep. In this place a cutting, and press the soil firmly around its base. It is advisable that the base of the cutting rests upon the bottom of the hole made for its reception. In a similar manner insert other cuttings in lines until the box is filled. Thoroughly saturate the soil in the box with water and place it in a shady spot. If the soil in the box be kept constantly moist, roots will be formed in a few weeks and the cuttings may be then transplanted.

When large quantities of plants have to be raised from cuttings it is more convenient to insert them in beds prepared in a similar manner to that recommended for seed sowing. These beds should be kept well shaded and properly watered.

Layering.—Plants which are difficult to propagate from cuttings may be propagated by what is known as layering. Select some branches of ornamental plants which can be readily bent down to the ground. Make some wooden pegs sufficiently strong to hold these branches down to the ground. At the point where a leaf touches the ground, and just below a leaf or leaf scar remove a ring of bark from the stem. Now fix the branch firmly to the ground by means of a peg, and cover the portion which touches the ground with some moist soil. Within two or three weeks roots will be produced and the branches may be severed from the parent and transplanted.

Marcotting.—Another method of propagating is sometimes employed with regard to valuable plants which are difficult to propagate from cuttings. This method is termed marcotting, and it should be performed as follows. Select a young, strong growth, and strip off a ring of bark just below a leaf or leaf scar. Similar results may be obtained if the stem be partially severed at the same point instead of removing the bark. Bind some moss or similar material around the cut portion and keep this bandage constantly moist. As soon as roots are observed protruding through the moss the growth may be cut off and planted in the ground.

For older branches a pot containing soil is required. Cut a section of bamboo pole about 9 in. long and split it in half. Take off ½ in. of bark all around the stem, enclose the barked portion with the two sections of bamboo and tie them together. Fix some moss or dry leaves in the bottom of the bamboo to keep it in position, and then fill it with soil. Should any difficulty be experienced in keeping the bamboo in position fix a stout stake firmly in the ground and fasten the bamboo to this. As before it is necessary to keep the soil moist. The production of roots is sometimes hastened by cutting a small notch in the branch below the pot and gradually increasing the depth every few days.

CHAPTER IV

THE STEM

Description of Various Stems.—When we were discussing the various parts of a seed, it was pointed out that the stem or shoot of the plant is developed from the plumule. The stem is the ascending, leaf-bearing part of the plant. On all stems of the same kind of plant the leaves are arranged in a similar manner. The point on the stem from which the leaf springs is called a node. The space between one node and the next is spoken of as an internode.

The different kinds of stems should be noted. The stem of the cotton and the chillie plant is described as erect, that of the gourd and many grasses is creeping. The yam and various beans have climbing stems and require supports of some kind to grow up. If all the scale-like leaves be stripped off an onion, a solid cone-like base is found. This represents the stem of the onion plant. There is certainly very little resemblance between this and the stem or trunk of a forest tree. Note the manner in which certain plants produce numerous branches, while others, such as palms, have only a main stem. Some underground stems closely resemble roots, but they may be readily distinguished from them if it be remembered that roots do not produce buds nor scale leaves.

Young stems are usually green in colour, but they may be pink or reddish owing to these colours being present in the outer tissues. Examples of this are seen in the young stems of cassava and many ornamental plants. As stems grow older their leaves fall, but the positions they occupied are for some time marked by leaf scars. Later on the stem becomes covered with a more or less corky layer. The shape of the stem may be round, such as that of maize or bamboo; square, as in the West African artichoke (*Plectranthus*); triangular, as in sedges, the grass-like plants which grow in swampy places; or flat, as that of certain peas.

Climbing Stems.—Students' attention should be drawn to the manner in which the stems of certain plants are used for climbing. The stems of yams and certain beans twine around any convenient support. To encourage this habit the farmer inserts long stakes in the ground by the side of these plants. The stems of other plants are provided with special climbing organs, known as tendrils. Notice that the passion flower vine climbs by means of tendrils. These are long, thin filaments which arise in the axils of the leaves. As soon as they touch any thin support they coil around it and assist the plant to climb and also support itself. Pumpkin and melon plants also produce tendrils.

The Functions of Stems.—The principal uses of the stem are to support the leaves, flowers, and fruits, in a position favourable for their development. Also to serve as a channel for conveying to the leaves the raw food materials taken up by the roots, and the elaborated food materials from the leaves to the other parts of the plant. These processes will be more fully discussed later. In some cases stems are utilised for storing reserve supplies of food for the plant. Some of these are employed by man as an article of food. Familiar examples of this nature are the yam, potato, and tania.

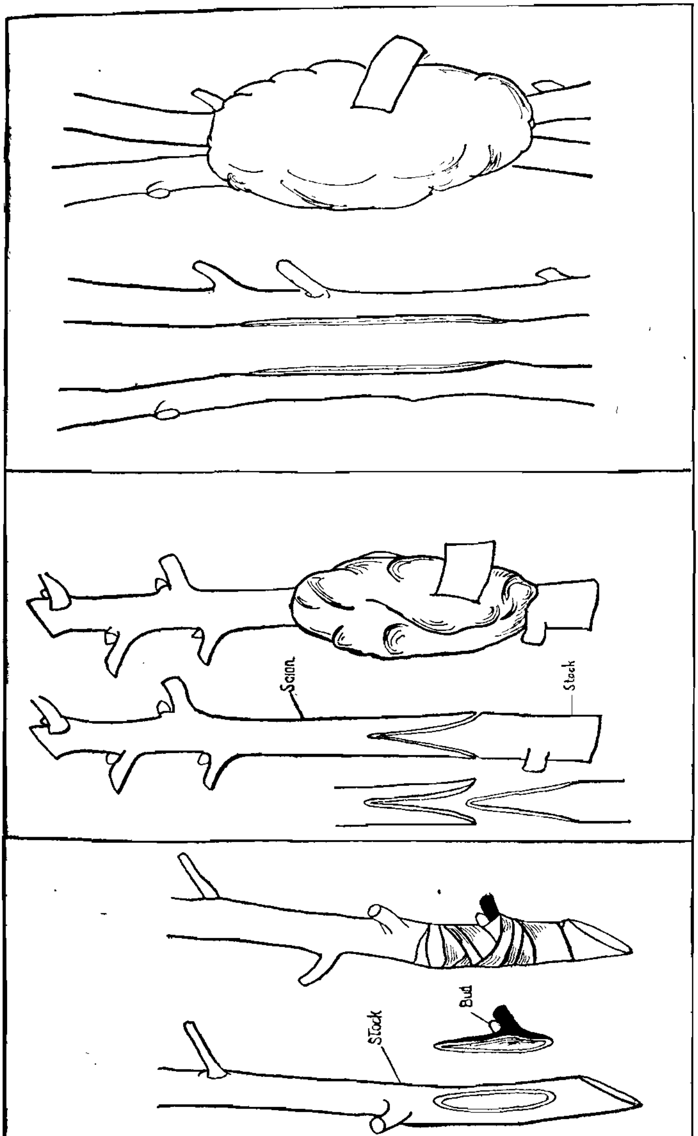
The Structure of the Stem.—In order to examine the different interior parts of a stem, select some young branches from a quick-growing shrub. Cut these through crosswise and it will be found that the parts have a definite arrangement. The centre consists of very soft tissue which is known as pith. This can be easily picked out with the pointed blade of a pocket knife. Next to the pith is a ring of woody tissue. Very young stems are principally composed of pith, but as they grow older, wood gradually takes the place of the pith.

Outside the wood is what is commonly described as bark. This is easily separated from the wood. It consists of three distinct layers of tissue. The innermost layer contains a quantity of fine fibres. The central layer is green coloured. The outer layer is often a brown colour, it contains no fibres, and is easily broken. At the point where the bark and the wood join is a thin layer of soft, juicy, light-coloured tissue. This is the cambium and it requires special attention. It is the growing layer, and is composed of young, growing tissue similar to that found just behind the root-cap. From the cambium new material is added to the wood on one side and to the inner bark on the other. An examination of older branches will show that more material is added to the wood than to the bark.

For comparison a young monocotyledonous stem should be cut through crosswise. A young maize, palm, or bamboo stem is suitable for this purpose. No rings of tissue such as were found in the dicotyledonous stem will be seen. The bark cannot be stripped off. There is no pith and no cambium ring. There is likewise no central woody tissue. Instead, we find a mass of soft tissue in which are scattered small masses of hard, fibrous material. The fibres are more easily recognised when the stem is cut lengthwise. Similar fibres are also very abundant on the outer edge of the stem.

Budding and Grafting.—We have already discussed the manner in which the stems of plants in the form of cuttings or layers are utilised for propagating purposes. Plants may be also propagated by methods known as budding and grafting. These operations are rendered possible by the presence of the cambium, the region in which rapid growth takes place. When the cambiums of two nearly related plants are brought in contact in a suitable manner, the new tissues formed by the two cambiums become united and grow together as one stem. The plant which is budded or grafted is called the stock, and the bud or graft is the scion.

Budding is really another form of grafting. It consists of cutting off a bud with a little of the



Budding. "Saddle" Grafting. Inarching or Grafting by Approach.

FIG. 7.

attached wood and bark from one plant, and binding it on to another in such a manner that the cambium of the scion and the stock are brought in contact. In grafting a section of the stem is used as a scion.

The principal object aimed at in budding and grafting is to convey the superior qualities of one plant to another which does not possess these qualities. For example, amongst a large number of mango trees one may be found to produce far superior fruits to all the rest. By budding or grafting the poor varieties from the specially good tree all may be made to produce superior fruits.

It frequently happens that the best kinds of fruit and other trees and plants grow very slowly, and consequently take a long time to reach the productive stage. Common and more quick-growing plants are therefore grown as stocks, and the better varieties are budded or grafted on to them. The number of plants of the superior varieties is quickly increased and fruit is obtained at an earlier date than if seedlings had been grown. For example, plants of the sour orange and the coarse lemon grow far more rapidly and produce fruits earlier than the best varieties of the orange tree. The advantage of budding the sweet orange on a stock of the sour orange or coarse lemon will thus be apparent.

Inarching or Grafting by Approach.—The form of grafting termed inarching or grafting by approach probably gives better results than any other, and it is specially suited for the tropics. In this method the scion is not separated from the parent plant until it has formed a junction with the stock. The plants to be used as stocks are generally grown in pots under nursery shelters. When they are large enough they are taken to the tree or plant which is to supply the scions. In the case of large trees a platform is erected around them, and on this the stock plants are arranged in such a way that they are brought close to the branches. A branch is then selected the same size as the stem of a stock plant. A piece of bark of similar size and shape is sliced off both stock and scion, and the two cut surfaces are bound together. When the two points have united the scion is severed from the parent tree at a point just below the junction.

Demonstrations

Water absorbed by the roots passes up the stem to the leaves. The course which this water takes in the stem may be shown by placing some young, leafy shoots in a glass containing water coloured with red ink. The passage taken by the inky water in the stem will be coloured, and also the stalk and veins of the leaves.

How to Bud.—Until experience has been acquired it is not advisable to attempt to bud and graft valuable trees and plants. It is safer to practise upon wild ones. Later such plants as Hibiscus, croton, mango, and orange may be operated upon. The best season to bud is when growth is most rapid, and this usually takes place at the beginning of the rainy season. Select two plants of the same kind. Search among the young shoots until one is found on which young buds are present in the axils of the leaves. Cut off a leaf so that about $\frac{1}{4}$ in. of the stalk is left attached to the bark. Now slice off a strip of bark about 1 in. long, and with the bud in the centre, and remove the strip of wood attached to the bark. Choose a woody shoot on the plant to be budded. Now slice off this a piece of bark similar in size and shape to that removed from the first shoot. To facilitate this operation lay the bud bark on the shoot and mark round the edge of it with the point of the knife blade. Lay the scion in place and carefully bind it round with waxed tape. Care must be taken not to cover up the bud or to damage it in any way.

A second method of budding is as follows. Instead of taking a slice of bark off the stock make a downward cut in the bark about $1\frac{1}{4}$ in. long. Above this, but touching it, make a cross cut $\frac{1}{2}$ in. long. The two cuts should form a T. Gently loosen the bark along the edges of the cut sufficiently to allow the piece of bark with its bud to be inserted. The end of the handle of a budding knife is specially made for this operation. Great care should be taken not to break the bark. Gently insert the scion and bind it up with waxed tape as before. It is necessary to get the scion placed in position and bound up as soon as possible to prevent the cut surfaces of the bark drying up. It is advisable that the budded stock be shaded from the sun.

The scion and the stock should unite in from two to three weeks, and the budding tape should be then removed. The growth of the bud is encouraged by breaking down the stock several inches above the point where the bud was inserted. This checks the flow of sap to the upper part of the stock, and more is directed towards the bud. When the bud has developed into a shoot about 6 in. long, all the stock above the shoot should be carefully pruned away with a sharp knife.

Grafting.— In addition to a good, strong, budding knife and some waxed tape, specially prepared wax is required for grafting operations. Suitable wax for this purpose can be made as follows. Weigh 4 oz. of resin, 2 oz. of beeswax, and 1 oz. of tallow. Place these in an iron pot over a fire until they melt, and then thoroughly mix them all together. The mixture is ready for use when it is cool.

Scions and stocks may be cut in several different ways. What is known as saddle grafting is one of the simplest methods, and if properly carried out can be relied upon to give good results. The stem of the scion should be the same diameter as the stock. Opposite sides of the stock should be sliced in such a manner that a wedge-shaped portion is left on top. The base of the scion must be cut so that it fits exactly on to the wedge-shaped top of the stock. A scion should not be more than 6 in. long but should have at least four buds upon it. Bind the cut surfaces of the scion and the stock carefully but firmly together with waxed tape. Then cover the tape with grafting wax in order to exclude air. As soon as the cut surfaces of the scion and the stock have united, the wax and the tape covering may be removed.

Inarching.—Grow some mango, coffee, or cocoa plants in bamboo pots. When the stems are about ½ in. in diameter they are ready to be inarched. Select a branch of similar size from the tree it is proposed shall supply the scions. Arrange one of the pot plants so that it and the selected branch can be easily brought close together. A low branch may be brought near to the pot when it is stood upon the ground by fixing a stake in the ground and tying the branch down to it. When this plan is not practicable a box, barrel, or a light wooden platform must be utilised for standing the pot upon.

Slice off a strip of wood and bark, about 2 in. long, from one side of the stock but not deeper than one-third of the thickness of the stock. Also slice a similar piece from the branch chosen as a scion. If these cuts be properly made, the cambium tissues of both stock and scion will meet when the two cut surfaces are brought together. Any leaves which exist upon the cut portions of the two stems should be pruned off. The cut surfaces should be bound firmly together with waxed tape and the whole covered with wax.

The soil in which the stocks are growing must be kept moist. In dry weather it will be necessary to water them at least once a day.

As soon as the cut surfaces have united, a strip of bark, extending about half way round the stem, should be stripped from the scion just below the point where it is joined to the stock. If after two or three weeks the scion shows satisfactory progress, it may be completely severed from the parent tree. The upper portion of the stock should now be cut back to the point where it is joined to the scion. In order to protect the young, grafted plant from the sun and the wind, it should be placed either under a nursery shelter or in an open shed. It may happen that its leaves will droop; it should be then placed in a dark place for a few days. The reason why darkness is beneficial to a plant in this condition is explained in Chapter V.

When the grafted plant is able to bear full exposure to the sun without drooping it is ready to be planted out.

It is necessary to remember that, whatever method of budding or grafting is used, all growths which develop below the buds or grafts must be pruned away.

CHAPTER V

LEAVES

In the absence of flowers and fruit many plants may be recognised by the shape and character of their leaves. The extraordinary manner in which leaves vary in shape and size must be noted. Collect all sorts and conditions of leaves and request students to name the plants from which they were picked, and also to draw various leaves from memory. Collect various tubers and underground stems and endeavour to discover the tiny scale-like leaves present on some of them. Notice that some leaves are smooth and shiny while others are quite rough, especially on the under surface. This roughness, if examined under a magnifying glass, will usually be found to be due to the presence of innumerable small hairs. Attention should be directed to the manner in which the young leaves of different plants are folded up in the buds.

Leaf Veins and their Uses.—Most leaves have a framework of woody tissue which is usually described as the veins. In grasses, bamboos, palms, and other Monocotyledons the veins run lengthwise with the leaf, and are more or less parallel. The leaves of Dicotyledons have their veins arranged in the form of a net. If some young leaves and stems be examined, it will be seen that the framework is a continuation of the woody tissue of the stem. We have already seen that the liquid matter taken up by the roots is conveyed to the leaves by means of this structure. In a similar manner materials manufactured in the leaf are distributed to other parts of the plant. The framework helps to protect the leaf from being easily torn, and keeps it spread out in the light and air.

Stomata.—If the outer, colourless skin of a leaf be pealed off and placed under a magnifying glass it will be found to contain a large number of minute holes or pores. These are the stomata by means of which the plant is able to breathe. Each stoma (stoma is the singular of stomata) is provided with a pair of guard-cells. These open in the light and close in darkness, or when the plant is not properly supplied with water. It is also principally through the stomata that water is transpired by the plant.

FIG. 8.—Stomata on Leaf (Magnified).

Transpiration.—The water and soluble matter absorbed by the root-hairs passes up the stem of the plant to the leaves and is used up in the various processes which take place therein. This upward flow of water is induced by two main factors, which are described as transpiration and root-pressure. Leaves or flowers which have been plucked from a plant quickly droop unless their stalks be placed in water. This is due to the water which they contained having been transpired, and the supply from the roots being cut off. Many cultivated plants, such as cotton and maize, droop on a very hot day. This is because water is being transpired from the leaves more rapidly than it is being taken up by the roots.

The water taken up by the roots contains a very small proportion of plant-food material. A considerable quantity of liquid has therefore to be absorbed in order to provide sufficient nutriment to support growth.

How Carbon is obtained by Plants.—In a previous chapter we learned that a gas known as carbon dioxide is present in the atmosphere, also that this gas is composed of carbon and oxygen. Carbon is familiar to everyone in the form of charcoal. A large proportion of the substances of which plants are composed is made chiefly from carbon. The black or charred appearance which all organic substances assume when they are strongly heated shows that they contain carbon.

By suitable experiments it can be proved that plants do not obtain their supplies of carbon from the soil but from the carbon dioxide in the atmosphere. This gas enters the leaves by means of the stomata. Within the leaves various processes take place, and as a result, and under suitable conditions, carbon is retained by the leaf and oxygen gas is expelled.

Chlorophyll.—The conditions suitable for carbon absorption are the presence of both sunlight and chlorophyll. Chlorophyll is the colouring matter which gives leaves and young stems their green tint. In many ornamental plants, such as acalypha and coleus, which have red or yellow leaves, the green colouring matter is present but it is obscured by other colours. Chlorophyll is only formed in the leaves when they are exposed to the light. Notice how grass and weeds lose their green colour if a box or plank be laid on them. Also that the shoots produced by yam tubers stored in a dark room are white, but as soon as they are planted in the ground green shoots are produced.

Starch Formation.—In conjunction with carbon absorption, another process which takes place in green leaves exposed to the light is the formation of starch. We have learned how starch is stored up in tubers, thickened roots, and seeds. The starch manufactured in the leaves does not remain there, but is transferred to different parts of the plant. This can be proved by experiment. The leaves of a plant grown in a pot or box, which has been exposed to the light all day, will be found to contain an abundance of starch. If this plant be placed for a whole day in a dark place, scarcely any starch will be found in the leaves. No starch has been formed in the absence of light, but if the plant be brought into the light again for a few hours starch will be formed in the leaves.

Respiration.—During daylight plants are constantly engaged in purifying the atmosphere by absorbing carbon dioxide gas. This gas is, however, just as constantly replaced by the respiration of animals, as well as by decaying animal and vegetable matter. Plants also respire or breathe out carbon dioxide. It was at one time thought that plants do not respire during daylight. This was due to the fact that during daylight carbon absorption is considerably more active than respiration, and respiration is hidden during daylight. It follows that because carbon absorption ceases at night, the carbon dioxide expelled during the respiratory process must come from the plant.

Demonstrations

Collect a large number of different leaves, and notice the way in which the veins are arranged. They are often most clearly visible when a leaf is held up to the light. Soak some of these leaves in water until it is possible to remove all the soft parts. A skeleton consisting of the framework of each leaf is then obtained.

Transpiration.—Put some water in a small bottle and fit a cork to it. Select a young shoot with several leaves upon it, and bore a hole in the cork so that the stalk of the shoot may be forced through into the water. Now cover the whole with a glass jar, and stand it on a table in the sunlight. In a very short time moisture will form on the inside of the jar. This cannot be formed from the water because it is covered up. It must therefore have been transpired from the leaves. By moving the bottle and the jar to different places it will be noticed that the brighter the light the greater is the amount of water transpired.

Place some freshly collected leaves under a dry glass in the sunlight. In a short time the inside of the glass becomes coated with moisture; this is due to the water transpired by the leaves. As transpiration proceeds they become limp because they can obtain no water to replace that transpired.

Obtain a plant growing in a pot, and cover the pot and the soil with waterproof paper or some similar material so that no moisture can evaporate from the pot or the soil. Cover the whole with a bell glass. Moisture forms on the inside of the bell glass; this must have been transpired by the plant. In this case the leaves of the plant do not become limp, for the water transpired is replaced by that absorbed by the roots.

Oxygen Exhaled by Plants.—When discussing the absorption of carbon by plants, it was stated that carbon dioxide enters the leaves by the stomata. Further, that it is there split up, carbon being retained in the leaf, and oxygen expelled. Pick a bunch of leafy shoots, put them in a glass vessel of water and place it in the sunlight. In a short time bubbles of gas are formed on the leaves; these are caused by the oxygen expelled during the process of carbon absorption.

Starch Formation.—Pick a young, green leaf from a plant growing in the open and dip it for a minute or two in boiling water to kill it. Then soak it in methylated spirit or gin until all the green colour is abstracted. Now place the almost colourless leaf in a weak solution of iodine and it will turn a dark blue.

Pour about a pint of boiling water on a salt-spoonful of starch and stir this until the starch dissolves. When the liquid is cold pour a little of the iodine solution into it and it turns a dark blue similar to that of the leaf. Iodine is a recognised test for starch, and its presence in the leaf is thus proved.

To prove that starch is not produced in leaves unless they are exposed to the light, conduct the following experiment. Cover up a part of both sides of a leaf in such a manner that light is excluded from it while the remainder is exposed to the light. This may be done by taking two pieces of thick cardboard or of cork of similar size and shape and pinning them together with the leaf between them. They should be left in this position for about two days. Then pluck the leaf, kill it as before, extract the green colour from it by means of spirit, and dip it in the iodine solution. That portion of the leaf exposed to the light assumes a deep blue colour, due to the action of the iodine on the starch formed therein. The portion of the leaf which was covered up remains colourless.

This experiment may be made more impressive by having the word "starch" cut out of two pieces of tin or tin foil so that when they are fixed to the leaf all the leaf is covered up except where the letters occur. When the leaf is killed, decolorised, and stained, the word starch shows up plainly in dark blue letters, while the rest of the leaf is colourless. Young, thin leaves should be used for these tests as they are more quickly decolorised.

FIG. 9.—Showing Leaf Tested for Starch after being covered with a Stencil-plate.

Respiration.—Put a tablespoonful of slaked lime in an ordinary wine bottle, nearly fill the bottle with water, and fit a cork to it. Shake the bottle until the contents assume a milky appearance, and then allow it to stand for a few hours. A white sediment will be deposited at the bottom of the bottle, but the liquid above it is quite clear. This liquid is known as lime water, and it should be carefully poured off and kept in a well-stoppered bottle.

We have learned that carbon dioxide is respired by all plants and animals. Pour some lime water into a small bottle, and, by means of a straw or glass tube, blow into the lime water. In a very short time the lime water becomes cloudy. When discussing soils, it was stated that lime is manufactured by heating limestone (chalk) or carbonate of lime, so as to drive off the carbon dioxide which it contains. The lime in the lime water is reconverted into carbonate of lime, owing to its combining with the carbon dioxide in the breath.

Obtain a glass jar with a large mouth, and fit a cork to it. By means of a pin and some cotton thread attach a few fresh, green leaves to the bottom of the cork, so that when the cork is inserted in the bottle the leaves are suspended in the jar but do not touch the bottom. Pour some lime water into the jar, rub some grease around the cork and fit it into the bottle so as to make it air-tight. Place the bottle in the sunlight and it will be observed that after several hours the lime water is quite clear. This is because the carbon dioxide respired by the leaves is being reabsorbed by them. Now place the jar in a cupboard away from the light, or cover it with a black cloth. In a few hours the lime water will have become quite milky. The leaves have stopped absorbing carbon dioxide owing to the absence of light, and respiration has proceeded unchecked.

Cover up some short grass with a piece of board so that no light can reach it. About a week afterwards lift up the board and the grass will have lost all its green colour. This is because no chlorophyll has been formed in the absence of light. When the board is removed the grass will again produce green leaves.

CHAPTER VI

THE FLOWER

THE principal function of a flower is to produce seeds. If a plant be kept under observation, it will be noticed that no seeds are produced unless flowers have appeared. The flowers of different plants vary in size, shape, and colour. If, however, they be carefully examined large numbers will be found to be designed upon a similar model.

The Organs of Flowers and their Functions.—The different organs of flowers are most readily distinguished in large flowers such as the white, trumpet-shaped Crinum, which may be found growing in many swampy places in West Africa. An examination of one of these flowers will show that on the outside there are six large, white, leaf-like bodies. These are the flower leaves. Considered as a whole they represent the floral envelope or perianth, and serve to protect the interior organs.

Within the floral envelope are six long, slender stalks with a small, yellow body placed crosswise at the end of each. These are the stamens. The small, yellow body at the end of each stamen is an anther. When the anther is ripe it ejects a mass of yellow powder which is the pollen.

In the centre of the stamens is another long, slender stalk, which is connected with a green body, the ovary. This is situated just below the floral envelope. The ovary, together with the slender stalk attached to it, is the pistil.

The stalk of a stamen is a filament, but the stalk of the pistil is a style. The free end of the style, which is swollen and glutinous, is the stigma.

If the ovary be cut in half crosswise it will be found to consist of three cells. In these cells are small, white, rounded bodies which are ovules. Under satisfactory conditions the ovules eventually develop into seeds.

The Orange Flower.—Now let us examine the flower of the orange tree. In this case the floral envelope consists of two rings of flower leaves. The outer ring is composed of five small, thick, green bodies, which are situated at the base of the flower. They form the calyx. Each of the five separate parts of the calyx is a sepal. Inside the calyx are five white, leaf-like bodies which are petals. Collectively they form the corolla. Next to the corolla we find the stamens, but, unlike the stamens of the Crinum, they have short filaments. In the centre of all these parts is the pistil. It has a short style which thickens towards the stigma end. Notice that in the Crinum flower the ovary is placed at the base of the floral envelope, but in the orange flower the floral envelope is situated below the ovary.

The Cotton Flower.—The different parts of the cotton flower may be readily distinguished.

There are usually five green, short sepals and the same number of yellow petals. The three large,

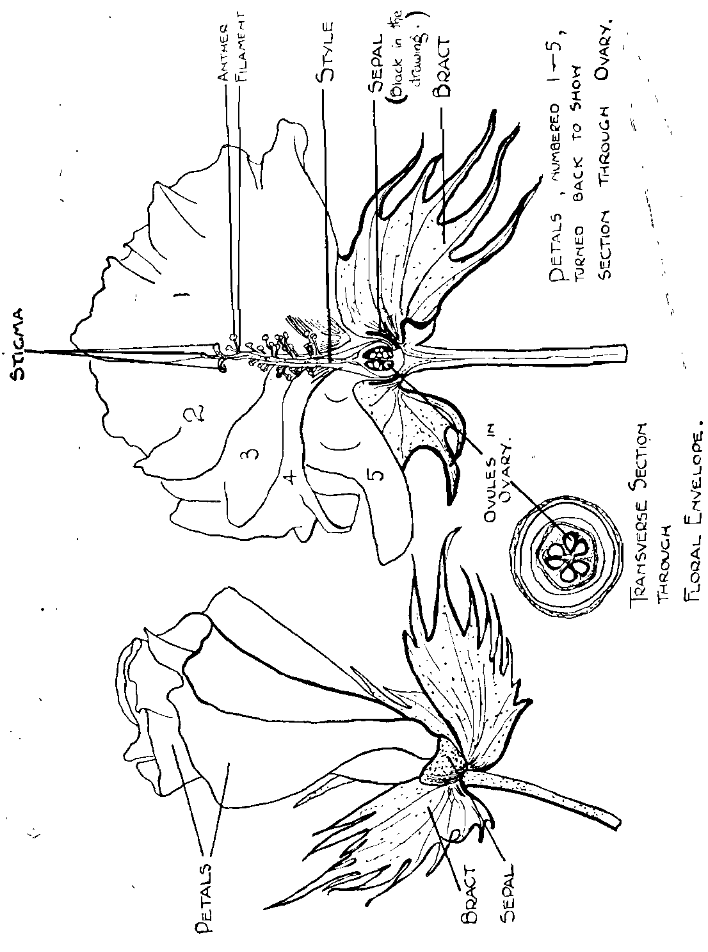


FIG. 10.—The Organs of a Cotton Flower.

leafy bodies attached to the base of the flower must not be mistaken for sepals; these are bracts or extra leaf-like parts. The cotton flower has a large number of stamens and the filaments all grow together at the base and form a tube around the style.

Although we found slight differences in the three flowers examined, on comparing them it will be observed that the principal parts are common to all. Each has a floral envelope, stamens with anthers containing pollen, and a pistil composed of an ovary with ovules and a style and stigma. One important difference between the Crinum and the other two flowers should be noted. The parts of the Crinum flower are arranged in threes, but those of the orange and cotton flower are arranged in fives. These two characters serve to distinguish the flowers of the two divisions of flowering plants which we have previously discussed (Monocotyledons and Dicotyledons). Usually the parts of monocotyledonous flowers are divided into threes, while those of dicotyledonous flowers are divided into fives.

Complete or Perfect Flowers.—Each of the three flowers just referred to has stamens and a pistil in the same flower. In certain instances the stamens are present in one flower and the pistil in another. A flower which possesses both stamens and a pistil is described as a complete or perfect flower. The stamens and the pistils are referred to as the essential organs of a flower because they are the organs which are connected with the production of fruits and seeds.

Incomplete Flowers.—If a careful search be made amongst some melon or gourd plants when they are flowering, it will be observed that these plants produce two different kinds of flowers. Some of the flowers have stamens but no pistil, the other flowers have a pistil but no stamens. These may be described as incomplete flowers. Certain plants, such as the West African date palm, produce upon one palm flowers without stamens, and upon another flowers without a pistil.

If a melon or gourd plant be carefully watched it will be noticed that fruits are not produced on the flowers which have no pistil. Bearing in mind what has just been said about the stamens and pistils being necessary for the production of fruit, it is advisable to consider what part the stamens play in this production.

Pollination.—Let us pay a little more attention to the small, yellow bodies, the anthers, which are situated at the end of the stamens. Notice that when the anther is ripe a yellow, powdery mass, the pollen, is set free. Some of this powder is conveyed by insects, wind, or other agencies to the stigma. When this occurs the flower is said to be pollinated. When a flower is pollinated by its own pollen, it is said to be self-pollinated. When a flower is pollinated by pollen from another flower of the same kind, it is said to be cross-pollinated.

If all the anthers of a flower be removed before the pollen is liberated, and the flower be tied up in a muslin bag, so that it is impossible for any pollen to reach the stigma, the flower will wither up and no fruit and seeds will be formed. The word fruit as used in this book has a much wider meaning than that generally associated with it.

We shall learn later that a fruit need not necessarily be edible, for, correctly speaking, it is the fertilised and ripened ovary of any plant.

If the stigma of a flower be dusted with the pollen produced by the same kind of flower, and be then tied up in a muslin bag as suggested above, the flower will wither but the ovary will develop into a fruit. It must be particularly noted that it is only when the pollen is brought to the stigma from a flower of the same kind that these results are obtained. For instance, it is useless to apply the pollen of a Crinum flower to the stigma of a cotton flower.

Fertilisation.—When a pollen grain reaches a suitable stigma, various complicated processes take place. The pollen grain germinates and a tube grows down the style and enters an ovule. Thus is an ovule fertilised and it eventually develops into a fertile seed.

The terms pollination and fertilisation must not, therefore, be confused. When pollen reaches a suitable stigma the flower is pollinated, but it is not fertilised until the complicated processes referred to have taken place.

Cross-Pollination.—It has been proved by experiment that seeds which result from cross-pollination have greater vitality than those resulting from self-pollination. This is probably the reason why many flowers are so arranged that self-pollination is impossible.

In some cases the anthers and stigmas of the same flower mature at different times. The parts of other flowers are so placed that it is difficult for the pollen to reach the stigma of the same flower. Then how do these flowers become pollinated? That suitable pollen reaches their stigmas is obvious, for they produce fertile seeds.

Insects and Pollination.—We have seen that the floral envelope serves to protect the essential organs of the flower. In many cases it has other uses as well. Some flowers have a brightly coloured or an odorous corolla which serves to attract insects. When passing from flower to flower insects become dusted with the easily detached pollen, and this is brushed off on to the sticky stigmas of other flowers that they visit. Bees, butterflies, moths, and other insects may often be seen hovering close over certain flowers which contain honey. The insects feed upon this honey, and in abstracting it from the flowers get their bodies coated with pollen. This they carry to the stigmas of other flowers which they visit later.

Wind-Pollinated Flowers.—Many flowers are pollinated by the wind. These flowers usually produce an abundance of pollen, and have large hairy or feathery stigmas which offer a large surface to the wind. A great deal of the pollen is of course wasted, but it is produced in such large quantities that it is only necessary for one out of several hundreds of grains to be effective.

Maize furnishes an excellent example of wind-pollinated flowers. What is generally described as the "tassel" is composed of a great number of flowers which have stamens, but without a pistil.

When the anthers are ripe, the pollen, which in this case is of a dry, powdery nature, falls like a cloud of dust if the plant be slightly shaken. The mass of fine hairs, known as the "silk," which is produced at the top of a young cob, consists of stigmas. It will be seen how readily they may be pollinated from the cloud of pollen liberated by the "tassel" flowers.

Demonstrations

Organs of Flowers.—Students should collect a large number of different kinds of flowers for examination. They should then be encouraged to name the various parts of each flower. Complete flowers suitable for a first examination are lilies, cotton, okro, orange or lime, beans, and guava. Attention should be invited to the manner in which the size, shape, and colour of the corolla varies in different flowers.

Large drawings should be made of the various parts of flowers. The filaments and style vary greatly in shape. In some cases the style is longer than the filaments, in others it is shorter. Attention should be drawn to the various kinds of anthers and stigmas.

Notice that in such plants as zinnia and marigold what at first sight appears to be a single flower is really a mass of flowers collected together in a head on a single stalk. Cut through the stalk and the head, and numerous tiny flowers will be found.

Incomplete Flowers.—From a collection of flowers students should separate those which are complete and incomplete. Suitable incomplete flowers for a first examination are: gourd or melon, papaw, cassava, and castor oil. Keep some gourd or melon flowers under observation, and notice that no fruits are produced from the flowers which have no pistil. A stamen-flower (staminate) may be distinguished from a pistil-flower (pistillate) of these plants before they open by the tiny gourd or melon which forms at the base of the bud of the latter kind.

Select some pistil-flower buds and tie them up carefully in some fine muslin so that no pollen can reach them. When the stigmas are ripe bring some stamen-flowers, remove the muslin and dust some pollen on the stigmas of some, but not on others. The muslin should be then replaced. No fruit will be produced on the flowers which were tied up and received no pollen. But in a short time the gourd or melon on the pollinated flowers will commence to develop, and it will be necessary to remove the muslin so as not to check their growth.

Remove the young "silks" from one side of some young, maize cobs and notice that no grains are produced on that side of the cob. Each of the "silks" is connected with a grain space in the cob, and unless the "silk" is pollinated no grain is formed.

Pollination.—Remove the young, undeveloped stamens from some cotton flowers and tie each one singly in a muslin bag. Later bring some cotton flowers in which the stamens are shedding their pollen, and dust the pollen on the stigmas of some of the flowers which were tied up. On the stigmas

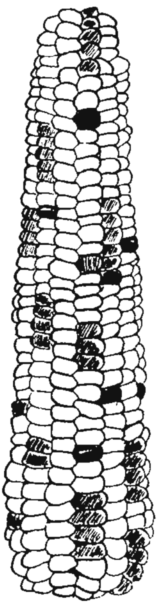


FIG. 11.—Cross-Fertilisation of Maize.

of the others dust some pollen from a lily or a maize "tassel." Notice that no cotton bolls are produced by the flowers which were dusted with the lily or maize pollen. The reason is that the pollen of maize or lily is not suitable for fertilising the ovules of the cotton flower.

Cross-Fertilisation.—When maize cobs are being harvested it is frequently found that some of the cobs have grains of different colours. This is due to what is known as cross-fertilisation. Pollen from the "tassels" of one kind of maize has been carried, probably by the wind, to the "silks" of another kind. Different kinds of maize should therefore not be planted close together, otherwise mixed grain is produced.

CHAPTER VII

THE FRUIT

We have now traced the development of the plant from the sowing of the seed to fruit and seed production, which is the primary object in the existence of plants. In a very large number of instances the plant dies as soon as it has matured its fruit. We have discussed the manner in which seeds germinate, the uses of roots, leaves, and flowers.

Definition of Fruit.—The word fruit as generally used is understood to mean the ovary and attachments of any plant which, on becoming ripe, is edible. The botanist, however, applies the term fruit to any fertilised and developed ovary. The student should therefore consider the fruit as those parts of the flower which develop after fertilisation has taken place. Care must be taken not to confuse fruit with seed. Seeds develop from the ovules, and a fruit may contain one or more seeds.

Seed Distribution.—We know that the seeds of wild plants and trees grow and develop into plants without the aid of man. How then are the seeds distributed? When discussing the germination of seeds we learned that it is not advisable to sow seeds too closely together. Now, if all the seeds produced by a particular plant fell to the ground beneath that plant they would certainly be sown too closely together. When the seedlings germinated there would not be sufficient room for them to reach maturity, for besides being too close together they would be over-shaded by the parent plant.

The seeds of plants are distributed in several different ways, but the principal agents in this distribution are wind, water, animals, and various contrivances with which some fruits are provided to eject their seeds to a long distance.

Wind-Borne Seeds.—The seeds distributed by wind are mostly small and light in weight, or are provided with some attachment which enables them to be readily carried away by the wind. The small seeds of many grasses may be frequently seen carried about by the wind. The minute seeds of the tobacco plant are distributed through a small hole in the top of the fruit when the wind agitates the plant. When the fruit of the silk-cotton tree is ripe it splits open, and the seeds, each of which is enveloped in a mass of silky cotton, are carried away by the wind. The fruits of the Funtumia rubber tree also split open when they are ripe. The seeds in this case have a number of long, silky hairs attached to one end. When the seeds fall from the split fruit-shell these hairs spread out, and the seed with its hairy attachment is carried away in the form of a parachute. The seeds of the yam are provided with wings which facilitate their distribution by the wind.

Water-Borne Seeds.—Water is not such an important factor in seed dispersal as the wind, still it is responsible for the transport of a large number of different kinds of seeds. Some seeds are not injured by salt water. An excellent example of this nature is the coco nut. This seed is covered with a thick, fibrous coat which renders it buoyant in the water, and it is sometimes carried for hundreds of miles by the sea. The fatty nature of this seed prevents water filtering through readily. It is sometimes carried about by the waves for a long time, and when it is washed ashore germination may take place. Experiments have shown that certain seeds may be immersed in salt water for more than a year and still retain their capacity for germination. Large numbers of seeds are also distributed by rivers. Some of these are naturally carried out to the sea and lost, but others find a favourable spot to germinate on the river bank or on the seashore.

Animals and Seed Dispersal.—Many succulent fruits are swallowed by animals and germinate satisfactorily when they are ejected. The fruits of several Landolphia rubber-vines contain seeds which are enveloped in a sweet mucilage. Monkeys and other animals are very fond of this sweet stuff. They break open the ripe fruits and swallow the mucilage, and in some cases the seeds as well. Many of these fruits which have not been opened by animals fall to the ground. As the seeds are unable to escape from the hard fruit-shell they often lose their power of germination before the fruit-shell rots away and liberates them.

Many birds feed upon fleshy or succulent fruits. In certain cases the seeds are swallowed and then ejected, while in others the succulent matter is eaten and the seed is discarded. Loranthus, a troublesome parasite which grows on cocoa and other trees, produces a small fruit with a succulent covering. Birds feed upon this succulent matter, and, in cleansing their bills upon a branch, leave the seed in a suitable situation for germination.

Insects are also very active agents in seed distribution. Ants are very fond of the seeds of the papaw which they often carry away to their nests, and three or four ants sometimes may be seen struggling along with one of these seeds. In vegetable gardens ants often cause a good deal of annoyance by carrying off the seeds which the gardener has sown.

Some seeds are provided with small hooks, claws, or sticky hairs by which they attach themselves to animals or birds, and are by this means widely distributed. Notice how such seeds cling to wearing apparel when it is brushed against them.

Fruits with Ejectory Contrivances.—Many fruits are so constructed that, when they are ripe or under special conditions, the seeds are ejected with considerable force. Examples are seen in the fruits of the sandbox tree, Ceará and Pará rubber, castor oil, and balsam. In the case of the sandbox tree the fruits split with such force that an explosion similar to the report of a pistol is given off.

Demonstrations

The characters of various fruits can be made a very interesting subject for study, and specimens of a large number of different kinds should be collected for this purpose.

Description of Various Fruits.—The fruit of the bean is termed a legume, and when it is quite ripe it splits in half longitudinally to liberate the seeds. The cotton boll is a capsule, and when it is ripe the fruit-wall splits and sets free the cotton-covered seeds. The fruit of the coffee tree is termed a berry; it contains two horny seeds. The mango fruit is called a drupe; it contains only one seed. Note that, unlike the bean and cotton fruits, those of the mango do not split, but, when they are properly ripe, they fall to the ground entire.

Notice the manner in which the seeds are arranged in different fruits. In the cocoa fruit they are arranged on a central column which is only attached to the base of the fruit. On the other hand, there is a vacant space in the centre of the passion fruit, and the seeds are arranged on the fruit-wall surrounding this.

Collective Fruits.—What is usually looked upon as the pineapple fruit is really a thickened, succulent stem, in which a number of small fruits are imbedded. Examine a very young pineapple, and a large number of tiny, blue flowers will be found on the outside of the young growth. The pineapple must therefore be considered as a collective fruit. Other instances of this nature are the bread nut and the Jak fruit.

The fig is commonly called a fruit, whereas it is a receptacle containing numerous fruits. If possible collect some of these so-called fruits, cut them in half, and a mass of what appear to be tiny seeds is found. Each of these represents a separate fruit, for it has developed from a single flower. If young figs be examined under a magnifying glass it is possible to distinguish these flowers.

For comparison with the collective fruits of the pineapple, bread nut, Jak fruit, and fig, fruits of custard apple, sour sop, and sweet sop should be examined; the latter are produced from a single flower in each instance.

In the cashew nut (*Anacardium*) the edible portion consists of the fruit stalk which assumes a swollen pear-shape. Attached to this is what appears to be a black seed; this is, however, the fruit and it contains a single seed.

CHAPTER VIII

THE FOOD OF PLANTS

It will be remembered that, when we were discussing the uses of roots and leaves, it was mentioned that food from the soil is taken up by the root-hairs in a liquid condition, also that leaves absorb and assimilate carbon from the atmosphere.

Ingredients of Plant Food.—In the food which plants take up from the soil are nine or ten different elements. When a soil does not contain a sufficient quantity of any one of these to supply the plants' requirements, growth is checked. The agriculturist is, however, mainly concerned with three of these substances, because fortunately the soil nearly always contains an abundance of the others. The names of the three substances which are sometimes lacking in the soil are: nitrogen, potash, and phosphorus. Less rarely lime is absent, or sufficient may not be present to supply the needs of a crop.

Nitrogen.—We have already learned that four parts of the atmosphere is composed of nitrogen. One would therefore think that plants should be able to obtain all they require of this substance from the atmosphere. This, however, is not the case, for, with the exception of one group of plants, the *Leguminosæ*, to which we shall refer later, they are not able to make use of the nitrogen in the atmosphere. In the soil are substances known as nitrates, and it is from these that plants obtain their supplies of nitrogen. Nitrogen is present in all living things, and when these decay in the soil the nitrogen which they contain is changed to nitrates.

Soil Bacteria.—This change is effected by extremely minute organisms called bacteria, which live in the soil. Some idea of the size of these organisms may be formed when it is stated that an ounce of soil may contain many millions of them. The student must not, therefore, expect to see them with the naked eye. *Until nitrogenous substances have been acted upon by soil bacteria* plants are unable to feed upon the nitrogen which they contain.

It will thus be seen that these bacteria perform a very valuable service for the farmer, because his crops would not grow successfully if there were no nitrates in the soil. In order that soil bacteria may multiply and carry out their work properly they require warmth, air, and moisture. It is also necessary that lime should be present in the soil to prevent its becoming sour. It is not likely that they will suffer through a lack of warmth in the tropics. They may and do suffer when the soil is too dry or when air does not freely circulate through the soil. We have learnt that warmth, moisture, and air are necessary in the soil for the proper development of plants.

When the farmer cultivates his soil in order to improve its condition for the growth of his crop, he is, therefore, also improving the conditions for the growth and work of his friends the soil bacteria. There may be an enormous quantity of nitrogenous matter in the soil, but, unless the soil bacteria be present and are able to perform their work, plants will not be able to make use of the nitrogen which it contains. Because of the nature of the work which this kind of bacteria perform they are generally known as nitrifying bacteria.

Mineral Ingredients of Plant Food.—The other two substances which are likely to be deficient in a soil are potash and phosphorus. They are two of the mineral constituents of plant food. When a plant is burned the nitrogen, carbon, hydrogen, and oxygen disappear in the smoke. The mineral constituents remain in the ash which is left behind. These mineral constituents are supplied to the soil by the breaking up of rocks (referred to in Chapter I.).

The soil, as we see it, consists of a mass of more or less gritty particles. Before plants are able to obtain their food from it various complicated processes have to take place in order to render this food soluble and available for their use.

Manuring.—When a piece of land is cultivated year after year, and the crops are removed, a great deal of plant food is taken away from it. Now, if the soil contain only a small quantity of nitrogen, potash, or phosphorus, the crops planted will soon suffer, and it will not be possible to cultivate this piece of land with profit unless the missing plant food ingredients be added. Near many large towns in West Africa are extensive areas of land which, after being farmed for several years, have been abandoned, and now produce little else but coarse weeds and grasses. This is mainly due to the fact that their supplies of certain plant food constituents have been exhausted by repeated cropping. To prevent land becoming unprofitable in this manner, the experienced farmer adds to his land various materials which contain the food materials that are missing. Substances applied to land for this purpose are known as manures.

Certain of these substances are applied in order to supply all the different elements that plants require for food; these are known as general manures. Other substances contain only one or two of these elements, and are known as special manures.

General Manures.—Animal manure is the commonest form of general manure employed. This consists of the dung of domestic animals, together with the grass or other litter used in the buildings where the animals are kept. Animal manure does not contain a high percentage of plant food. It is specially valuable because it adds a large amount of humus to the soil. This addition enables light soils to retain more moisture, thus assisting crops to survive a period of drought. When applied to heavy soils it converts them into a more porous condition, and more easy to cultivate. Weeds and leaves dug into the soil have a similar effect, and at the same time manure the soil.

Special Manures.—Special manures are distinguished as nitrogenous, potassic, or phosphatic, according to the manurial substance which they contain. One of the commonest forms of nitrogenous manure is nitrate of soda or Chile saltpetre. This contains about 15 per cent. of nitrogen. It is a very soluble manure, and is consequently quickly taken up by the crop. For the same reason it is rapidly washed out of the ground. It should, therefore, be applied in small quantities, and preferably while the crop is growing actively. If applied at other times it is liable to be washed out of the ground and wasted. Nitrate of soda must be kept in a dry place, otherwise it will absorb moisture from the atmosphere and turn into a liquid state. Sulphate of ammonia and guano are also commonly used as nitrogenous manures.

Wood ashes contain a large amount of potash, and are, therefore, a valuable potassic manure. A large proportion of commercial potassic manures are obtained from the Stassfurt potash salt mines in Germany. One of the commonest potash salts is called Kainit. This consists of about 12 per cent. of potash and 35 per cent. of sodium chloride, or common salt. It is a readily soluble manure, and tends to increase the amount of moisture in the soil. On this account it is not advisable to apply Kainit to heavy clay soils. Other potassic manures employed are sulphate of potash and muriate of potash.

The bones of animals are rich in phosphate of lime, and they are largely used for making phosphatic manures. In some cases they are merely ground up into powder and applied in this form.

In this condition the manure acts slowly, as the plant food which it contains is not available for the use of the crop until certain changes have taken place in it. To render the phosphate of lime more soluble manufacturers treat bones with strong sulphuric acid ; it is then known as superphosphate. Basic slag or Thomas' phosphate powder is another form of phosphatic manure. It is sold in the form of a finely-ground, black powder, and is a waste product in steel manufacture.

Green Manuring.—Plants belonging to the bean or legume family [*Leguminosæ*] are the only ones which are able to make use of the nitrogen in the atmosphere. If some plants of cow pea or native bean be dug up, on their roots will be found a number of small swellings or tubercles. In these tubercles live tiny bacteria, but not the same kind that assist in forming nitrates in the soil. The bacteria which live in the tubercles feed upon the nitrogen in the air, and then hand it over for the use of the plants upon which they live. In consequence of this the plants upon which the tubercles are found are able to flourish in a soil which is lacking in nitrogen. The knowledge of this fact is of great importance to the farmer, for if he attempted to cultivate plants possessing no tubercles on this land they would not grow satisfactorily. Not only do these bacteria supply nitrogen to the plants upon which they live, but it has been found that when these plants die they add nitrogen to the soil. There is thus more nitrogen in the soil than before they were planted.

The soil can be improved by digging in ordinary plants. When these decay they return to the soil the various plant foods which they have absorbed from it. This operation also increases the stock of humus in the soil, and the presence of this substance, as we have learned, is of very great importance.

The burying of leguminous plants is, however, far more beneficial, for they supply in addition the nitrogen which they have taken from the atmosphere, and this is the element of plant food which is most frequently deficient in the soil. For this reason leguminous plants are cultivated, and then dug into the soil in order to manure it. By this means the farmer is able to manure his land without buying expensive manures or transporting bulky material such as animal manure.

Demonstrations

Plant Food taken up in Solution. — That root-hairs take up food in solution may be illustrated by a simple experiment. Take two glass bottles with wide mouths, such as jam jars. Fill them with water; to one add sufficient eosin to colour the water bright pink. To the water in the other bottle add some Indian ink. Dig up two young maize seedlings, taking care not to injure the root-hairs. Now fit a cork to each bottle, split the corks, and make a hole in the centre of each as large as the stems of the seedlings. Fix a seedling in each cork, and pack a little cotton-wool around it, so that when the corks are inserted in the bottles the roots dip into the coloured liquid.

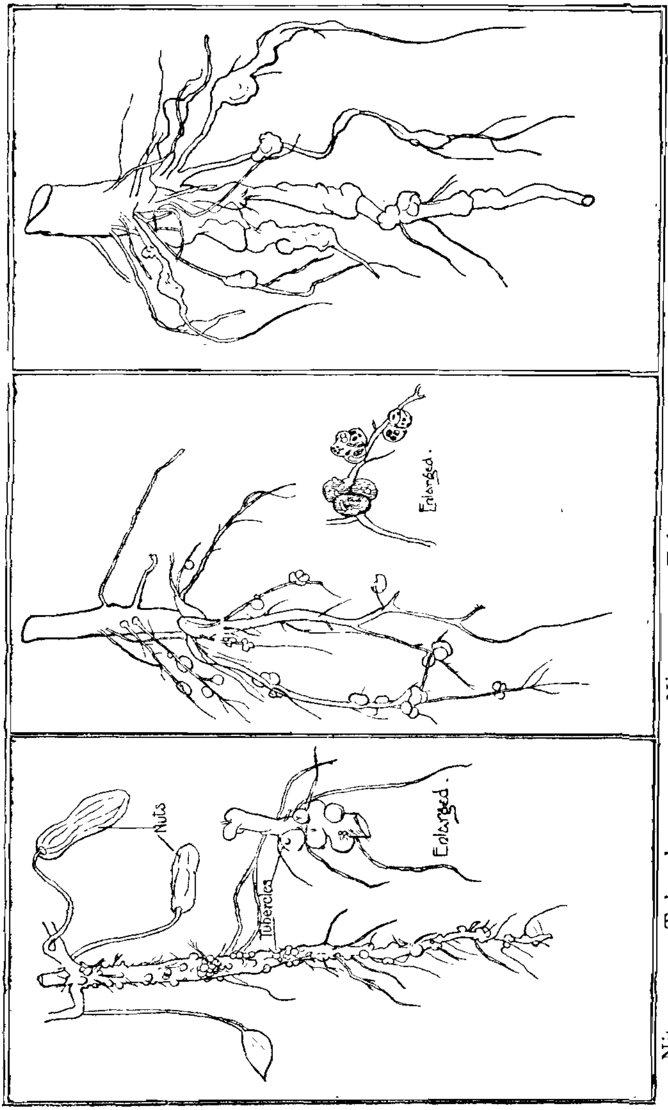
Notice that the tissues of the seedling become coloured with the eosin, but not with the Indian ink. The reason for this is that eosin is soluble in water, and is thus taken up by the roots. Indian ink, on the other hand, is not soluble in water, the water in this case being merely coloured with solid matter held in suspension. In the chapter on soil it was mentioned that solid matter is held in suspension in river water. Also that when such water is allowed to stand in a vessel for a short time the solid matter sinks and forms a sediment at the bottom of the vessel.

Combustible Matter in Soil.—Put a little garden soil in a shovel or on an iron sheet, place this over a fire, and notice the changes which take place in the soil. At first steam is given off owing to the heat driving the moisture out of the soil. Gradually the soil turns a darker colour; this is due to vegetable matter becoming charred. Later, as the vegetable matter ignites, dark-coloured smoke is produced. In this smoke are the carbon, nitrogen, and other combustible matters which the soil contained. When the soil has become thoroughly red-hot all through, remove it from the fire and place it on one side to cool. It is now a reddish colour, similar to burnt bricks, and it contains nothing but the mineral matters which were originally present in the soil. Now burn some plants, and similar changes will be found to take place.

Collect some sheep or cow manure and mix it with some half-rotted leaves. Select two beds of the same size in the school garden which have been cultivated for a year or two without any manure being applied. To one of these apply a good dressing of the manure mixture. Plant the same kind of crop on each bed, and notice the different growth of the plants on the two beds. Harvest the crop from the two beds separately, and weigh them for comparison.

Eelworms.—Examine the roots of plants which have flowers like the bean and which produce leguminous fruits. Many of these will be found to have tubercles, but the manner in which they vary in shape should be noticed. Also examine the roots of such plants as garden egg, tomato, and chillie pepper. These also sometimes have tiny swellings on their roots. These swellings are not, however, nitrogenous tubercles, for they are caused by minute creatures known as eelworms, which feed upon the roots, and often seriously injure them.

Test for Lime.—A simple method of ascertaining whether a soil contain sufficient lime is to take a small sample and pour some dilute hydrochloric acid upon it. If lime be present in sufficient quantity effervescence takes place, or in other words, tiny bubbles of gas will be formed. Remember that effervescence takes place when acid is poured upon ground-up snail shells. In the chapter on soils we learned that these bubbles contain carbon dioxide gas. Soils found in swampy places, which are mainly comprised of organic matter, are most frequently lacking in lime. Samples of these should



Nitrogenous Tubercles on Ground Nut.

Nitrogenous Tubercules on Cow Pea.

Galls caused by Eelworms on Egg Plant.

FIG. 12.

be collected and tested along with ordinary cultivated soil.

Sour Soil.—In low-lying situations, where water stagnates, the soil is frequently of a sour or acid nature. Soil in this condition is unsuitable for cultivation, for soil bacteria are unable to live in it. Various root-diseases of cultivated plants are also commonly met with on such land. This sourness may be improved by drainage, and also by applying lime. When blue litmus paper is brought in contact with an acid its colour is changed to pink or red. The following simple test will demonstrate whether a soil is sour or not. Take several strips of blue litmus paper, and make slits in the soil with a knife. Place a strip of the litmus paper in each slit, and press the soil against it. If the soil be sour the colour of the litmus paper is changed to pink in a few minutes. The more acid there is in the soil the deeper or redder will the colour of the litmus paper become.

Samples of soil should be collected in swampy places and tested in this manner. Any which are found to be acid should be mixed with a little lime, and again tested after a few days. It will then be found that the soil produces no effect upon the blue colour of the litmus paper, for the lime has destroyed the acidity originally present.

CHAPTER IX

DISEASE IN PLANTS

Causes of Disease.—Plants, like men and other animals, suffer from various diseases. By disease is meant ill-health, no matter how this is brought about. Plants may become diseased through their being grown under unsatisfactory conditions, or by the attacks of fungi, insects, and other small animals. One or more of these causes may be responsible for a particular disease. Plants may become diseased if the soil be too wet, also if it be too dry. A plant introduced from another country may become unhealthy if the climate be unsuitable for its growth. It may suffer from disease because the soil is not properly cultivated, or because the soil is lacking in certain plant foods. Undue exposure to the sun or excessive shade may induce disease, for certain plants require shade, while others prefer the full sunlight. Cocoa trees prefer shade, but cotton flourishes best in the sun. Plants growing under one or more of these unsatisfactory conditions are most likely to suffer from fungus or insect attacks.

It will thus be seen that the farmer who carefully cultivates his crops is also adopting the best method of warding off disease.

Fungi.—When we were considering the uses of leaves we learned that their green colour is due to the presence of a substance known as chlorophyll. It was then demonstrated that chlorophyll and starch are only produced in leaves when they are exposed to the light. Now there are certain plants called fungi which produce neither leaves nor flowers, and contain no chlorophyll. These peculiar plants are not able to obtain their food like green plants, but feed upon dead or living plants and animals. The majority of them live upon decaying organic matter. Others obtain their food from living plants. The latter are known as parasitic fungi, because they live on and obtain their food from other plants.

Fungi vary in size, form, and colour in an astonishing manner. Some are so small that a microscope is required to examine them, while others grow several feet in size. Several are edible, and at least two different edible fungi grow upon decaying oil palms. Many fungi are, however, extremely poisonous. In the tropics they seem to abound everywhere. The greenish mould which forms on boots which are not regularly worn is caused by a fungus. So also is the pinkish mass which grows on half-burnt cassava and other sticks on farms which have been recently fired. Many variously coloured fungi of different shapes grow on decaying wood and leaves.

A Mushroom.—Some of the common edible fungi or mushrooms which grow on farms and upon decaying oil palms should be chosen for examination. If one of these be carefully dug up, it will be noticed that the stalk of the mushroom is connected with a mass of delicate white threads. These comprise the mycelium, by means of which the fungus obtains moisture and food material from the substance upon which it is growing.

FIG. 13.—Mushroom Showing Gills.

Under the umbrella-shaped body of the mushroom are numerous blades or gills, which are often darker coloured than the rest of the mushroom. If the stem be removed from several fully developed mushrooms, and the heads laid gills downwards on a piece of white paper for a few hours, a mass of fine, powdery material will be deposited. This material will be found arranged in lines corresponding to the position of the gills, and from which it has been shed. When examined under a microscope it is found to consist of numberless rounded bodies, termed spores. Some of these mushrooms produce white spores, and these are most readily seen on black paper.

Just as flowering plants are propagated by seeds, so are fungi propagated by spores. The minute size of these spores may be estimated when it is stated that if 4,000 could be placed in a line touching each other, this line would not be more than an inch long. Under favourable conditions these spores germinate; in course of time a mycelium is produced, and eventually mushrooms are formed.

Diseases Caused by Fungi.—It is the fungi that live on plants with which the agriculturist is mainly concerned, for they are responsible for many of the most serious plant diseases. Some of these grow on the roots, others grow on the leaves, while in some instances they inhabit every part of a plant. Fortunately it is not common to find a particular fungus disease attacking a large number of different kinds of plants. It is, therefore, when large areas are cultivated with one kind of crop that fungus diseases are most troublesome, for a disease is then able to spread rapidly from plant to plant. The rate at which fungus diseases spread is not surprising when one considers the countless numbers of spores that are produced, and the ease with which they are carried about by the wind.

The spores of some fungi will germinate when they fall on leaves. The mycelium forces its way through the skin of the leaf, usually through the stomata, and feeds upon the plant food therein. Some behave in a similar way as regards fruit. Others are unable to force their way through the skin of a leaf or fruit, but when they come in contact with a cut or a bruise, they are then able to effect an entrance to the plant tissues. In each case, once they get inside the plant, they are able to develop rapidly by feeding upon the material which the green plant has prepared for its own use. When this happens it is impossible to destroy the fungus without destroying the tissues in which it is living.

"Rust" Diseases.—If a careful search be made amongst wild grasses and other weeds some will be found with unhealthy looking blotches, usually yellow in colour, on the leaves or stems. On closer examination it will be noticed that the exterior skin or epidermis has burst in different places. From these ruptures a yellow or dark brown powder is expelled. This powder is composed of the spores of a parasitic fungus commonly known as "rust."

There are a large number of different kinds of "rusts," and they cause some of the most serious diseases with which the farmer has to contend. One kind of "rust" may produce several different kinds of spores. Sometimes these are all produced on one plant, but frequently different kinds of spores are produced on different plants.

When the spores are expelled they are carried about by the wind or insects. If they fall upon their particular host plant they germinate, and frequently obtain an entrance to the plant's tissues through the stomata. Once inside the tissues of the host plant it is impossible to destroy the fungus without also destroying the plant, or the part of the plant in which the mycelium is living. The fungus lives at the expense of the host plant, destroys its health, and sometimes kills it.

"Smut" Diseases.—In a field of Guinea corn there are usually present a number of "heads" which do not bear properly developed seeds. In place of kernels the seed-coats contain a mass of black powder. This is due to a fungus disease known as "smut," and the black powder consists of minute fungus spores. Several cereals are affected by fungus diseases in a similar manner. Usually plants are infected in the seedling stage, and the mycelium continues growing as the plant develops, but no ill effects are noticed until it is found that fungus spores are produced instead of grain.

One kind of fungus "smut" affects maize in a different way from that described above. Large, whitish blisters or galls appear on various parts of the plant. These burst and liberate vast numbers of black, powdery spores. It will readily be seen that a plant cannot produce good, healthy cobs when it is diseased in this manner.

Farmers often suffer serious losses through "smut" diseases destroying their crops. It is, therefore, important that all smutted plants should be burned. If this be not done some of the spores may fall on the ground and infect the succeeding crop.

Fungus Disease of Cocoa Fruits.—A fungus disease which injures cocoa fruits may be observed in nearly every cocoa plantation in West Africa. This disease is usually not noticed until a brown patch appears. This in course of time extends all over the fruit, and sometimes penetrates to the interior and destroys the seeds. The spores are first produced in the form of a whitish powder, but later they turn black.

These spores are carried about by the wind, rain, or insects, and infect healthy fruits. The same fungus also occasionally attacks and destroys the roots and branches of cocoa trees. Many farmers, after extracting the seeds from cocoa fruits, throw the shells down in the plantation. Needless to say this is a very big mistake, for if any of them are diseased the spores will be carried to and infect healthy fruits. When this disease is noticed in a plantation, all the shells should be either burned or buried deeply in the ground.

Fungicides.—The growth of the spores of parasitic fungi, such as that which attacks cocoa fruits, may be checked by spraying the trees with a solution made up of certain chemicals. Formalin and copper sulphate are two of the substances most commonly used for this purpose. Both are poisonous to green plants, but when applied in a sufficiently diluted condition they destroy the tender fungus tissues, but are not injurious to the more toughened tissues of green plants.

Seed corn which is suspected of being smutted should be immersed for about two hours in a mixture made up of $\frac{1}{4}$ lb. bluestone (copper sulphate) and one quart of water. This should be done one day previous to sowing, in order that the seed may be thoroughly dried. A thin film of copper sulphate is then left on the seed, in which fungus mycelium is unable to grow. Substances of this kind used for the destruction of fungi are known as fungicides.

Demonstrations

Fungus Diseases.—Search amongst fields of Guinea corn for smutted "heads," and notice that if these are left, black, powdery spores are liberated. To check the spreading of this disease, smutted "heads" should be burnt. If it be not possible to find "smut" on Guinea corn, examine the wild grasses, and numerous instances of it will be found. It is always very prevalent on the *Cyperus*, the group of grass-like plants to which the tiger nut belongs.

Notice that some cocoa fruits turn an unhealthy brown colour. If such fruits be collected and kept in a damp, shady place masses of tiny white spores, which later turn black, will be produced. In some cases the seeds of such fruits will be found to be destroyed. These spores can usually be found in abundance on heaps of decaying cocoa fruit-shells, which careless farmers leave about their plantations. If these shells be not destroyed the spores will be blown on to other fruits, and they may become diseased.

When seeds are too thickly sown in seed-beds, many of the seedlings often appear to rot off near the ground. This is especially the case when the beds are heavily shaded and the soil is too moist. This disease is known as "damping off," and is caused by a fungus which is only able to grow in very moist places; it is often very common on seedlings of imported plants like mustard and cress, tomato, lettuce, and cabbage. It rarely attacks these plants when the seeds are not sown too thickly, and when the seed-beds are not kept too moist.

CHAPTER X

INSECT PESTS

EVERYTHING in nature is included in one of three divisions or kingdoms, named respectively the animal, vegetable, and mineral kingdom. Insects belong to the animal kingdom, and there are more different kinds of insects than all the other kinds of animals added together. It is estimated that there are at least three million species of insects. Many of these, such as the silkworm and the honey bee, are of great use to man. The valuable services rendered by insects in pollinating flowers have been already referred to. Other insects, such as the mosquito, are very injurious to man.

Plants often suffer severely from insect attacks. They injure plants in various ways. Caterpillars feed upon the leaves and young branches. Aphides, or plant lice, insert a slender tube into the tissues and suck up the plant juices. In each case the growth of the plant is checked, and sometimes it dies as a result.

The damage caused by caterpillars may frequently be seen in fields of young maize. The seedlings are sometimes so badly eaten that it is necessary for the farmer to replant a whole field.

Young cotton plants are destroyed by the tiny plant lice which congregate on them in great numbers and suck up the plant juices from the young tender leaves.

Everyone is familiar with the damage which weevils cause to maize when it is stored.

The Structure of an Insect.—The body of an insect is made up of a number of rings or segments, which form a more or less hard shell. This shell serves as a protection to the more tender parts of the insect which are situated within. An insect's body may be divided up into three principal parts—the head, thorax, and abdomen.

The Head.—In the head are the mouth parts, the eyes, and the antennæ or feelers. The antennæ are placed at the front of the head. They are usually very conspicuous on butterflies, in the form of two organs shaped like drum-sticks. They are the sensitive organs, and correspond to our organs of smell, touch, and perhaps hearing as well. An insect's eyes are large; they are, however, in reality compound eyes, for they are made up of a very large number of tiny eyes. They are usually so arranged that it can see objects in different directions without turning its head.

The Thorax.—The thorax is composed of three parts or segments, and there are a pair of legs on each segment. On the two hind segments are a pair of wings as well. All mature insects have six legs. This is an important fact to remember, because by this means it is often possible to distinguish them from other small animals which have a greater number of legs. A spider has eight legs and millipedes have many more than this; they are, therefore, not insects.

The Abdomen.—Behind the thorax is the abdomen. In insects like wasps the point where the thorax is connected with the abdomen is clearly marked by a constriction at this point. The abdomen has no limbs, but that of the female is sometimes provided with a sting, as in the case of bees and wasps. It may also have an organ known as an *ovipositor* by means of which it is able to lay its eggs in particular places. The abdomen is composed of eight or more segments.

An insect does not breathe through its mouth, but through numerous air-tubes which are called spiracles (see Fig. 15). These are scattered over, and open at, the surface of the body. They are most readily seen on large, fleshy caterpillars and grubs. The spiracles should receive particular attention, because it is sometimes possible to destroy troublesome insect pests by choking up their spiracles, and thus suffocating them.

Insect Metamorphosis. — Insects such as butterflies and beetles, after being hatched from the egg, pass through three distinct stages during their lives. In each of these stages they have a different form, and their habits are different from that of the other stages. Other insects, such as grasshoppers and cotton stainers, do not pass through these changes. In these cases the tiny insect hatched from the egg is very much like the adult insect, except that it may be a different colour and has no wings.

Insects which pass through three stages in their existence are said to undergo a complete change or metamorphosis. The life history of those which, upon being hatched from the egg, are similar to the adult, is described as incomplete metamorphosis.

The Army Worm Moth.—As an example of complete metamorphosis, let us consider briefly the life history of the army worm moth. The female moth lays its eggs on grasses or on young maize plants. From these hatch out little green insects known as caterpillars or larvæ. These at once commence feeding upon the leaves. This caterpillar is called the army worm because it occurs in such great numbers. It has a hard head with strong jaws, and a long, soft body which is divided into very distinct segments. Each of the three segments nearest the head is provided with a pair of short legs. On some of the others are sucker-like feet which are termed pro-legs. As the caterpillar grows bigger it sheds its skin, but not before a new one is formed underneath. This may happen three or four times.

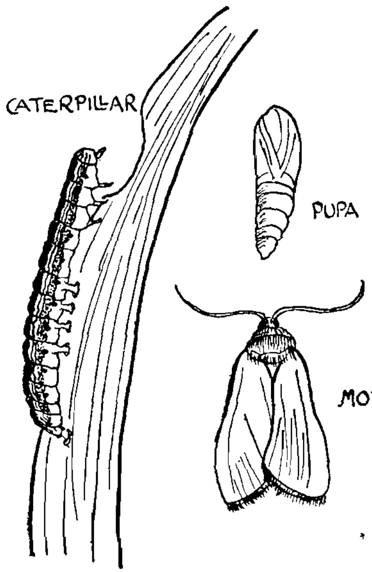


FIG. 14.—Army Worm.

The last time the skin is shed the insect appears as a torpedo-shaped pupa or chrysalid, with a brown, hard, shiny coat. The insect usually only remains in this stage for a few days. This is the resting stage as far as feeding is concerned, but important changes take place in its structure. When these are completed the chrysalid-coat ruptures and the perfect insect or imago, in the form of a moth, emerges.

The moth is altogether different in form and in its habits from the caterpillar. It has two pairs of wings, which are covered with tiny, dust-like scales, and three pairs of long legs. Instead of the hard-biting jaws of the caterpillar it has a long, tube-shaped mouth, which is known as a proboscis. When not in use this is curled up like a watch spring. The moth inserts this trunk into flowers, and by this means sucks up the nectar upon which it feeds.

The Rhinoceros Beetle.—The various beetles pass through the same number of changes as the butterflies and moths. The female rhinoceros beetle lays its eggs in decaying vegetable matter, and frequently in a dead or dying oil-palm. From these hatch out white, fat, worm-like grubs. These grubs will be familiar to many students as an article of food. They have a hard head and strong, biting jaws. The three segments nearest the head have each a pair of small legs. In this instance the insect passes the resting stage in the form of a pupa, from which the perfect insect, the rhinoceros beetle, eventually emerges.

It is in the beetle stage that this insect is destructive. It generally flies at night, and is often attracted by the light to dwelling houses, which it enters with a loud, buzzing noise. It has two pairs of wings. Those of the first pair are hard, black, and shiny. When they are closed they form a protecting sheath to the second pair, which are thin and membranous. On the head of the male beetle is a horn shaped like that of a rhinoceros, and it is from this that it derives its name.

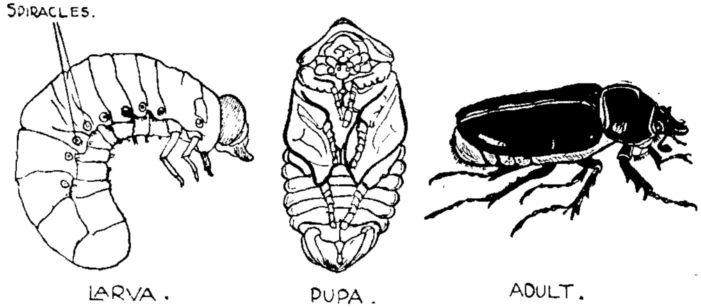


FIG. 15.—Rhinoceros Beetle.

It feeds upon the young, undeveloped leaves of different palm trees. In some cases it destroys the growing point, and the tree dies as a result. The damage that this beetle causes may be frequently seen. As the leaves which have been attacked in the young state develop, they exhibit a shredded appearance, due to portions of the leaf having been eaten away by the beetle. Its mouth parts are so arranged that when in use they work sideways, not up and down like our jaws. It has two pairs of jaws; one pair is used for biting off its food, and the other pair is used for chewing it.

The Cotton Stainer.—As an example of insects which do not pass through a complete metamorphosis we will consider the life history of the cotton stainer bug. This is the red insect so commonly found in cotton fields, and also on the ripe fruits and seeds of the silk-cotton tree. It is the most serious pest of cotton with which the West African farmer has to contend. It inserts its proboscis into the young fruits or bolls and sucks up the plant juices. Many bolls are seriously

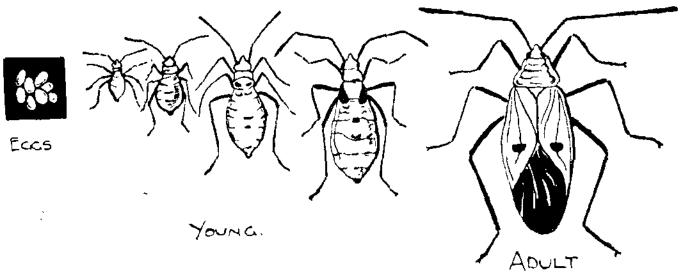


FIG. 16.—Cotton Stainer Bug.

injured by this means, and fail to develop properly. In the case of ripe bolls the stainers attack the seeds, and discolour the cotton lint with yellowish excrement.

The females usually lay their eggs on the ground. A single female has been known to lay more than one hundred eggs. These take about one week to hatch. The newly hatched stainer has no wings, and before the wing stage is reached it moults or changes its skin at least four times.

The adult insect has two pair of wings, six rather long legs, prominent black eyes, and conspicuous antennæ. The most important point to notice is the strong beak or proboscis. This consists of an outer cover or sheath, and encloses a strong, sharp, stabbing organ. It is with this that the insect pierces the leaves, fruits, and seeds of various plants, and sucks up the plant sap from within.

From the three examples given it will be observed that all insects are not destructive in the same stage of their existence. It is in the larva or caterpillar stage that the army worm moth is destructive. The rhinoceros beetle is only troublesome in the adult stage. The cotton stainer commences to feed on plants almost as soon as it is hatched from the egg, and continues all through its existence.

Biting and Sucking Insects.—In attempting to destroy a particular insect pest it is of great

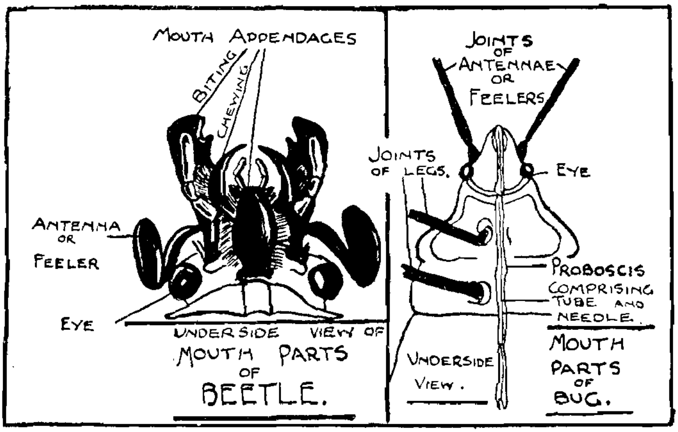


FIG. 17.—Mouth Parts of Biting and Sucking Insects.

importance to know whether it obtains its food by chewing like the caterpillar, or by sucking like the cotton stainer. Caterpillars may be destroyed by spraying poisonous substances on the leaves upon which they feed. The poison is then taken into the insect's stomach along with its food, and it is then killed. An insect which obtains its food by sucking cannot be killed in this manner, for it inserts its proboscis into the leaf and sucks up its food from inside the leaf. It has not been found possible to poison the sap of plants, and to destroy sucking insects. They may, however, be killed by choking up the spiracles or breathing pores with such substances as oil or soap.

Demonstrations

Collect a large number of insects, and in each case endeavour to find the different organs of the body which have been named in this chapter. Many of these parts are most readily distinguished in the grubs or larvæ of beetles, which may usually be found in decaying vegetable matter, and especially in decaying wood. Pay particular attention to the spiracles on these grubs.

Also collect small animals, such as spiders and millipedes, for comparison, and note how they differ from insects. The mouth parts of different insects should be carefully examined in order to find out how each insect obtains its food. Keep a list of insects which are found attacking cultivated plants, noting the name of the plant and the stage in which the insect is destructive.

Search for the tiny wrigglers or larvæ of mosquitoes, which live in water. Place them in a vessel of water, covered with mosquito netting, until they change into mosquitoes.

Observe the manner in which "honey-dew" is secreted by aphides or green-fly. Ants are very fond of this sweet material. They sometimes sip this liquid as it exudes from the aphides. Place leaves infested with aphides in a breeding cage, and notice the extraordinary rapidity with which those insects multiply.

The weevils that attack stored corn should also receive attention.

Breeding Insects.—Cover the bottom of some wooden boxes, about 2 in. deep, with soil, and fit some mosquito netting over each box in place of the lid. Now collect some caterpillars and some of the leaves upon which they are feeding. Place one kind of caterpillar in each box, and feed them daily with the same food. By moving some of the caterpillars from box to box it will be found that some feed upon several different kinds of plants, but others die unless they can find a particular kind of plant for food.

Take particular notice that, as the caterpillars grow, they shed their coats, and eventually pass into the resting stage in the form of a chrysalid. In some instances the chrysalids will be buried in the soil at the bottom of the box. The chrysalid of one of the caterpillars that causes such destruction to cotton bolls covers itself with a hard shell, which it makes from the soil. Other chrysalids will be found attached to the leaves or sides of the box.

When the moths or butterflies emerge from the chrysalid cases some of them should be killed by placing them in a "killing bottle." They can then be preserved for reference. Records should be kept of the dates when the caterpillars were collected, when they changed to the chrysalid stage, and when the perfect insect appeared.

Poisoning Biting Insects. — Collect some caterpillars of the army worm moth. Unfortunately these are only too abundant in fields of young maize plants. Place some of these and some young maize or grass leaves in one of the boxes covered with mosquito netting. Thoroughly mix one tablespoonful of Paris Green with ten tablespoonfuls of flour or lime. Lightly dust this on some maize or grass leaves, and place it in another box with some of these caterpillars. The following day examine both boxes, and it will be found that all the caterpillars which fed upon the dusted leaves have died. They have been killed by eating the dusted leaves, for Paris Green contains a poisonous substance known as arsenic.

Destruction of Sucking Insects.—The food of sucking insects cannot be poisoned by dusting it with Paris Green. Many of those which have soft bodies may, however, be killed by spraying them with certain substances. These choke up the spiracles, and they become suffocated. It is, of course, important that the substances employed are not injurious to plants.

Kerosine emulsion is one of the commonest mixtures used for destroying sucking insects. This is prepared as follows: Take 2 oz. of hard yellow soap and cut it up into fine shavings. Put a quart of rain-water in a tin or pot and boil it. Keep it boiling, and add the soap shavings and stir gently until they have dissolved. Remove the soapy water from the fire, and while it is still hot slowly add two quarts of kerosine. While this is being done a second person should churn the mixture with a syringe. If the kerosine be properly mixed no drops of oil will be seen on the surface when the mixture becomes cool. This is the stock solution, and it will keep in good condition for a long time. Before use, eight parts of water should be added to one part of the stock solution.

Kerosine emulsion is best applied with a spraying machine, but when this is not available a hand syringe may be used. Plant lice may be usually found on maize, cotton, and cocoa. These should be sprayed with kerosine emulsion and the effects noted.

Useful Insects.—Note specially the insects which feed upon smaller insects. These should not be destroyed, for they are often of great benefit to the farmer. The tiny beetles known as lady birds may be generally found upon plants attacked with plant lice, and upon which they feed. Some of the wasps are also useful in this respect, for they fill their nests with caterpillars and grubs for their young to feed upon. Break open some of the clay wasp nests, which are nearly always to be found on the walls and ceilings of buildings, and small caterpillars and grubs will be found inside. Before closing its nest the wasp stings the grubs and renders them insensible. Alongside them it lays its eggs, so that when these hatch out there is a good stock of food for the young ones to feed upon.

PART II

THE SCHOOL GARDEN

CHAPTER XI

FORMATION OF THE SCHOOL GARDEN

Site Suitable for the School Garden.—The site for the school garden should be carefully selected. If possible, the advice of an officer of the Agricultural Department should be obtained as to the suitability of the proposed site and in laying out the garden. In order to prevent waste of time in walking backwards and forwards, the garden should be near the school house. Level land is preferable, as there is then less danger of plants and beds being washed away by heavy rain. Land which is liable to be flooded must be avoided, as also should land which has been exhausted by constant cultivation. It is a distinct advantage to establish the garden near a good supply of water, for many of the plants and seeds will require to be constantly watered. Good, deep soil should be obtained if possible.

Size of the Garden.—A small, well-managed garden is far more suitable than a larger area which cannot be kept under proper control. A garden one-eighth of an acre in area is quite sufficient for a school of average size to start with. Should it be considered that the scholars are able to cultivate a larger area than this, additional land should be acquired with a view to extension at some future date. A plot of land 25 yds. square comprises slightly more than one-eighth of an acre, and can be readily divided up into the necessary beds and borders.

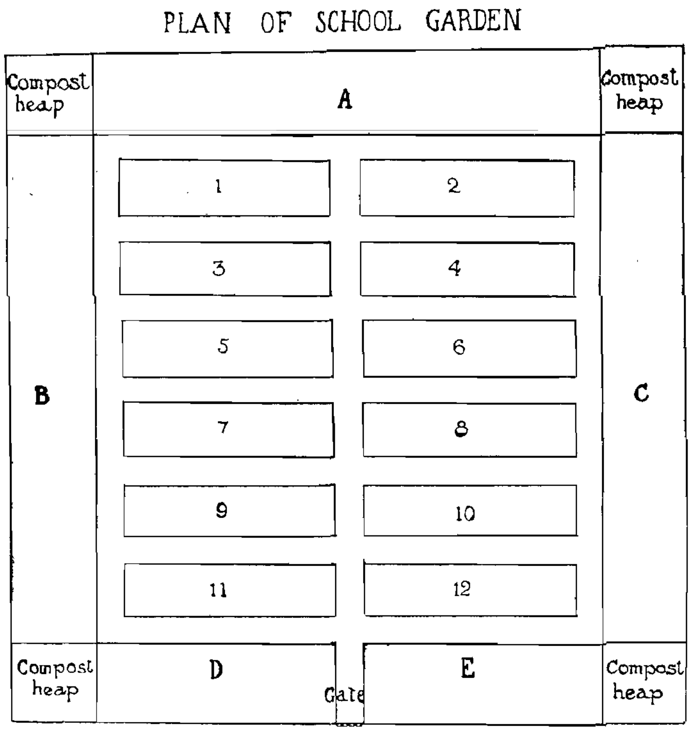


FIG. 18.

Planning the School Garden.—The plan on this page shows a convenient method of dividing up this area into borders, beds, and paths. Fix a straight pole at each corner of the square marked out for the garden. Starting from one corner pole place small pegs 1 yd. apart, and in line with the corner posts to mark the sides of the garden. Any unsightly mounds of soil must be levelled. Extract all tree and bush stumps, and properly weed the whole area. When the stumps have dried sufficiently they should be burnt, as well as any lalang grass (*Imperata*) or nutgrass (*Cyperus*) which may be discovered. Other weeds should be collected and piled in a heap on one of the areas set apart for compost heaps.

It will be necessary to plant a hedge around the garden to prevent animals entering and feeding upon the plants. Before this is done, however, it is advisable to fix the positions of the beds, borders, and paths. The plan given of a school garden provides for borders next to the hedge on three sides of the garden. These borders are all 3 yds. wide. On the fourth side provision is made for flower and nursery beds. The centre is occupied with twelve beds of uniform area, 8 yds. long by 2 yds. wide. The central path divides the garden into two equal parts, and is bounded at one end by a gate. Each of the four areas set apart for compost heaps is 3 yds. square.

Having decided which side of the garden is most suitable for the gate to be placed, proceed to fix the position of the central path. From one corner of this side measure off 12 yds. If the pegs were put in at a yard apart as suggested, it will only be necessary to find the twelfth peg from the corner. Place a straight pole at this point and another one a yard further on, that is, at the thirteenth peg. Put in two poles to correspond with these on the opposite side of the garden. Between the pole at the twelfth peg on one side and the corresponding pole on the other put in pegs at 1 yd. apart in a line. By similar means mark a line between the two poles at the two thirteenth pegs. Stretch a cord along these pegs, and with a spade make a shallow furrow along these lines. These furrows mark the position of the central path, which should be carefully levelled.

The borders may be marked by stretching a line from the third peg from the corner on two opposite sides of the garden, and marking it with a shallow furrow as before. In addition to fixing the edge of the borders, it will be observed that these four lines mark the positions of the four compost heaps. The same method may be adopted to mark a path a yard wide around the edge of the borders. When this has been done, it will be a simple matter to fix the positions of the twelve central beds and the paths that divide them. It is a good plan to place some mark, not easily removed, at the corner of each bed. If iron pegs be not obtainable, stout wooden pegs, painted with tar, make an excellent substitute. From these marks lines may be made at any time to maintain the uniform shape of the paths and beds.

All the paths must be carefully levelled. The beds and borders should be thoroughly dug up at least a foot deep with forks. Such work is too heavy for the younger pupils, but they may be employed in breaking up the lumps of soil, picking out roots and small stumps, and in removing stones. The roots and stumps should be burned, but the stones should be piled into heaps; they will be of utility for marking the edges of the borders and beds.

The Garden Hedge.—Any of the following plants make good hedges: Pitanga cherry (*Eugenia*), (*Lantana*), snuff box (*Oncoba spinosa*), or lime. If cattle be troublesome it will, however, be necessary to provide a temporary fence with sticks until the hedge plants grow sufficiently high to keep them out. This should be placed about 3 ft. outside the edge of the garden, so that it will not interfere with the permanent hedge. The purging nut (*Jatropha*) may be used for this purpose. Branches of this shrub, about 5 ft. long, will soon form roots if the base be sunk about a foot in the ground. A fence of this kind is considerably strengthened by tying stout strips of bamboo, parallel with the ground, in two lines 1 ft. apart, the lower line being about the same distance from the ground. The purging nut does not make a neat hedge, and cattle can break through; it is, therefore, not advisable to use it for a permanent hedge, if any of the plants recommended above can be obtained.

Propagating Hedge Plants.—It is advisable to raise the permanent hedge plants in nursery beds, and transplant them when they are about a foot high. This work should provide a valuable lesson in propagation for the pupils. All the plants mentioned above may be raised either from seeds or from cuttings. Beds for propagating should be made in the section set apart for the nursery. They should be about 3 ft. wide, the soil being thoroughly dug a foot deep, and all stones and roots extracted.

All lumps of soil should be broken and the surface raked smooth.

Cuttings about 6 in. long should be made from the young growths. These are best cut off just below a node, in a slanting direction, with a sharp knife. The nodes are the parts of the stem from which leaves and branches arise. Roots are most freely produced from these points, for it is there that growth is most active. When a slanting cut is made more cambium is exposed than by a cut at right angles to the stem. It is from the cambium that roots arise.

If there be several leaves on the cuttings, nearly all should be pruned off. The reason for this is explained in the remarks upon transpiration, p. 58. It will be found that when a clean cut is made with a sharp knife the wound heals better and the cutting is less likely to decay.

Shape a piece of wood, about 6 in. long, so that it is slightly thicker than the cuttings. Mark lines on the bed about 9 in. apart. In these lines make holes with the stick about 3 in. deep, and 4 or 5 in. apart. One cutting should be placed in each hole. With the stick and fingers press the soil firmly around the cuttings, and especially around the base. Keep the soil thoroughly moist by watering it with a watering pot to which a fine rose is attached.

Shade the cuttings by erecting over them a framework of sticks supporting a layer of palm leaves or long grass.

Beds for raising hedge plants from seeds should be prepared in a manner similar to that recommended for the cuttings. Make furrows about 1 in. deep and 6 in. apart across the bed. In these sow the seeds 2 in. apart. Cover them with soil, and press it down with a piece of flat board or the palm of the hand.

Shade and water the beds in the manner recommended in regard to the cuttings. When the seedlings are about 6 in. high they should be transplanted to another seed-bed in lines 9 in. apart, and a space of 6 in. should be left between them in the lines. The soil in the seedling bed should first be thoroughly watered. It will then be possible, by means of a pointed stick, to lift the seedlings without seriously damaging their roots. The bed in which they are transplanted should be shaded and watered as suggested before.

When the plants raised from the cuttings or the seeds are about 1 ft. high the shading material should be removed, in order to accustom them to the full sunlight. A fortnight later they will be ready to plant out in the lines marked out for the hedge. Along these lines the soil should be thoroughly dug up with a fork to a depth of 1 ft. and 2 ft. wide. Soak the soil in the bed with water, and carefully dig up the young plants with a fork, and plant them 2 ft. apart. Keep them well watered until they start growing freely. In order to encourage a good thick hedge to form, pinch out the buds of the leading shoots until the side branches of one plant touch those of the next one.

Plants to Select for Cultivation.—The next matter for consideration is the kinds of plants to be cultivated. It is very doubtful whether it would be advisable to attempt to cultivate fruit trees, and such trees as cocoa, coffee, cola, and rubber, in such a small area as that suggested for preliminary work. There is, however, no reason why, when this area has been brought under cultivation, more land should not be added for the cultivation of some of these trees. This additional work should not be undertaken unless there are sufficient scholars to attend to it properly. In any case it would be advisable to ask an Agricultural Officer to advise in regard to the trees which should be grown, and the best method of cultivating them.

In the following chapter brief, simple instructions are given for the cultivation of such plants as are considered suitable for the school garden. In each case the period required for the produce to come to maturity is indicated. It must, however, be specially borne in mind that these periods are only very approximate, and will vary in accordance with the season, and also in different districts. A schoolmaster should keep a carefully entered up diary showing the dates of sowing and reaping. This would in course of time furnish valuable information regarding the most suitable plants to cultivate, and the best time to sow or plant them in any particular district. In any case it is a good plan to cultivate, as far as possible, crops which can be disposed of locally. For example, European vegetables should not be grown unless some use can be made of them. It is important that the pupils should realise that the product of their labours is not wasted.

Where and when to Plant.—On the plan (p. 118) the border beds have been marked A, B, C, and the central beds numbered from 1 to 12. It is suggested that a separate history of the crops grown on each of the plots could be kept by fixing these distinguishing marks, and keeping an account of each separately.

It is not proposed to lay down any definite scheme of planting operations, for it is preferable that each teacher should formulate his own scheme, based upon the information given in this book. It is suggested that the border beds be reserved for tall-growing plants such as maize, Guinea corn, cassava, and yams, etc. The area marked D on the plan should be reserved for the cultivation of ornamental plants, and that marked E for raising seedlings and propagating by means of cuttings, etc.

In many parts of West Africa two fairly well-defined rainy seasons occur which are known respectively as the "early" and "late" rains. In these districts it is possible to grow two crops of maize, beans, tomato, etc., in one year, provided that the seed be sown at the beginning of the rainy season in each case. The best time to plant locally-cultivated crops may be learned from the farmers in the district. In regard to the distances at which it is suggested different crops should be planted apart, it will be probably necessary to modify these to suit local soil and climatic conditions.

Preparing Land for Seed Sowing.—Before any crop is sown the ground should be dug up with a fork to a depth of at least a foot. It should then be left for a few days for the sun and air to improve its condition. The surface should then be raked smooth. In order to avoid unduly trampling the beds where seeds are to be sown, a board should be placed upon the bed for the sower to stand upon.

Furrows in which to sow small seeds may be made with a pointed stick in the case of small seeds, and with a trowel or spade for larger seeds. The position of the furrow may be indicated by stretching a line across the bed. This line can be kept taut by fastening it at each end to a stake fixed firmly in the ground. Before the line is moved the position of the next furrow must be marked. This is done by placing two stakes, cut equal to the distance it is desired that the furrows should be apart, and laying one on the ground at each end of the furrow, and at right angles to it.

Seed Sowing.—Seeds should not be sown too deeply, nor, on the other hand, should they be sown too near the surface. To ensure regular germination sow all seeds of one kind at the same depth. This is one reason why the surface of the soil should be carefully raked smooth before the seeds are sown. It is a good general rule to cover seeds to a depth slightly greater than their average diameter. For example, if a seed be an inch long and half an inch broad it should be covered with nearly half an inch of soil. Always reserve a small quantity of seeds to fill up vacancies that may occur through germinating failures, or the death of seedlings from various other causes. Small seeds are sometimes taken away by ants; when this happens, sprinkle the surface soil with kerosine and water mixed at the rate of a teaspoonful of kerosine to a pint of water. Birds often carry off such seeds as maize and beans. To prevent this, prior to sowing the seeds, soak them in water, pour off the water and add tar to the moist seeds. A teaspoonful of tar is sufficient to treat a quart of seeds. Thoroughly mix the tar with the seeds to ensure each seed being treated, and then rub them with moist soil.

CHAPTER XII

THE CULTIVATION OF VARIOUS CROPS

Beans, French.—Shallow drills should be made 1 ft. apart. In these sow the seeds in pairs 6 in. apart. Cover the seeds with soil and then water them. When the seedlings are about 4 in. high, thin them out, leaving the stronger plant in each stand. At the same time draw up a little soil around each plant with a hoe. The legumes should be collected while they are quite young. The first ought to be ready for picking in about two months from the time the seeds are sown.

Beans, Native.—There is a large variety of native beans which may be grown with advantage, both for their seeds and for green manuring purposes. They vary a great deal in habit. The small, compact-growing kinds may be sown as recommended for French beans. For the large climbing varieties, drills should be made 2 ft. apart, and in these sow the seeds in pairs 1 ft. apart. When germination takes place thin out the weaker plant in each stand. At the same time fix a bushy twig, about 4 ft. high, in the ground for each plant to climb up. The beans take about two and a half months to mature.

Cabbage.—It is best to sow cabbage seed in nursery beds, and then transplant the young seedlings to the garden. Having prepared a seed bed, sow the seeds thinly in shallow drills 4 or 5 in. apart, and then cover them with a layer of finely sifted soil. Shade the bed from the sun with a layer of palm leaves and keep the soil well watered, using a water-can with a fine rose attached. When the seedlings are about 4 in. high they may be transplanted. A week before doing this remove the shade, so as to accustom the seedlings to the hot sun. Mark out lines 2 ft. apart, and in these plant the seedlings 1 ft. apart. The seed-bed should be thoroughly watered before the seedlings are removed. Make holes in the soil, with the fingers or a stick, sufficiently deep so that the seedlings' roots may be arranged in a manner similar to that which they are found growing in the seed-bed. Press the soil firmly around the plants and keep them well watered and shaded until they start into growth again. A small stock of plants should be left in the seed-bed for use in case any of those first transplanted fail to grow. Cabbages take from three to four months to mature, but they should not be cut until a hard, compact head is formed.

Capsicum and Chillie.—Seedlings of these require to be raised in seed-beds, and treated in a similar way to that described for cabbage. They may be transplanted when they are 3 in. high. A deep, rich soil is necessary. The tall-growing varieties, like the bird-pepper, commonly cultivated all over Tropical Africa, should be planted in rows 3 ft. apart, and a space of $2\frac{1}{2}$ ft. should be left between the plants in the rows. The smaller-growing varieties, but which produce much larger fruits, may be planted in rows 2 ft. apart, with a space of 18 in. between the plants in the rows. The fruits are ready for harvest in from three to four months.

Cassava.—Make cuttings about 6 in. long from full-grown woody stems. In rich ground the cuttings may be planted as much as 5 ft. apart each way, but usually 4 ft. is sufficient. With a stick thicker than the cuttings make holes in the ground in a slanting direction, and in these place the cuttings, leaving about 2 in. above the ground. Press the soil firmly around each cutting. When the plants have grown about 2 ft. high draw up the soil with a hoe so as to form a small mound around each plant. When this is being done, care should be taken not to injure the young, lateral roots. The tuberous roots take about eight months to mature. Cassava is a very exhausting crop, so the soil in which it has been grown should be well manured before being again planted.

Cotton. — This crop should receive special attention, for it is one of the most important in West Africa. Information as to the best variety to grow in any particular district can always be obtained from the officers of the local Agricultural Department. These officers are also generally in a position to supply properly selected seeds. The low-growing American varieties require to be planted 20 in. distant in rows 3 ft. apart. Native cotton and other tall-growing varieties should be planted 3 ft. apart, in rows 5 ft. apart. It is advisable to sow five or six seeds in each stand. When the seedlings are 3 in. high they should be thinned out, leaving the two strongest plants in each stand. At the same time seed should be re-sown in any vacant stands. When these two plants have grown about 9 in. high the weaker should be pulled up. After each thinning the soil should be drawn up around the plants with a hoe. In West Africa seeds of the native varieties should be sown in the middle of June, and those of the American varieties in the middle of July. Picking from both varieties should commence in December.

Cow Peas.—There are about twenty different varieties of cow peas. Some varieties are erect, and grow in a compact form, other varieties have a trailing habit. Seed of the compact varieties should be sown in rows 3 ft. apart, and 18 in. apart in the rows. Seeds of the trailing varieties should be sown in rows 4 ft. apart, and a space of 2 ft. should be allowed between the plants in the rows. Cow peas may be sown with advantage between rows of maize, Guinea corn, or millet, as soon as these crops commence to ripen. Both the young legumes and the ripe seeds of the cow pea make an excellent table vegetable.

Cucumber, Vegetable Marrow, and Melon.—Sow the seeds about 4 in. apart in a seed-bed, and keep the bed well shaded and watered. Prepare banks of rich soil 4 ft. apart, and in these transplant the young seedlings 3 ft. apart when they are about 4 in. high. During dry weather they should be frequently watered.

Garden Egg.—Seedlings of garden egg should be raised in nursery beds in the manner recommended in regard to cabbage. When they are 5 or 6 in. high transplant them to the garden in rows $2\frac{1}{2}$ ft. apart, leaving a space of 2 ft. between the plants in the rows. The fruits begin to ripen in about four months; the bud at the end of each branch should then be nipped out.

Ground Nut.—Sow the seeds of the compact-growing varieties in lines 3 ft. apart, leaving a space of 2 ft. between the plants in the rows. The spreading varieties require to be planted a foot wider apart in each direction. As soon as the plants commence to flower, with a hoe draw soil up towards the plants so as to form a little mound around each. When the branches commence to wither, pull up the plants with the nuts attached and spread them out to dry. The nuts may then be plucked off the vines, or the seeds may be shelled out by beating the dried plants with sticks. Ground nuts usually begin to ripen in about four months.

Guinea Corn.—Prepare shallow furrows 4 ft. apart, and in these sow the seeds thinly. When the seedlings are about 3 in. high thin out the weakest plants and leave the strong plants 18 in. apart. At the same time mound up the soil around the stems. There are several different varieties of Guinea corn, and these are sometimes grown mixed together in one field. This practice should be avoided, as it is more profitable to grow the different varieties separately. Guinea corn does not require a great deal of rain, and it generally gives quite satisfactory results in West Africa when planted late in the second rains. The grain takes from three to four months to ripen.

Lettuce.—Sow the seeds thinly in shallow furrows in a seed-bed, only slightly covering them with finely sifted soil. When the leaves of the seedlings are 2 in. long transplant them to the garden beds, leaving a space of 9 in. between the plants. They must be kept well watered and shaded until they start into growth. During dry weather the established plants must be constantly watered or they will run to seed. The lettuces should be ready for cutting in about eight weeks.

Maize.—There are several hundred varieties of maize. When different varieties are grown near each other cross-fertilisation frequently takes place. This should be avoided as it results in a mixed crop of grain. Tall-growing varieties require more root-space than the smaller ones. A fair average distance to leave between the rows is 3 ft. and 2 ft. between the plants in the rows. Sow five or six seeds in each stand. When the seedlings are 5 or 6 in. high thin them out, leaving the strongest plant in each stand, and this should be moulded up at the same time. Any suckers which grow on the base of the stem should be nipped off. In West Africa maize is often harvested before it is properly ripe, and immature, shrivelled grain is the result. The cobs should not be harvested until the grains are perfectly dry and hard. The cobs are ready for harvest in from three to four months from date of sowing.

Onion.—Spread a good layer of finely sifted soil over the seed-bed, and then sow the seed thinly in lines 4 in. apart. Slightly cover the seeds with finely sifted soil and press it down firmly with the back of a spade. Keep the seed-bed well shaded until the seedlings are 3 in. high. They are ready for transplanting when they are 5 in. high. Onions require a good, rich soil, so, if possible, the ground should be well manured a short time before they are transplanted. They should be transplanted in lines 9 in. apart, and a space of 6 in. should be left between the plants in the lines. The bulbs take about six months to mature.

The variety of onion known as shallot is grown from small shoots known as sets which are given off by the parent plant. The sets should be planted at the same distance apart as that recommended for onions. After planting, they should be regularly watered until they start into growth.

Okro.—In one of the borders of the school garden prepare shallow drills 3 ft. apart. In these sow the seeds thinly and cover them with fine soil. When the seedlings are 3 in. high thin them out to $1\frac{1}{2}$ ft. apart leaving only the strongest plants. To encourage these to form a bushy habit pinch out the terminal bud on the main stem when it is 1 ft. high. The first fruits should be ready for plucking in about three months.

Pigeon Pea.—This plant might with advantage be more widely grown in West Africa. The young seeds make an excellent green vegetable, and the dried, ripe seeds, as an article of food, compare favourably with the other legumes now grown. The habit of this plant with its light foliage makes it an excellent shade plant for young cocoa, cola, coffee, and rubber trees. Owing to its prolific leaf-fall and power of adding nitrogen to the soil by means of the bacteria which live in the tubercles on its roots, it has a valuable renovating effect when grown on exhausted lands. It should be sown in lines 4 or 5 ft. apart, a space of 3 ft. being left between the plants in the lines. Five or six seeds should be sown in each stand. When the seedlings are 6 in. high thin them out, leaving only the strongest plant in each stand. The first seeds should ripen in three months.

Pineapple.—Select strong, healthy suckers and plant these 3 ft. apart. When the young fruit appears carefully break off all the young suckers that form at its base.

Radish.—Make shallow drills 6 in. apart, and in these sow the seeds thinly. Slightly cover them with soil, and press it down with the back of a spade. Some of the largest radishes should be ready for use in about six weeks. By removing these, space will be provided for the smaller plants to develop.

Rice.—There are two different kinds of rice; one, the swamp rice, requires to be cultivated under irrigation, and the other, the dry land rice, can be grown under ordinary farm conditions. The latter should be chosen for cultivation in the school garden, Sow the seeds in drills 9 in. apart. When the seedlings are 6 in. high thin them out to about 4 in. apart. The grains ripen in from three to four months. The ears of grain should be then cut off and beaten with sticks to separate the grain from the straw. The hulls may be removed by rubbing the grain between flat stones or by pounding it with the end of a pole in a wooden mortar. The removal of husks is facilitated by first soaking the grain in hot water.

Sweet Potato.—Prepare ridges about 6 in. high and 3 ft. apart. Make cuttings of the vine about 9 in. long and insert them in the ridges leaving 1 ft. space between two cuttings. The potatoes mature within four months.

Tomato.—Sow and transplant in a manner similar to that recommended in regard to garden egg. When the plants are about 6 in. high fix a stout stake, about 5 ft. long, in the ground alongside each plant. The plants should be tied to the stakes with some material, such as bass, which will not cut the stems. Pinch out all side shoots which appear on the stems, and take out the terminal bud when it reaches the top of the stake.

Yam.—A deep, rich soil is required to grow yams successfully. It is, therefore, advisable to give the ground a good dressing of manure before planting them. There are a large number of different kinds of yam. Some produce tubers which only weigh a few ounces while the tubers of other kinds weigh as much as 56 lbs. Propagation is effected by cutting up the tuber into sections, leaving at least two good buds or eyes on each section. The small varieties should be planted 2 × 2 ft. apart, and the large varieties 3 × 3 ft. apart. One section of the tuber is sufficient to plant in each stand. As yam tubers take eight or nine months to mature, it is advisable to sow cow peas or low-growing native beans between the rows at the same time the yams are planted. Fix a stout stake for each plant to climb up and make a mound of soil around each plant when it has grown 6 in. high.

CHAPTER XIII

GENERAL CULTURAL INSTRUCTIONS

Weeds.—Special attention must be given to weeding, for as the different crops are planted at only sufficient distance apart for them to develop properly, there is no room for other plants. Any plant which grows in a bed other than that planted must be looked upon as a weed; for example, a cotton plant growing in a plot of maize must be rooted out as a weed. If other plants be allowed to grow amongst the crop they must do so at its expense and it will suffer as a consequence. Weeds not only take from the soil food which should go to the crop, but as they frequently grow faster, they rob the crop of light and air and thus tend to choke it. It is important, therefore, that weeds should be exterminated when they are quite young. Moreover, they are more easily killed at this stage, and seeding is then prevented. This work is best done with a light hoe.

Noxious Weeds.—There are, however, several noxious weeds, such as the lalang (*Imperata*) and nut grass (*Cyperus*) which cannot be exterminated

FIG. 19.—Underground Stems of Lalang Grass (*Imperata*).

in this manner. Lalang grass produces a quantity of underground, jointed stems. In addition to being propagated by its seeds, it is capable of producing a new plant from each joint of the underground stems. This plant, therefore, spreads

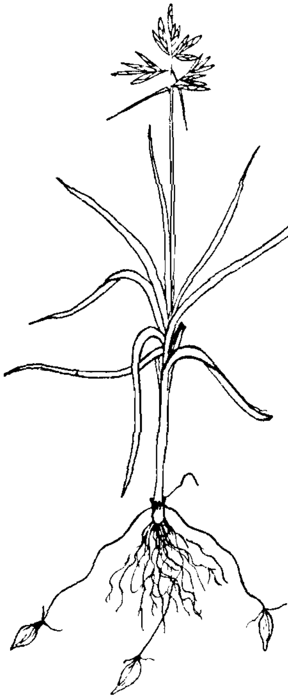


FIG. 20.—Nut Grass (*Cyperus*).

rapidly in all directions, often to the exclusion of other vegetation. When land in which lalang grass abounds is being weeded many sections of these stems may be seen scattered over the surface, and if the soil be turned up many more will be found therein. These soon develop into new plants, and a dense mass of grass is soon formed. *Instead of eradicating the grass it has been propagated in all directions.*

The nut grass bears numerous small tubers on its roots deep down in the soil, each one of which is able to produce a new plant. It is, therefore, useless to cut down this weed before it seeds to prevent its spreading, for when the plant is cut down new plants are at once formed from the tubers.

Land in which lalang or nut grass makes its appearance should be carefully dug up with a fork, and as many as possible of the underground stems or nuts should be picked out by hand and burned. On no account must these stems or nuts be thrown on the compost heap. When thrown there they take a long time to decay, and there would thus be a danger of distributing these pests along with the compost. When these weeds are abundant in the soil it is almost impossible to pick out all the stems and nuts at one operation. Any that are left, however, will quickly produce new leaves and they may then be dug up.

Crop Rotation.—When land is cultivated year after year and is not manured it soon loses its fertility. The period during which crops may be profitably grown on the same land without manure is more restricted when only one kind of crop is grown than when different crops are grown in a regular order. The practice of growing different crops in a regular order is known as crop rotation. The advantage of crop rotation is to a certain extent explained by the fact that different crops extract from the soil different proportions of the various plant food ingredients.

In addition to being economical of manure, several other important advantages are derived from adopting a proper system of crop rotation. Each crop is attacked by particular fungus and insect pests which do not usually affect other crops. After a crop has been harvested fungus spores and insects or their eggs are left behind. Many of these remain alive for a long time, so that if the same crop be cultivated the following season it is again attacked by disease. When crop rotation is practised, the fungus spores and the insects or their eggs have usually died before their particular host plant is again cultivated.

A leguminous crop, such as ground nut, cow pea, pigeon pea, or native beans, should be included in every rotation, for, as we have already learned, these plants are able to obtain their nitrogenous food from the atmosphere. The fertility of the soil is also conserved by alternating shallow-rooted and deep-rooted crops.

What is known as the four-course system of rotation can be practised with advantage in the school garden by growing crops in the order mentioned below.

First Crop.—Maize, Guinea corn, millet or rice.

Second Crop.—Yam, tania, cassava, sweet potato, or onion.

Third Crop.—Cotton, garden egg, tomato, or chillie.

Fourth Crop.—Legume.

The fifth crop would be maize, Guinea corn, millet, or rice, and so on in the same order.

It will not always be possible to follow a stereotyped system of rotation in regard to each bed in the school garden; still, it is important that cereal crops do not follow one another nor should root crops. The advantages of crop rotation should be demonstrated. On bed number one plant maize on four consecutive occasions, two crops being raised each year. On bed number two plant in the following order: maize, cotton, cow pea, maize. The growth and yield of the second crop of maize in bed number two should be superior to the fourth crop of maize in bed number one.

Manuring.—As the various beds will be more or less under continuous cultivation, the maintenance of soil fertility will be one of the greatest difficulties with which the schoolmaster will have to contend. Much good may be done by growing leguminous plants such as cow pea and native bean, and then burying them in the soil. This procedure adds nitrogen to the soil and also humus, but not potash and phosphorus.

Unfortunately animal manures are not abundant in West Africa, so that when these are not obtainable it would be advisable in certain cases to have recourse to artificial manures.

Artificial Manures.—Nitrate of soda, basic phosphate, and sulphate of potash contain nitrogen, phosphorus, and potash respectively. In particular cases it may be necessary to apply all three of these manures to the soil; in other cases two or even one may be sufficient. Some idea of the kind of manure a particular soil requires may be gained by a knowledge of the crops which have been grown upon it and the character of those being grown. Soils deficient in nitrogen produce plants stunted in growth, and with pale, unhealthy-looking foliage. It will be obvious from what has been said before that these remarks do not apply to leguminous plants. Soils in which phosphorus is lacking may produce plants of normal size, but their seeds will be inferior in quantity and size. Growth may also be satisfactory in soils deficient in potash, but the fruit crop will be poor.

Before applying artificial manures the teacher should if possible obtain the advice of an Agricultural Officer.

One lb. each of nitrate of soda and sulphate of potash and 1½ lbs. of basic phosphate is a sufficient quantity to apply to a bed measuring 8 yds. long by 2 yds. wide. The manures should be mixed with about six times their weight of finely sifted soil. This mixture should be evenly distributed over the surface of the bed, and then lightly forked in.

Compost Heaps.—In the plan of a school garden, p. 118, provision is made for four compost heaps. These can be made to serve a very useful purpose in the garden. If they be properly managed it is probable that they will provide the greater part of the manure required. All leaves, hedge clippings, and plants pulled up from the beds after harvesting the crops from them, should be thrown on these heaps. To this should also be added any animal manure procurable in the neighbourhood, such as the sweepings from buildings in which various animals are kept, and also from fowl houses. All ashes and refuse from kitchens, green and dry leaves collected in the neighbourhood, should be added to these heaps.

Substances collected for this purpose should be covered with soil to check the loss of valuable fertilising substances and also to prevent their giving off unpleasant odours. The material in compost heaps should not be applied as manure until it is properly rotted. It is, therefore, advisable that the heaps be formed in rotation so that by the time the fourth heap is completed that which was first made will be ready for use.

Mulching.—The manner in which moisture in the soil may be conserved by frequently stirring the surface and thus forming a dry-soil mulch was fully explained in Chapter I. on Soils. During the dry season the ground in which crops are growing should be raked or hoed as soon as the soil becomes caked on the surface. This serves the double purpose of killing weeds and forming a dry-soil mulch to prevent undue loss of soil moisture by evaporation.

The moisture in the soil may be still further conserved by covering the surface 3 or 4 in. deep with leaves or grass. As this material decays it improves the fertility of the soil by adding humus and various plant food ingredients.

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