THE DISEASES OF TROPICAL PLANTS

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Two-year-old cane-field on worn-out land, showing dying out. (After Cook and Horne, Bul. 7, *Estación Central Agronomica de Cuba.*)

Frontispiece.

THE DISEASES

OF

TROPICAL PLANTS

BY

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PREFACE

The very rapid development of plant pathology during the past few years and the increasing interest in tropical agriculture have led the writer to prepare this introductory work on the Diseases of Tropical Plants.

An extensive study of the fungi, bacteria, and other organisms which cause the diseases of plants was a necessary preliminary to the development of plant pathology, and the progress in this subject has been much more rapid in the north temperate zone than in the tropics. In the past few years, however, there has been a great awakening of interest in these studies throughout both the eastern and western tropics. Nevertheless, the literature is scattered, frequently indefinite in character, and presents an abundance of difficulties to the student at the present time. While gathering material for this book, one correspondent wrote that the time had not yet come when it was possible for any one to write a work on the diseases of tropical plants. The writer is now ready to agree with this gentleman, and to add that it is doubtful if the time will ever come when any one author can adequately treat of the tropics of the entire world and their plant diseases. The eastern and western tropics have each their own peculiar problems; and it is too much to expect of any one person that he should be familiar with all of them. In this connection the writer wishes to say that his own experiences have been restricted entirely to the American tropics.

This work is intended primarily for the planter; but it is hoped that it may be of some service to the student. The writer fully appreciates its many defects, and earnestly solicits correspondence with and suggestions from botanists and plant pathologists throughout the tropical world.

The author is deeply indebted to Prof. F. S. Earle and Prof. W. T. Horne for reading the manuscript and for valuable suggestions; to Dr. Haven Metcalf for a discussion of the diseases of rice; to Profs. E. A. Butler, H. S. Fawcett, C. W. Edgerton, H. R. Fulton, J. J. Taubenhaus, and R. E. Smith for illustrations; to Prof. C. A. M'Cue for valuable suggestions; to Messrs. G. W. Martin and G. W. Wilson for reading proof, and to many others who gave more or less assistance in many ways.

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February 22, 1913.

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INTRODUCTION

Both plants and animals are subject to diseases which reduce their vitality, check development, or cause abnormal growths, and frequently result in the death of the affected individuals. When these diseases attack the cultivated plants on which mankind depends for food, clothing, building materials, fuel, etc., they always cause loss. Such losses may be comparatively insignificant or they may be sufficiently great to cause financial disturbances and suffering in the community or nation. In many cases these losses have been so great as to cause local famine, and sometimes they have been so great as to increase the cost of the agricultural products throughout the world. As a result of certain [illegible]-known diseases, the export trade in many agri[illegible]al products has been greatly reduced or completely [illegible] in parts of the world.

The diseases of plants are so common that it is [illegible] impossible to find a field, orchard, or garden [illegible] there are not more or less diseased plants. [illegible] disease is not prevalent it does not attract the [illegible] of the casual observer, but when it becomes [illegible]ic it becomes an economic factor in the lives of [illegible]wer, the tradesman, the carrier, the consumer, [illegible]equently the manufacturer. If the loss is very [illegible] it becomes of national and sometimes of inter[illegible]al importance, and frequently involves extensive [illegible]tudies [illegible] experts to determine the cause and devise methods of control or eradication.

It is well known that many plant diseases, although recognised by the grower, receive very little attention from him until they become destructive to his crops. The fact that the disease which is of little importance to-day may become very destructive in the near future, does not excite most growers to use the precautionary measures necessary to prevent the spread of these diseases. A good crop attracts the attention, and proves so satisfactory to the average grower that he fails to see heavy losses which could be prevented at very small cost in time and money.

Plant diseases were mentioned by Aristotle in his writings about 350 B.C., and have been referred to by various writers since that time, but did not receive much attention until about the middle of the last century; and the greatest development has been within the last quarter of a century. The workers for many years could be divided into two groups, the botanists who were interested in the study of the organisms which caused the diseases and the practical growers who were interested in finding remedies. In most cases very little could be done towards securing a remedy until the cause was known, although in some cases remedies have been devised with a very incomplete knowledge of the organism causing the disease. Very little progress was made in the treatment of diseases previous to 1882, when the value of lime and copper sulphate as a fungicide was accidentally discovered, and very quickly resulted in the development of Bordeaux mixture, which is now used extensively throughout the world, especially in fruit-growing districts.

It was the custom of the grape-growers of some parts of France to sprinkle the grape vines near the road with a mixture of milk of lime and copper sulphate (bluestone), to give them the appearance of being poisoned, and thus prevent the encroachments of petty thieves. In 1882 Prillieux and Millardet observed that the vines which were thus treated were comparatively free from the downy mildew (*Plasmopora viticola*), a fungus that had been introduced from America, and which was causing heavy losses to the grape industry.

This observation was followed by a series of experiments by Millardet, who, in 1885, published the first formula for the making of Bordeaux mixture and instructions for its use.

The development of the science of plant pathology has been much greater and much more rapid in the temperate and semi-tropical countries than in the tropical parts of the world. This is no doubt due to the prolific production of most tropical crops and the lack of transportation facilities and market for perishable products, which would enable the people to dispose of their surplus or increased production. The rapid development of tropical countries, the increasing demand for tropical products, and the great advancement in transportation facilities of the past few years have stimulated a great interest in the plant pathology of the tropics.

Unfortunately, our knowledge of the diseases of tropical plants is comparatively limited. The literature is very much scattered, frequently popular, without even a scientific reference to make the identity of the disease possible, sometimes technical, and with little data as to the economic importance of the disease under consideration, and often unreliable. Some studies have been made by correspondence, and on material after it has been shipped great distances, and on plants grown under glass in northern climates and inoculated with organisms shipped from the tropics. Such studies are valuable, but must sometimes be compared with actual studies in the field before we can have anything like a satisfactory knowledge of the diseases under consideration. It is also unfortunately true that very few of our workers have been able to make studies in more than one tropical country.

Some diseases are not so widely distributed as the reports indicate, while others are, no doubt, far more widely distributed. Lack of information concerning a disease in a locality does not necessarily indicate that it is not present. Many cases are on record where two entirely different diseases have been reported under one name, and it is not uncommon for a widely distributed disease to be known by two or more names. Furthermore, there are many parts of the tropics which have never been studied by a trained plant pathologist. It will, therefore, be necessary in a work of this kind at this time to speak in very general terms. It is not possible to give a discussion of all the diseases or even to mention all of them. Neither is it possible to give the range of the various diseases or their relative importance in the various countries in which they occur. A disease that is very destructive in one part of the world may be of very little importance in other places.

It is the purpose of this work to call attention to some of the most common, most widespread, and most destructive diseases of tropical plants; to give as practical a knowledge as possible of plant diseases in general and their causes; and to give the most common remedies and methods of prevention. However, some attention will be given to certain diseases which are well known in the temperate zones, but not well known in the tropics. The introduction of certain vegetables into the tropics, where they are grown for winter markets in the north, has resulted in the introduction of many diseases, and no doubt many others have been introduced and not reported, or may be introduced at any time. Furthermore, certain diseases which we have considered characteristic of the temperate zones may occur on their recognised hosts when grown in the high altitudes of tropical countries. Therefore, a number of diseases are mentioned which are not well known or possibly not known at all in the tropics. The possibility and probability of the introduction and spread of destructive diseases makes it necessary for the practical agriculturist to keep in close touch with the experiment station of the country in which he lives for specific information concerning the diseases which are indigenous to the country or which may happen to be introduced from time to time.

CHAPTER I

THE NATURE AND SYMPTOMS OF DISEASES

It has been well said that "a plant is in health when all its organs or parts are doing their proper work, and the processes of growth and reproduction are going forward in the natural and regular manner."[1] It must then be equally true that when any of the organs and parts of a plant are not doing their proper work, and when either the growth or reproduction are not going forward in the natural and regular manner, the plant is diseased, regardless of the cause or causes of its abnormal condition.

It therefore becomes necessary to distinguish between the cause of a disease of a plant and the diseased condition of the plant. Insects which eat parts of a plant or suck the juices are not diseases, but they may interfere with the performance of the normal functions of the plant and cause a weakened or unhealthy condition. This weakened condition may also so reduce the vitality of the plant as to make it susceptible to organisms of disease.

Fungi, bacteria, and flowering plants growing upon or within the tissues of a plant are not diseases, but frequently the cause of some of our most serious diseases. Likewise the character of the soil, the amount and distribution of moisture, and the climatic conditions may be the causes of severe and destructive diseases.

[1] Earle, F. S., "Health and Disease in Plants," *Journal New York Botanical Garden*, vol. iii., No. 35, pp. 195-202.

The diseases of plants may be attributed to some one or more of the following causes :—

Fungi.	Soils.
Bacteria.	Moisture.
Slime moulds.	Temperature.
Flowering plants.	Gas and smoke.
Insects.	Physiological.
Mites.	
Nematodes.	

The first group may be considered organic, and the second group non-organic; or the first group may be considered parasitic (although some of them are not strictly parasitic), and the second non-parasitic. The first group includes that great host of living organisms which live within or are attached to the host plants, affecting their health and frequently causing death. The extent of this parasitism varies from that of organisms which depend upon the hosts for all of their food supply, to that of those which receive very little sustenance. Some parasites destroy their hosts in very short periods of time, while others live upon their hosts for long seasons, even for many years, before death results. Still other parasites never cause the death of the host plant, but do reduce its vitality, growth, or fruit production. Some parasites do not require a great amount of food from the host plant but grow in such a manner as to interfere with the performance of its ordinary functions. Some which are of little importance in themselves open the way for the attacks of organisms which cause other and more destructive diseases. A disease may also produce conditions suitable for the growth of organisms which are in no way the cause of the disease in question. The presence of two or more organisms in or on a diseased plant frequently prevents a satisfactory diagnosis and treatment.

Diseases resulting from the second or non-organic group of causes are frequently very difficult to diagnose. Often they are of little importance in themselves, but so weaken a plant as to make it possible for one of the specific organisms of the first group to attack it.

In the study of a disease it is desirable to gain as thorough a knowledge as possible of (1) its causes; (2) the effects upon the plant; and (3) the methods for prevention or remedy. The practical grower is more especially interested in this last phase of the subject, but in many cases it is impossible to treat a plant successfully for a disease without a thorough knowledge of the cause. However, in some instances, methods have been devised for keeping diseases under control without a complete knowledge of the organisms causing them.

A disease may be serious on one species or variety of plant, and of little importance or not present on one closely related; or it may be serious under certain climatic conditions, and harmless under other conditions. For these reasons a disease-producing organism, when introduced from one part of the world to another, may become more or less virulent than in its original home. It may find new host plants which may be more or less susceptible than its previous hosts, or it may find the climatic conditions more or less favourable to its growth. It is also true that when a plant is introduced into another part of the world that it is liable to meet enemies which will endanger its existence.

Diseases make themselves manifest by certain peculiar characters or symptoms which readily distinguish a sick plant from a normal or healthy one. The most common characters or indications of disease are: (*a*) discoloration of the foliage and of new growths; (*b*) wilting; (*c*) dropping of foliage; (*d*) spotting of foliage; (*e*) perforation of foliage (shot-hole); (*f*) variegation of foliage (mosaic); (*g*) wilting or "damping off" of seedlings; (*h*) death of leaves, twigs, stems, etc. (necrosis); (*i*) reduction in size of parts (dwarfing or atrophy); (*j*) increase in size of parts (hypertrophy); (*k*) formation of excrescences, namely galls, pustules, corky outgrowths, etc.; (*l*) cankers; (*m*) malformation of fruits; (*n*) witches' brooms; (*o*) leaf curls; (*p*) leaf rosettes; (*q*) hairy root; (*r*) exudations (gums, resins); (*s*) sun burns; (*t*) rots.

A symptom may appear as the result of any one of a number of causes, for example, wilting may be due to attacks from insects, fungi, nematodes, or unsuitable soil conditions; hypertrophies may be due to the attacks of insects, nematodes, fungi, or bacteria; mechanical injuries and witches' brooms to insects or fungi.

However, it must be remembered that the part in which the disease becomes manifest to the eye is not necessarily the seat of the disease; the cause of the disease may be in a part of the plant very remote from the part in which some one or more of the preceding symptoms appear, *e.g.* a disease of the roots may cause a discoloration, wilting, or dropping of the leaves. It is also true that some diseases may be present in the plant for a long time before the plant shows any external evidence of the disease.

This last fact increases the difficulties of detection of certain diseases by inspection, and thereby increases the dangers in the introduction of foreign plants.

If the disease is due to a specific organism, the organism may bring about the unhealthy condition in its host: (*a*) by feeding upon its tissues or sucking its juices or otherwise drawing upon it for food; (*b*) by covering the surface of the leaves or stem and thus interfering with the action of the light and proper transpiration; (*c*) by clogging up the tubes of the fibro-vascular bundles and interfering with the circulation of water and other fluids; (*d*) by attacking the growing regions, especially the root tips, and interfering with or preventing their development; (*e*) by attacking the cambium, the growing part of the stems, as in the case of the canker fungi; (*f*) by living inside the host and feeding upon it and secreting poisons which kill, as in the case of some of the "damping off" fungi; (*g*) by attacking the fruit but doing little or no damage to the plant itself; (*h*) by injuries to the leaves, interfering with their activity; (*i*) by malformations of various parts of the plants.

A disease may be of comparatively little importance in the economy of the growing plant, but its injuries may be of very great importance in the sale of the plant products. Leaf spots may be of little importance to the tobacco in preventing its normal functions, but may reduce the market value of the leaf. Fruit rots may not interfere with the growth and reproduction of the plants, but may reduce or completely destroy the commercial value, or prevent shipments to markets which would otherwise be available. Other rots which are practically unknown on the growing plants are very destructive on stored plants. Still others (which are not strictly the cause of diseases) attack seasoned timbers and seriously interfere with its use for building purposes.

The most common terms used in designating diseases are: *Rots*, which attack fruits and other parts of the plants, and are caused by fungi, bacteria, or unfavourable soil and climatic conditions: they may be soft or hard, wet or dry, odourless or offensive. *Blights* of the leaves, stems, flowers, or fruits, which may be due to fungi or bacteria: they may cause the death of part or all of the plant, and may be followed by rots. *Spots* on the leaf and fruit, usually due to fungi: on the leaves they interfere with the normal functions of the plant and the sale if it is of commercial value; on the fruit they cause discolorations and reduce the market value. *Scabs* on fruit, leaves, and stems: they are usually caused by fungi, and reduce the vitality of the plant, sometimes causing death, or interfering with and reducing the market value of the fruits. *Mildews*, which are always whitish, powdery, fungus growths on leaves, twigs, and sometimes fruits: they may be partially or entirely parasitic, and often the cause of heavy losses. *Burns* on leaves and fruits, usually due to climatic conditions, but frequently of great importance. *Smuts*, which consist of masses of spores of certain fungi: they are usually black and powdery and are most destructive in the flowers and ovaries of the cereals. *Rusts*, which are fungi and usually noted in their fruiting stages: they are widely distributed with reference to both host and localities; they are of greatest importance on the cereals. Some diseases are referred to as rusts which are not caused by the true rust fungi (Uredinales). *Yellowing*, refers to a discoloration of leaves or wilting of twigs and leaves (namely, reduction of size and increase in number): the causes are usually obscure. *Mosaic* or *calico*, which in most cases is due to enzyme action within the cells, but may be due to other causes. *Chlorosis* refers to reduction of chlorophyll, and may be due to any one of many causes. *Cankers*, which are roughenings or splittings of the bark, usually due to fungi but may be due to any one of many other causes. *Galls* or *cecidia* are enlargements on roots or stems, or on leaves and fruits, and may be caused by insects, mites, fungi, bacteria, slime moulds, or mechanical irritations of many kinds; they are sometimes very injurious. *Witches' brooms* are malformations which consists of great masses of distorted twigs and sometimes of the flowers: they are caused by fungi and mites. *Fasciations* are abnormal growths of stems, leaves, flowers, or fruits; they may take various forms and are sometimes of considerable economic importance: the causes are usually obscure.

CHAPTER II

THE STRUCTURE AND FUNCTIONS OF PLANTS

Before taking up a study of the diseases of plants, it will be necessary to know something about the plant kingdom as a whole, and more especially about the fungi which are the cause of the great majority of plant diseases. For this reason, the first part of this book is devoted to a general discussion of the higher plants, with which we are most interested in agriculture; and to a discussion of the systematic arrangement, the morphological character, the physiology, and the methods of reproduction of the fungi and other organisms which cause disease. The second part is devoted to a discussion of the diseases of the most important crops, and methods for prevention and cure of these diseases.

The term "plant" as generally used refers to the higher or seed-producing plants, and comparatively few persons take into consideration the great number of plants which do not produce seeds and which differ materially in character and habit from the higher plants. This is not because the seed plants are more numerous, although in general they may be said to be more conspicuous than the plants which do not produce seeds; but because they are the plants on which mankind is dependent in a great measure for food, clothing, fuel, and building material.

However, there is an enormous number of plants which do not produce seeds, but reproduce by the formation of very small bodies known as spores. Many of these plants are extremely small and insignificant, in fact some of them are so small that they cannot be seen singly without the use of a microscope. Many of these non-seed-producing plants are responsible for the diseases of the higher plants, and thus seriously interfere with both great and small agricultural industries of the world.

The plant kingdom may be subdivided into the following groups :—

Thallophyta
- ALGAE—Live in the water and possess chlorophyll, although many of the salt-water forms and some fresh-water forms possess other colouring matters which conceal the chlorophyll.
- FUNGI—Plants without chlorophyll and living either parasitically or saprophytically on other organisms.

Bacteria.—Minute organisms possessing some of the characters of fungi and living either parasitically or saprophytically.

Slime moulds.—Organisms possessing some of the characters of fungi, and some characters of the lower animals.

Bryophyta
- HEPATICAE—Liverworts.
- MUSCI—Mosses.

Pteridophtya.—FILICES—Ferns, etc.

Spermatophyta (seed-bearing plants)
- GYMNOSPERMA—Cone-bearing plants.
- ANGIOSPERMA—True flowering plants.

All of these groups of plants contain chlorophyll (the green colouring material) except the fungi, bacteria, and slime moulds. The presence or absence of this chlorophyll makes a decided difference in the habits and life of the plants. Those possessing chlorophyll are able to lead an independent existence if provided with the necessary soil, water, sunlight, and heat ; while those which do not possess it must live parasitically on living plants and animals, or saprophytically on dead and decaying organic materials.

It will be readily seen that this work relates more especially to the Spermatophytes, which are of such great importance to mankind, and to the fungi, bacteria, and slime moulds, which are responsible for so many of the diseases of the Spermatophytes.

The green plants obtain their food supply from the air, the water, and the soil. In order to do this they are provided with special organs which vary in character in the various groups. In the higher plants these organs are much more complex in both structure and function than the corresponding organs in the lower plants. The organs are composed of tissues and the tissues of cells or units. These cells or units are little box-like structures, so small that they cannot be distinguished without the aid of a compound microscope. They vary greatly in shape, size, and thickness of the cell wall. In the dense parts of plants they are fitted closely together, while in the softer parts they are much less compact, usually larger and with thin walls. Not all the cells of a plant are living, although the non-living cells may contribute to the support of the whole plant. The living cells contain a substance known as protoplasm, which is the real life substance of the plant. This protoplasm, which is the same as the corresponding material of the same name in animal cells, more nearly resembles the white of an egg than any other substance to which it can be compared. Many other substances and bodies, such as colouring materials, starches, sugars, fats, etc. are also found within the cells, but they and the cell walls themselves are all dependent either directly or indirectly upon the activities of the protoplasm.

In some of the lowest plants these cells, which constitute an individual, are all alike or very similar in both structure and function. But in the higher plants, the individuals are composed of groups of cells which may differ widely in both structure and function. Such a group of cells is known as a tissue, and these tissues are so related as to form the organs of the plant.

The vegetative organs of the plant are three in number: (*a*) the leaves or foliage, which are primarily for the purpose of utilizing the sunlight in the manufacture of starch, but which may also serve the purpose of storage, holdfasts, etc.; (*b*) the roots, which are primarily to serve as holdfasts and to take water and food from the soil, but which may also be modified for various other purposes; (*c*) the stems, which connect the other two sets of organs and which may also serve other purposes.

If we cut through a leaf (Fig. 1), and then examine the cut edge with a microscope we find the most common structure as follows: both the upper and the lower surfaces are composed of a single layer of cells which are usually clear and have very thick walls, the outer or exposed walls being thicker than the inner walls. This layer of cells is known as the epidermis, and the thickened outer wall as the cuticle. The epidermis is in reality the skin of the leaf. Just below the upper epidermis are the palisade cells which are elongated, somewhat cylindrical in shape, and placed at right angles to the upper epidermis. Between the palisade and the lower epidermis is the mesophyll, or spongy cells, among which are intercellular spaces or tunnels which ramify among the cells and have external openings called stomata. These external openings may be readily seen by peeling a little of the epidermis (Fig. 2) from the leaf and examining it under the microscope. They are always between two crescent-shaped cells, which are known as guard cells, and are much more abundant on the lower than on the upper surface of the leaves. The palisade and mesophyll cells contain the chlorophyll or green colouring matter, which is confined to definite bodies known as chloroplasts. These chloroplasts are the real laboratories of the plant, and it is here that the raw food material is transformed

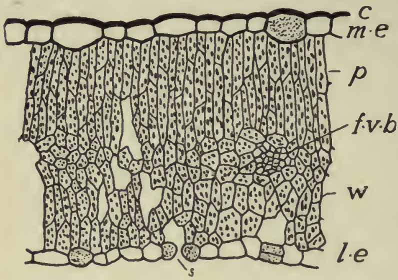

FIG. 1.—Cross section of leaf.
c, Cuticle; *e*, upper epidermis; *p*, palisade cells; *f.v.b.*, fibro-vascular bundles; *w*, mesophyll; *l.e.*, lower epidermis.

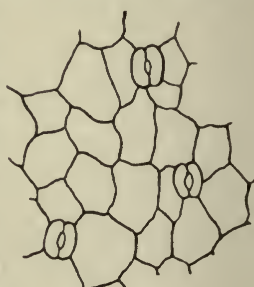
FIG. 2.—Lower surface of leaf showing stomata.

into substances suitable for the life and growth of the plant. In the cross section of the leaf may also be seen the cut ends of the fibro-vascular bundles or veins. The surface of the leaves of many plants are covered more or less profusely with hairs (trichomes) (Fig. 3).

The ROOTS, in the great majority of plants, penetrate the soil and serve as holdfasts and for the absorption of water and the various salts which are contained in solution. However, they may also serve as aerial hold-fasts for climbing plants, and in many cases for storage of reserve materials.

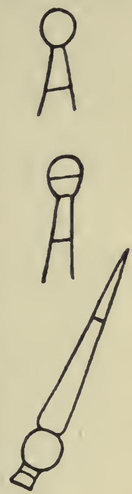

FIG. 3. Trichomes from leaf.

The typical root, or rather the type of root (Figs. 4 and 5), which is most common, consists of an axial cylinder of cells surrounded by a cortex, which in turn is enclosed by the epidermal layer of cells. At the tip of the root is a mass of dead cells, which are in reality a part of the epidermis. This mass is known as the root cap, and serves to protect the more delicate cells within. The epidermal cells give rise to a great number of delicate hair-like structures which are known as root hairs (Figs. 6, 7, and 8). Each root hair consists of very delicate living cells. They ramify among the very fine particles of soil, and absorb the moisture and the salts which are in solution. The water and the salts are transmitted from the roots through the stem to the leaves, to be used in connection with the carbonic acid gas which is obtained from the air

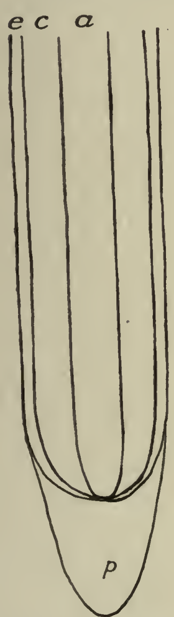

FIG. 4.—Diagram of longitudinal section of young root. *a*, axial cylinder; *c*, cortex; *e*, epidermis; *p*, root cap.

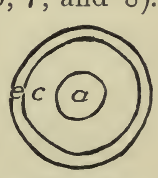

FIG. 5.—Cross section of young root.

in the formation of the food substances previously referred to.

The STEM, as previously stated, is the part connecting the roots with the foliage, and through it must pass the water and the dissolved salts on their way from the roots to the leaves. The elaborated food substances which have been manufactured in the leaves must also pass through the stem to the other parts of the plant,

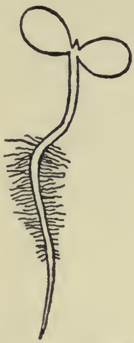

FIG. 6. — Seedling plant showing root hairs.

FIG. 7.—Particles of soil held in place by root hairs.

FIG. 8.—Root hairs.

where they are to be utilised in the economy of the growing plant. The stem, therefore, forms a connection between the foliage and the roots, and also serves for the conduction of both raw and elaborated food materials. Its complicated branching arrangement facilitates the bearing of an enormous amount of foliage, which is so important in the economy of the growing plant. A cross section of a dicotyledonous stem (Fig. 9) shows it to be made up of a number of fibro-vascular bundles which are arranged in cylindrical form, surrounded by the cortex on the outside and enclosing the pith within. In young plants, in the young parts of old plants, and in soft succulent plants the fibro-vascular bundles are separated by masses of soft cells of the same character as the cells in the pith. In old, woody plants the bundles are dense and packed closely together. The

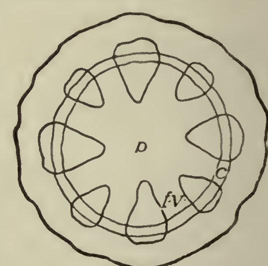

FIG. 9.—Cross section of dicotyledonous stem.

entire stem is enclosed in an epidermis. Each fibro-vascular bundle is made up of three parts, the outer part or phloem through which the organic or elaborated food substances are carried, the inner woody part or xylem through which the crude substances (water and salts) pass, and a delicate or growing part between the two which is known as the cambium. In the very hard and woody plants these fibro-vascular bundles are packed closely together and there is a minimum amount of cortex and pith. In the monocotyledonous (Fig. 10) plants, such as corn, palm, etc., these fibro-vascular bundles are scattered irregularly through a mass of pith. The fibro-vascular bundles are extended into the leaves, where they divide and subdivide repeatedly, thus forming the intricate venation which supports the softer parts of the leaf. Therefore all parts of the plant are brought into the most intimate communication.

Fig. 10.—Cross section of monocotyledonous stem.

The parts of the flower are modified leaves which are set aside for specific duties. The structure of the lower groups is less complicated than that of the Spermatophytes, the complexity decreasing as we pass from the Spermatophytes to the algae.

PHYSIOLOGY

Although we have a fair understanding of the more conspicuous functions of the green plants, much more remains to be learned. The leaves are the real laboratories of the plant. They take in the carbon dioxide (CO_2) from the air, and receive from the roots, by means of the fibro-vascular bundles, the water (H_2O) which has been taken in by the root hairs. Then by means of the sunlight acting upon the chlorophyll they tear down and reconstruct these two substances into sugars and starches, namely, cane sugar ($C_{12}H_{22}O_{11}$), grape sugar ($C_6H_{12}O_6$), and starch ($C_6H_{10}O_5$), at the same time setting free a part of the oxygen, which is returned to the air and can be utilised by animals. A part of these starches and sugars is utilised in the construction of the cell walls of the plant; part is removed to other parts of the plant and either used for growth or stored up for future use; and, finally, part is reconstructed in combination with the salts which were taken up in solution in the water and formed into proteids and fats. The sun being the source of all energy, the greater part of the work must be done in the sunlight, but the process is by no means clearly understood. The transferring and storage of these food substances in the fruits, tubers, roots, etc., for future use is accomplished largely during the night.

The magnitude of the work done by plants cannot be comprehended. The enormous number of plants with their varied character, feeding mankind and all forms of animal life, and either directly or indirectly furnishing us with clothing and fuel and a great part of our building material, are nothing more nor less than the combination of these raw materials which have been influenced in some mysterious manner by the sun's energy. Although the leaves are the great laboratories for the manufacture of foods they have also been called the lungs of the plant, for it is through them that the respiration or breathing takes place. In this process, the plant gives off some carbon dioxide and takes up oxygen, but the ratio between the two is quite different in different plants, and can be only briefly referred to at this time. The leaves also give off water through the stomata, which are so regulated as to control the transpiration.

All plants that contain chlorophyll, whether the simplest of the algae, the liverworts, mosses, ferns, or the highest of the spermatophytes, are able to perform these duties of taking the gases from air, water and salts from the soil, and building them up into complex parts of themselves. This process is briefly summarised in the following diagram :—

Solar energy
↓ ↓ ↓

$O \leftarrow$ $CO_2 \leftarrow$ $O \rightarrow$ $CO_2 \rightarrow$	Plants, possessing chlorophyll, integrate complex chemical compounds (sugars, starches, fats, oils, and proteids), storing up solar energy in the process. They form	the food of	Animals and plants not possessing chlorophyll, which disintegrate complex chemical compounds, liberating energy in the process.	$\rightarrow CO_2$ $\rightarrow O$ $\leftarrow O$ $\leftarrow H_2O$ $\rightarrow H_2O$ $\rightarrow NH_3$ $\rightarrow$ Salts

↑ ↑ ↑
NH_3 H_2O Sats

↓ ↓ ↓
Radiate energy chiefly as heat.

When a plant or animal dies and undergoes decay, the various substances are reduced and returned to the air and soil, and may eventually form the food of plants.

BACTERIA

The processes of decay are carried on by certain bacteria, aided to some extent by fungi and other organisms. They are closely related to the lower fungi and lower algae, and are the smallest and probably the simplest forms of life known. There are an enormous number of species, and they are more widely distributed and live under more diversified conditions than the members of any other group of plants; in varying depths of water, in air, in soil, in and on both dead and living plants and animals, and in extremes of temperature and desiccation. They live either singly or in colonies, and can be classed in three general groups with reference to form; (*a*) the *coccus* forms which are spherical, the *bacterium* or *bacillus* forms which are oblong or rod-like, and the *spirillum* forms which are curved or twisted. Some are ciliated and have the power of motion, while others cannot move except when carried by other agencies. In reproduction they divide, each cell forming two, each of which divides, etc., at such a rate as to result in the formation of many millions in a few hours. With the reduction of the food supply the individuals form heavy membranes and become extremely resistant to external influences until conditions are again favourable for their growth and reproduction. In this condition they are known as spores.

Bacteria are of the very greatest importance in the economy of nature. Some of them cause the decay of dead animals and plants and thus make the materials which have been stored up in these bodies available for plant food; others live in the soil and in the tubercles on the roots of leguminous plants and are able to take the free nitrogen from the air and form the definite ammonium compounds which are so important for the growing plants; while still others are the causes of many diseases of both animals and plants, such as tetanus, diphtheria, tuberculosis, typhoid and other fevers, cholera, crown galls, olive knot, and cabbage rot.

FUNGI

The fungi do not contain chlorophyll and therefore cannot make use of the energy of sunlight and manufacture food from the gases of the air, the water, and salts of the earth. They must make use of food which has already been manufactured by the chlorophyll-bearing plants and must therefore live upon other plants or animals. Many of them live upon living animals or plants, reducing their vitality and in some cases causing death. They are known as parasites or parasitic fungi. Many other species of fungi live upon the dead and decaying animals and plants, and are known as saprophytes or saprophytic fungi. Some fungi have the power of living both parasitically and saprophytically.

The greater number of fungi are very small. In many cases they are so small that they cannot be seen without the aid of a microscope. Some plants consist of a single cell (Saccharomyces or yeast, and Synchytrium) while others consist of long thread-like growths composed of one or many cells and known as mycelia. In some species of fungi the mycelium spreads over the surface of the plant (mildew), or substances from which they derive their food, while other species send their mycelia into the substances and ramify throughout the substratum (bread mould). The mycelia of the fleshy fungi penetrate the substances on which they live, but at some time in their life-history the accumulated growth is concentrated at a definite point as the fleshy structure with which we are familiar.

In structure the fungi resemble the algae, the group of plants to which they are the most closely related. The absence of chlorophyll is the most conspicuous and most important character and at once sets them apart from all other plants. Although they can and no doubt do absorb gases and water, and dissolve salts to some extent, they cannot utilise the sunlight to elaborate these raw materials into food substances for their own use, but are dependent on other organisms in which the raw materials have already been elaborated.

The *bread mould* (*Rhizopus nigricans*) (Figs. 11 and 12) is a most excellent example of a fungus, and one with which we are all familiar. It consists of a mass of thread-like filaments (mycelium), which extend over the surface of, and through the bread. Each thread is in reality a tubular structure filled with protoplasm. It acts upon the bread in such a manner as to make it soluble, and then takes this soluble food material in through the cell wall and makes it a part of itself, thus enabling it to grow and extend farther and farther, and to produce its fruit or spores (see page 24).

While the bread mould may be looked upon as a typical fungus, other fungi may radically differ from it in certain characters. Some fungi are much smaller and much less conspicuous. The yeast plants are not filamentous but each plant is a single, very minute, roundish cell. Some fungi are so small that they live in a single cell of a higher plant.

Saprophytes. — The saprophytic fungi are those which live upon dead organic material, such as bread, decaying fruit, and vegetables, wood, meats, leather, horn, dung, etc. The decay of these various substances is due partially to the action of the fungus and partially to the action of bacteria and other organisms which are so often associated with them.

Fig. 11.—Sweet potato affected with wet rot, due to *Rhizopus nigricans*. (Photograph by J. J. Taubenhaus.)

Fig. 12.—*Rhizopus nigricans*, showing sporangia.

Parasites.—The parasitic fungi are those which live on living plants or animals; the number which live upon other plants is much greater than those which live upon animals.

There are three types of parasitism :

1. Internal, free parasites, which float or swim in the liquid parts of the host. The bacteria, the myxomycetes, and the *Synchytria* belong to this type.

2. The internal, fixed parasites, which usually form mycelia within the tissues of the host and grow to the surface only for the purpose of reproduction. They may discolour the surface or they may cause deformities. In some cases they are confined to a very small part of the host, while in other cases they spread throughout all or a considerable part of the host. (The Uredinales, Peronosporales, etc.)

3. The external parasites, which form mycelia on the surface and penetrate only the outer cells. (The Erysipheae.)

Facultative Parasites.—Some fungi have the power of becoming either parasitic or saprophytic as the conditions may necessitate. They are known as facultative parasites, and some of them, of which certain "damping off" fungi are conspicuous examples, are very troublesome in agriculture.

Trichosphaeria sacchari, a parasitic fungus, which is the cause of a disease of the sugar-cane, is thought by some workers to have been originally saprophytic. It is possible that the increase of injurious insects or other causes so weakened the cane as to make it a prey to this organism. The organism having once gained a foothold on the weak cane, increased in parasitic strength, and eventually became the severe pest which we now recognize (see pages 52, 81, 132).

Reproduction.—The fungi do not produce seeds, but small microscopic bodies which answer the same purpose. The methods of formation of these spores in the different groups of fungi can be classed under two general methods; then on-sexual, in which but a single individual plant is concerned, and the sexual, in which two individuals or parts of individuals, or two parts of the same plant (gametes) unite.

The *non-sexual* method is by cutting off of a small fragment of the mycelium ; but this may be accomplished in many ways. Some of the more common methods are :—

(*a*) The formation of swarm spores within a part of the mycelium. By this method a cell wall is formed separating a part of the mycelium into a separate cell. Then the contents divide into a large number of small cells, each of which is provided with small cilia or thread-like processes, which enable it to swim in the water or in a very thin film of moisture on the surface of a plant. After swimming for a time they attach themselves and grow, eventually becoming mature fungi like the parent by which they were produced. Such spores are sometimes called zoospores because of their resemblance to little animals (Fig. 13, Saprolegnia).

(*b*) The formation of conidia, either solitary on the ends of simple branched

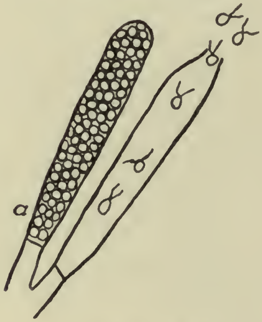

FIG. 13.—The sporangia of Saprolegnia, showing the formation of zoospores.

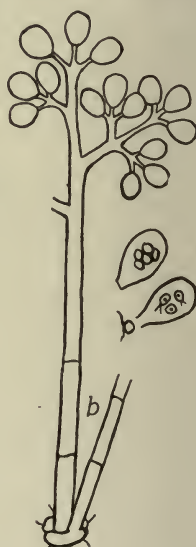

FIG. 14.—Conidiophores and conidiospores of downy mildew.

hyphae (Fig. 14, Downy Mildew), or in chains (Fig. 15, Powdery Mildew; Green Mould). These spores may produce swarm spores by internal cell division as above, or they may grow directly into new plants.

(*c*) The formation of sporangia, within which are formed great numbers of spores by internal cell division (Fig. 16, Bread Mould).

(*d*) The formation of special bodies known as pycnidia. These are more or less complicated structures which are globular or sac-shaped, and form the walls from which numerous conidia are produced (Fig. 17, Leaf Spot Fungi).

(*e*) The formation of special bodies known as

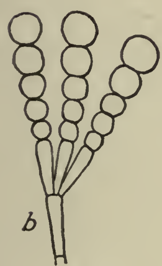

FIG. 15.—Conidiophores of *Penicillium.*

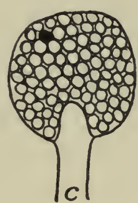

FIG. 16.—Sporangium of *Rhizopus nigricans.*

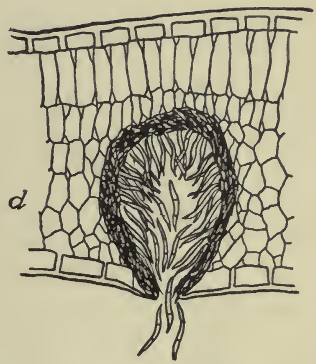

FIG. 17.—A pycnidium.

perithecia. These are flask-shaped cavities usually within the stroma of the fungus with openings to the outside. Within these cavities are the asci or sac-shaped structures containing the spores. Although the perithecium is formed from vegetative or non-sexual filaments, the asci are formed as the result of sexual activities.

The spore-bearing hyphae are known as conidiophores. The character of the spores and the manner in which they are borne are among the points which enable the botanist to separate the fungi into groups.

The non-sexual spores are usually produced in great numbers during the most active season of the fungus growth, and serve to distribute the organisms over wide areas of country. They are usually spoken of as spring or summer spores.

The *sexual* method of reproduction involves two parts and thus gives the new plant a double parentage. The spores are—

(*a*) Formed by the union of two similar parts which unite and produce a zygospore (Fig. 18, Bread Mould).

(*b*) Formed by the union of two dissimilar parts producing an oospore (Fig. 19, Downy Mildew).

(*c*) Formed by the union of two dissimilar parts producing a sporocarp (Fig. 20, Powdery Mildew).

The sexual spores, which are usually referred to in

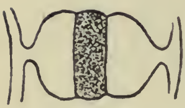

FIG. 18.—Zygospore of *Rhizopus nigricans.*

FIG. 19.—Oospore of *Albugo candida.*

FIG. 20.—A sporocarp of powdery mildew.

temperate climates as winter spores, are usually resting spores and serve to carry the fungus over the winter in cold climates, and over unfavourable seasons in warm countries, and thus perpetuate its existence from year to year.

Distribution of Spores.—Spores are frequently carried for a great distance by wind currents. In this way the spores of fungi that attack the crops may be carried from field to field and from farm to farm. Also in this way spores of fungi which attack forest trees may be carried from tree to tree and from forest to forest. Spores are also carried by the drainage water for long distances. The water also affords a means of distribution for swarm spores.

Insects are great carriers of spores, which are carried either on or within their bodies. In fact, many fungi which are the cause of serious diseases would be of little consequence if it were not for insects. Insects also aid many fungi by feeding on plants and producing wounds by which the fungi gain entrance.

Spores are carried by larger animals in the same manner as by insects, namely, on or within their bodies. Small animals carry them into their burrows, and large animals carry them from place to place. The spores of many fungi will readily pass through the alimentary canal of an animal uninjured, and are frequently distributed in the manure.

Spores are carried on plants, and in the soil and packing materials around the plants, which are shipped from place to place and country to country, in stock cars, on the wheels of wagons, on the feet of the labourers, on pruning tools, and in many other ways which receive very little attention.

Some fungi are provided with an explosive apparatus, by which the spores are thrown to considerable distances, and are then more readily caught by the wind and carried. Some of the black moulds develop a peculiar explosive structure just beneath the sporangium, which matures just as the spores are ripe, and explodes with sufficient force to throw the entire sporangium into the air. The cups of the cup fungi are lined with little tubes which stand upright. When the spores are ripe these tubes open at the end, and the spores are forced into the air in such abundance as to form very noticeable little clouds.

Resistance and Germination.—Spores show very great differences in vitality. Some of them die very quickly when exposed to unfavourable conditions, while others may live for a number of years. As a rule, the spores which live in an excess of moisture cannot withstand much drying. Those spores which will tolerate a long period of dry condition will usually withstand greater variations in temperature when dry than when wet. Some spores will persist in the soil for many years without germination, unless brought in contact with suitable hosts when they germinate very readily. Some spores must undergo certain periods of rest before they will germinate, even though the conditions for germination may be favourable. When the conditions are favourable the spores germinate, producing a thread-like mycelium which penetrates the host, if it be a parasite, or the food body, if it be a saprophyte, in a manner peculiar to itself. In some cases the parasite enters the host through the stoma, in other cases directly through the cell wall, and in other cases through wounds.

Habits.—Fungi feed upon nearly all kinds of living and dead organic bodies, both animal and plant. They may live upon insects, and are no doubt very important in holding this class of pests in check. Sometimes there is an outbreak of disease among insects which becomes a veritable epidemic, and destroys them in enormous numbers. These insect diseases sometimes attack the larvae only, and at other times the mature insects (see page 260).

Some species attack fish (see page 34), and thousands of fish die each year from this cause. If the aquarium is not properly cared for, or the pool or stream of water becomes low and foul, the fish are likely to contract these diseases. Injured fish and young fish in the hatcheries are especially subject to them.

Birds and barnyard fowls are also subject to diseases which are caused by fungi, which cause inflammation of the respiratory organs and scab diseases of the combs and crops. Cattle, horses, and sometimes men suffer from a fungus disease known as lumpy jaw, which is contracted from the fungus on the food. The fungus no doubt gains entrance to the tissues through very slight wounds which, in the case of the lower animals, are easily made by the rough edges of the blades of grass. Rabbits, cats, dogs, many other lower animals, and human beings sometimes suffer from pulmonary troubles which are caused by the growth of certain fungi.

Ringworm, scab, barber's itch, and similar skin diseases of human beings are due to fungi. Sometimes these diseases occur in other forms on lower animals, from which they are readily transferred to human beings who are working with them.

Practically all parts of all plants are subject to diseases. In some instances we have immediate and complete destruction of the host, while in others death may be very slow, and in others the plant may even live and support the parasite indefinitely.

The simplest form of parasitism is where the fungus attacks and destroys a single cell without destroying the surrounding cells. However, in some cases the surrounding cells are stimulated to excessive growth, and form small galls (see page 33).

Most leaf-inhabiting fungi attack groups of cells, which are destroyed, causing the characteristic leaf-spots with which all agriculturists and horticulturists are so familiar.

Certain species of fungi cause the leaves to fall, and thus prevent the plants from performing their regular functions. The plant may die, or be stunted and unable to produce fruit.

Some fungi are known as "damping off" fungi, because of their tendency to attack very young seedlings, which they cause to die and fall over. These fungi frequently come from the manures, on which they grow very readily. After the death of the plant they continue to grow saprophytically on its decaying tissues, and spread rapidly to neighbouring seedlings, which are killed in turn. Older plants are not often attacked by these organisms because of the development of the protecting coats of cork and cuticle. These "damping off" fungi are, no doubt, quite prevalent under natural conditions, and sometimes become important as field and garden pests, but are most destructive in seed beds.

Rots, which are frequently very destructive to fruits and vegetables, are due to many species of fungi and bacteria which live partly parasitically and partly saprophytically. These organisms are most important on mature fruits and vegetables, attacking them at a time when the cells are most dormant, and when the contents are most suitable for fungus growth. Many of these organisms cannot attack their host except through wounds, while others have the power of penetrating the uninjured surface.

Many of the saprophytic fungi which attack and destroy timbers of various kinds also have the power of living parasitically on the growing timber. They usually, probably always, gain entrance to the growing trees through wounds, or start upon dead branches. After living saprophytically for a time they gain sufficient strength to penetrate the active, living tissues, and frequently cause the death of the host plants. These organisms are very destructive to forest, shade, and orchard trees. The wounds may be caused in many ways; such as storms, rubbing together of branches swayed by the wind, injury by animals, birds, and insects of various kinds, lightning, sun scalds, and by pruning.

The action of some fungi upon plants reduces their vitality and makes them more susceptible to other diseases, or checks the growth of parts or of the entire plants. Other fungi may stimulate parts of the plant, causing the formation of galls, witches' brooms, etc. While some fungi attack the leaves, others attack the stems, causing cankers, and frequently causing the death of all the parts beyond the point of attack. Still other fungi attack the roots, injuring or killing them, and thus resulting in a lowered vitality or in the death of the plant. Still others attack the fruits, and prevent their maturity or cause their decay.

CHAPTER III

CLASSIFICATION OF FUNGI

In the classification of the fungi in a work of this kind, only the most important groups can be considered. In this part of the work will be given a discussion of the fungi and other organisms that cause disease, and in the latter chapters will be given discussions of the diseases of the various crops.

The Fungi are divided into three large groups as follows:—

1. The Phycomycetes (Lower or Algal Fungi).—The members of this group are very much like the algae in both structure and reproduction, but since they do not contain chlorophyll, their habits are necessarily very different. They range in structure from species consisting of a single cell composed of an undifferentiated mass of protoplasm to species consisting of a well developed mycelium. The reproduction is usually by the non-sexual method, and some species are parasitic while others are saprophytic.

2. The Ascomycetes (Sacspore Fungi).—This group includes the great majority of fungi that cause diseases, and its members are usually much more complicated in structure than the preceding and bear very little resemblance to the algae. They may range from species in which the individual consists of a single, small, spherical cell floating in a liquid, to species in which the individuals are large and fleshy. However, the great majority are inconspicuous. Some of the large fleshy forms are edible.

The reproduction is both non-sexual and sexual: in the non-sexual method the conidia spores are borne on the surface, while in the sexual method the spores are borne in delicate membranous sacs called asci. The asci contain eight spores usually, and are collected into well defined bodies known as ascocarps. Many species are saprophytic but a very large number are parasitic and are the causes of a great variety of diseases among plants.

The Fungi Imperfecti are frequently included under the Ascomycetes, although it is well known that many species do not belong to this group. The Fungi Imperfecti are so called because we do not understand their life-history and development. It is very probable that the life-history of some species is truly imperfect, but in many cases the students of this subject have been unable to learn the facts and therefore cannot tell where the species should be placed (see page 52).

3. The Basidiomycetes (Basidial Spore Fungi) are far more complicated in their structure than either of the preceding. They are subdivided into two groups. The lower Basidiomycetes, which are parasitic on plants and include the rusts and smuts; and the higher Basidiomycetes, which are primarily saprophytes and include the puff balls and mushrooms.

Phycomycetes

This class is subdivided into three sub-classes as follows:—

Sub-class 1. **Archimycetes.**—In which the organisms consist of little or no mycelia, and in which the sexual method of reproduction is rare.

Sub-class 2. **Zygomycetes.**—The members of this group have irregular, branching mycelium, non-sexual reproduction by conidia or sporangia, and sexual reproduction by the union of two equal similar bodies which are also known as gametes.

Sub-class 3. **Oomycetes.**—The organisms of this sub-class consist of irregular, branching mycelium; they reproduce non-sexually by means of both conidia and sporangia, and sexually by the union of two unequal or dissimilar structures, which are also known as gametes.

Under Sub-class 1, the Archimycetes, will be considered but a single order:—

Order 1. CHYTRIDIALES.—The members of this order are very small, unicellular, and parasitic upon many plants, although of no great economic importance. In many instances they stimulate the growth of certain cells of the host plant and cause the formation of numerous small swellings or galls (Fig. 21). These galls may be the result of the swelling of the cell within which the fungus lives, or they may be caused by the swelling of that and the neighbouring cells. The many species of this order are known to attack cabbage and apples and many wild plants, but are not considered of any great economic importance. Small, free-swimming spores are produced which escape from the host plant and swim in the water, or in the moisture on the surface of the plant in the case of land plants. These spores eventually come to rest, penetrate the new host and grow into mature plants.

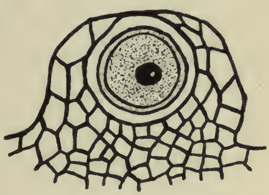

FIG. 21.—Gall containing *Synchitrium*.

The sub-class Zygomycetes consists of two orders, Mucorales and Entomophthorales.

Order 2. MUCORALES.—This order includes the most common black moulds,[1] and they are mostly saprophytic, but some are parasitic on other moulds. The best example of this order is *Rhizopus nigricans*[2] Ehr. (Figs. 11 and 12), or common bread mould, which develops readily on bread when left for a few days in a damp, warm place. It consists of great quantities of white, irregular, branching mycelium, which penetrates the bread and gives rise to upright branches,

[1] For green mould, see *Penicillium*, page 43.
[2] *Mucor stolonifer.*

on which are borne the sporangia containing great quantities of non-sexual spores. When these upright branches or aerial hyphae are forming, they are white, and the bread has the appearance of being covered with loose cotton. As the spores mature, the sporangia turn black and eventually the whole mass falls and blackens. When it becomes dry the spores are so light that they float readily in the air and are carried about until they fall under suitable conditions, when they grow and produce new plants. The sexual reproduction is comparatively uncommon; two short hyphal branches, which so far as we can determine are practically alike, are produced. These branches grow until they unite and then form a thick-walled spore, known as a zygospore or resting-spore. These sexual spores are rather uncommon in many species but they are no doubt capable of carrying the organism over very long periods of time which are unfavourable for growth.

This species is the cause of a very severe rot on both the white and the sweet potatoes (page 238). *Acrocystis batatas*, E. & H., is another species belonging to the Mucorales, and is the cause of another rot of the sweet potato. Other species of the mucors are more or less common on dungs, ripe fruits, and stored vegetables, and are frequently the causes of considerable losses.

Order 3. ENTOMOPHTHORALES.—Most species of this order are parasitic on insects, which they sometimes destroy in great numbers. They no doubt hold insects in check in some measure, and are therefore beneficial. The body of the insect becomes filled with mycelium, and after its death the fungus continues to grow saprophytically, breaks through the body wall, and produces a number of sporophores, each of which bears a single conidium. The sexual spores are occasionally formed in a manner similar to the mucors.

Under Sub-class 3, the Oomycetes, will be considered the orders Saprolegniales and Peronosporales.

Order 4. SAPROLEGNIALES.—The majority of species in this order are aquatic parasites or saprophytes and live on living or dead insects, pin-worms, fishes, etc. They consist of branching mycelium which force their way through the body wall, ramify throughout the body of the host, and eventually come to the surface where they produce masses of long cotton-like mycelia. Some of these hyphae form long tubular sporangia in which are produced, by internal division, great numbers of zoospores (Fig. 13). These zoospores are very active, swim rapidly for a short time and attach themselves to some dead or wounded animal, penetrate the body and produce a new growth. In the sexual reproduction an oogonium or female organ containing a few egg cells, and an antheridium or male organ are formed; the antheridium penetrates the oogonium, but so far as known, its contents do not unite with the egg cells. However, the egg cells rest for a time, and then under favourable conditions break up into a number of zoospores which behave the same as the zoospores from the sporangia. These fungi are the source of great annoyance in the fish hatcheries where they sometimes kill great numbers of young fish.

Certain other species of the genus *Pythium*[1] (Fig. 22) of this order, are saprophytic on the decaying organic materials in wet soils and manures, but when opportunity offers make parasitic attacks on seedling plants, causing the well known "damping off" disease (pp. 29, 106, 221, 236). The attack is made at the surface of the ground and usually results in the death of the host. These young plants then undergo decay, and the fungus continues to live saprophytically upon them. The cork and cuticle covering of these young plants is so thin that they cannot withstand the attack of the fungus, but if protected in their early growth, they very soon become strong enough to resist the disease. These are among the most troublesome and destructive seed-bed diseases. The members of the mustard family are especially susceptible, and in tropical countries tobacco, cotton,

[1] Certain characters indicate that *Pythium* may be intermediate between Saprolegniales and Pronosporales.

palms, and other plants are frequently injured (see pages 106, 206). These semi-aquatic species reproduce non-sexually by conidia and sometimes by spherical sporangia. Zoospores are produced in both cases, and by this means the fungus is enabled to travel over considerable distances. In sexual reproduction, enlargements known as oogonia are formed. These are the female organs. At about the same time the antheridia or male organs

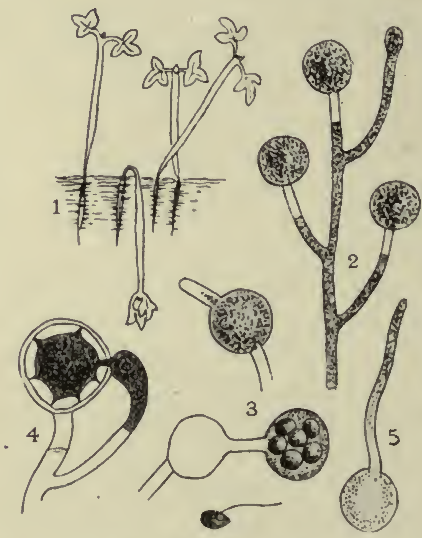

FIG. 22.—*Pythium Debaryanum*, a fungus having aseptate mycelium during its vegetative condition. Septa appear when the fruit is produced by which the latter is cut off from the remainder of the mycelium.

1, Seedlings of cress (*Lepidium sativum*) attacked by the fungus; 2, mycelium bearing conidia at the tips of the branches; 3, sporangia of different ages, also a free zoospore; 4, an oosphere, with an antheridium or male organ, which has pierced the wall of the oosphere and inserted a fertilising tube (after this blending of the contents of oosphere and antheridium, the oosphere becomes surrounded by a thick wall, and becomes the oospore, or sexually formed resting-spore); 5, a germinating conidium. All figs., except 1, magnified (after Massee).

are formed near them. A tube from the antheridium penetrates the oogonium and fertilization occurs, and in due time an oospore or resting spore is formed. Probably the most important species of this genus found in tropical countries is *P. Debaryanum*, Hesse, which attacks the seedlings of a very large number of different host plants. Another very important species is *P. palmivorum*, Butler, which is the cause of the Godavari disease of India (page 206).

Pythiacystis citrophthora, R. E. Smith, is the cause of a disease of the lemon and other citrus fruits. The fungus is a very much branched, irregular mycelium, which penetrates the peel of the fruit. The conidia are somewhat subspherical with a very prominent point at one end. They germinate and produce a number of zoospores.

Order 5. PERONOSPORALES. — The species of this order are parasitic, most of them living on the higher plants and some of them being the causes of very destructive diseases. They are more highly developed than the preceding, since they cannot be considered either aquatic or semi-aquatic, but have adapted themselves to aerial conditions. However, they still require a moist atmosphere. The mycelia penetrate the plant, branch, spread, and send small suckers (haustoria) into the cells. This ravenous method of feeding results in the early death of the diseased parts and sometimes of the entire plant. In time mycelial threads grow out through the stomata, branch profusely, and bear conidial spores. The spores are readily carried by the wind, and when they fall upon suitable host plants and under proper conditions of temperature and moisture they either grow directly into a mycelial thread, which penetrates the plant, or they produce zoospores which swim for a time in the moisture and then grow into mycelia. In some species the formation of the oospore or egg spore within the tissues of the host is well understood, but in other species it is unknown and is probably not formed. Where known it is very similar in character to the preceding. Some of these fungi also cause the damping off of seedlings and attack many mature and hardy plants.

Under this order we will consider two families, Albuginaceae and Peronosporaceae. The Albuginaceae contains but one genus *Albugo* (or Cystopus), or the so-called white rust (Fig. 23). The mycelium penetrates the host plant through the stomata, branches and ramifies among the cells, from which it obtains its nourishment by means of haustoria. Eventually the mycelium comes to the surface and forms white blisters just below the epidermis. Each hypha becomes constricted, thus forming a chain of conidia or non-sexual spores. These spores

FIG. 23.—Radish affected by white rust, *Albugo candida*. (Photo by H. S. Jackson.)

are released by the breaking of the epidermis, and are then scattered by the wind. Within these spores are produced the zoospores which germinate and penetrate new plants. The sexual spores are produced by oogonia and antheridia and remain embedded in the tissues of the host plant until released by the decay of the host tissues. They give rise to numerous swarm zoospores.

Albugo candida, (P.) Rou., is widely distributed throughout the world, and attacks many of our cruciferous vegetables, such as radishes, horse radish, cress, cabbage, etc. These host plants are frequently very much deformed by the mass of mycelium which accumulates within the tissues.

The second family, Peronosporaceae, is distinguished from the first by the conidia, which are always produced singly and aerially. It includes the following important and destructive genera :—*Plasmopara*, *Sclerospora*, *Peronospora*, *Bremia*, and *Phytophthora*, which are usually referred to as downy mildews, blights, etc.

The species of the genus *Peronospora*, are widely distributed throughout the world, and are the cause of many of our most troublesome diseases. *Peronospora Schleideni*, Unger, the onion blight (Fig. 24, and page 234), has proved very destructive in the Bermudas and the United States, and is no doubt much more widely distributed. The mycelium penetrates the leaf and eventually gives rise to the conidiophores, which come out through the leaf. The conidia are elliptical and germinate by the formation of a tube which enters the new host through a stoma. The fungus also produces oospores very freely and spreads rapidly. *P. parasitica*, (Pers.) De Bary, is a well-known, widely distributed fungus, which causes the mildew of the cabbage and allied plants. *P. trichotoma*, Massee, is the cause of a disease on the malaga (see page 234), and *P. Nicotianae*, Speg., attacks the tobacco.

Bremia is another well-known genus containing *B. lactucae*, Reg., which is widely distributed and well-known as downy mildew of the lettuce.

The species belonging to the genus *Plasmopara* are also very abundant and destructive in both tropical and temperate regions. Among the most common are *P. cubensis*, (B. & C.) Humphrey, on the cucumber, and *P. viticola*, (B. & C.) Berl. & De Toni, on the grape.

The mycelium ramifies through the tissues of the leaves and eventually produces the conidiophores which grow outward through the stomata. The character of these conidiophores and conidia vary somewhat in the different species, but the conidia in most cases produce

FIG. 24.—*Peronospora Schleideni*, a fungus with a much-branched conidiophore.

1, A conidiophore that has emerged into the air through a stoma in an onion leaf 2, free conidia; 3, oospore or resting-spore. All magnified (after Massee).

zoospores. These zoospores germinate readily and the disease spreads rapidly. In many species the oospores are rather uncommon, and in some species entirely unknown.

Sclerospora is a genus with but few species, the most important of which is *S. graminicola* (Sacc.) Schroet. (see page 97), which attacks the grasses.

The conidiophores are somewhat evanescent. The oospores are formed in great numbers.

The genus *Phytophthora* contains many species which are the causes of numerous diseases in both the tropical and temperate zones. In general it may be said that the mycelium penetrates the tissues of the host in practically the same manner as other members of this order. They also give rise to conidiophores and

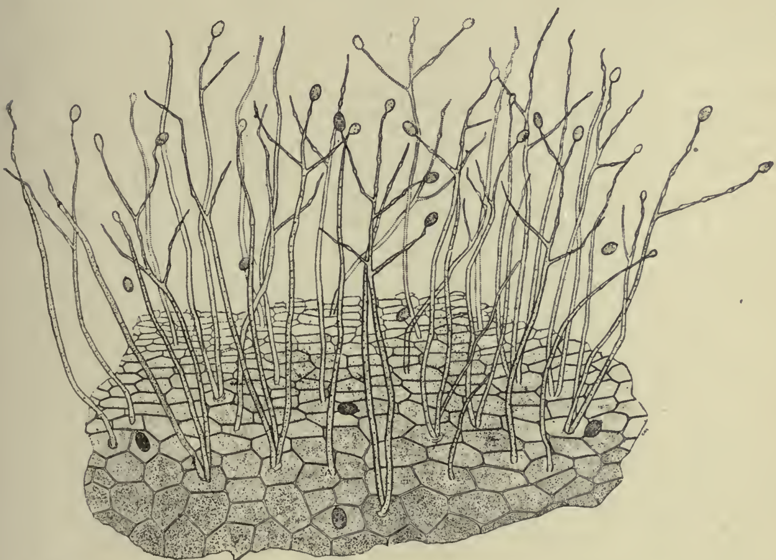

FIG. 25.—Sporophores of late blight of potato, *Phytophthora infestans* (after R. E. Smith).

conidia, and these conidia in turn produce the zoospores. The oospores are very common in some species, and very uncommon in others, and in some species unknown. Among the most important species of this genus are *Phytophthora infestans*, (Mont.) De Bary, of the potato and the tomato (Fig. 25); *P. phaseoli*, Thaxt., of the bean; *P. nicotianae*, de Haan, of the tobacco; *P. omnivora*, de Bary on seedlings; and *P. faber*; Maub., on cacao, and Para rubber tree (*Hevea braziliensis*).

Ascomycetes

The **Ascomycetes** contain more species than any other class of fungi. The following orders are the most important in connection with plant diseases :—Saccharomycetes, Exoascales, Aspergillales, Perisporiales, Hypocreales, Dothideales, Sphaeriales, Phacidiales, Pezizales, Lichens.

Order 1. SACCHAROMYCETES.—The yeasts are the simplest of the sac fungi, and, in fact, it is very doubtful if they can be properly classed as Ascomycetes. Each plant consists of a single spherical microscopic cell. They grow in or on materials containing sugar, and reproduce by the formation of bud-like cells which from time to time become separated from the parent plant and become independent plants. The asci are seldom produced, and when so, it is by the formation of four cells or spores within the parent plant or cell (Fig. 26).

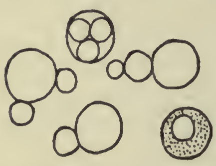

FIG. 26.—The yeast plant, *Saccharomyces.*

The yeasts are used in the manufacture of bread, and in the brewing of beer. There are a number of species of yeast, some of which grow upon ripe fruits, and no doubt aid to some extent in their decay, but are of little or no importance in connection with plant diseases.

Order 2. EXOASCALES.—This order includes a number of fungi which are parasitic on plants, especially those which bear drupaceous fruits. They attack the leaves, causing them to curl, and finally to wither and die. The mycelium of the fungus works within the host plant, but eventually produces a great mass of elongated cells placed at right angles to the surface of the leaf. Each of these cells or sacs contains eight spores from which the plant can be reproduced. The most common species is *Exoascus deformans*, (Berk.) Fckl., or leaf curl of the peach (Fig. 27), which is probably as widely distributed as the peach itself.

Certain species also attack plums, cherries, and forest trees, causing deformities of the leaves or fruits, or forming the unsightly witches' brooms with which we are all familiar.

Among the most important of tropical disease-producing fungi, is *Exoascus theobromae*, Ritz. Bos., and *E. bussei*, von Faber, of the cacao (see page 183). However, witches' brooms frequently develop from other causes.

Order 3. ASPERGILLALES.—This order contains the common green moulds (*Penicillium*), which grow so abundantly on decaying or preserved fruits and

FIG. 27.—Peach leaves affected with leaf curl, *Exoascus deformans.*

vegetables and also on many other substances. The fungus consists of a mass of mycelium which ramifies throughout the food substance. The mycelia finally come to the surface, branch and produce a chain of conidial spores on the end of each branch. These spores are produced in such great abundance as to give the appearance of a thick coating of green powder. The ascospores when formed are in capsules within the food body. They are not common. These fungi are responsible for much of the decay of fruits with which we must contend. They also are associated with other fungi in causing the decay of timbers.

Order 4. PERISPORIALES.—This order contains both parasitic and saprophytic species, and is widely distributed. The two most important families are the Erysiphaceae and the Perisporiaceae. The most characteristic types of the former are the powdery mildews, which form delicate white mycelium over the surface of the leaves and sometimes of the young stems and fruits. The white appearance of the plant is very noticeable, but the mycelium is frequently mistaken for a layer of dust. The mycelial threads send short projections (haustoria) into the leaves and absorb a considerable amount of food. The covering also interferes with the action of the sunlight on the chlorophyll of the plant. The mycelia produce upright branches, which become constricted, forming numerous chains of conidial spores. These spores are carried by the wind, and when they fall upon the proper host plant, and under suitable conditions, grow and thus cause the spread of the disease. The perithecia (ascogonia) are small spherical bodies, which are at first white but finally become black, and are clearly visible to the naked eye. Upon examination, with the microscope they are found to have rather complicated systems of appendages which are characteristic of the different genera. These appendages aid in the distribution of the perithecia, since they catch and hold on other plants. The appendages vary in the different genera, and present definite characters which are very important in the determination of the species. Within the perithecia are small transparent sacs which contain the spores. The perithecial stage is usually not so common in tropical countries as in the colder parts of the world. The powdery mildews are very abundant in the tropics, and include *Erysiphe communis*, (Walls) Lev., on tobacco, and many other species on beans, peas, and other plants; and *Phyllactinia corylea*, (Pers.) Karst, on mulberry (page 246). *Thielaviopsis ethacetica*, Went., which is the cause of the pine-apple disease of the sugar-cane (page 84), and *Thielavia basicola*, (B. & Brl.) Zopf., which causes the root disease of the tobacco (page 150), belong to this order.

Order 5. HYPOCREALES.—Some of the species of this order are parasitic on higher plants, some on fleshy fungi, some on insects, while others are saprophytic. They vary in colour from white to yellow, purple, scarlet, and red, although a few are brown. Among the

FIG. 28.—*Claviceps purpurea,* or ergot.

1, Ergot on rye-grass; 2, ergot on rye: the black, horn-like bodies are stromata or sclerotia of the fungus, and bear the conidial form of fruit; 3, portion of conidial form of fruit produced on a stroma: the conidia are mixed with a sweet substance attractive to flies; 4, a stroma bearing the stalked ascigerous form of fruit, after lying on the ground throughout the winter; 5, head of fertile portion of ascigerous fruit, showing the warted surface due to the projecting mouths of the perithecia; the section shows the numerous perithecia sunk in the fleshy stroma; 6, an ascus containing eight needle-shaped spores; 7, a single spore. Figs. 1 and 2, nat. size; the remainder magnified (after Massee).

most common are the ergots (*Claviceps*), which occur on ryes, other grains, and grasses, (Fig. 28). They attack the young grains which they destroy and convert into a rather hard spherical or elongated body composed of a compact mass of mycelium. On its surface are produced thousands of condiophores. At the same time a sweet fluid is produced which attracts insects, and ensures a distribution of the spores. In due time this fungus body turns black, and becomes the ergot of commerce. After a resting period small cylindrical stalks grow out, and on the end of each is a spherical body which is pitted by very small pear-shaped cavities. Within these cavities are the sacs or asci containing the spores. The ergots are poisonous, frequently causing sickness, and often causing death of animals which feed upon the diseased grain. They also cause sickness, and occasionally death, of people who unsuspectingly eat bread made from the diseased grain. They possess properties which make them valuable in medicines.

Another genus of this order is *Cordyceps* (Fig. 29), the species of which attack insects and their larvae, and eventually cause their death. The body of the insect or larva becomes thoroughly infested with the mycelium, which eventually assumes the character of a sclerotium and in due time sends up club-shaped, frequently bright-coloured bodies. These bodies contain numerous small cavities, within which are the asci or sacs containing the spores. These fungi are very common in the tropics, and no doubt are very beneficial in the destruction of insect pests (see page 260).

The genus *Nectria* includes a number of species, all of which have either yellow or red fruiting bodies. They are the cause of a number of diseases of tropical plants occurring on the cacao, tea, rubber, and many forest trees (pp. 175, 183, 191, 253). The fungus enters the host through a wound and makes its growth in the water-conducting tissues of the wood. It attacks the cambium, and gradually girdles the tree or branch, causing death. It continues to live in this dead wood as a saprophyte, and finally comes to the surface, forming clusters of soft, bright red or yellow bodies. Upon these bodies are borne the small, non-sexual, summer or conidial spores, by which the disease spreads very rapidly. After a time they cease to form conidial spores and form superficial perithecia. Within each perithecium are the long

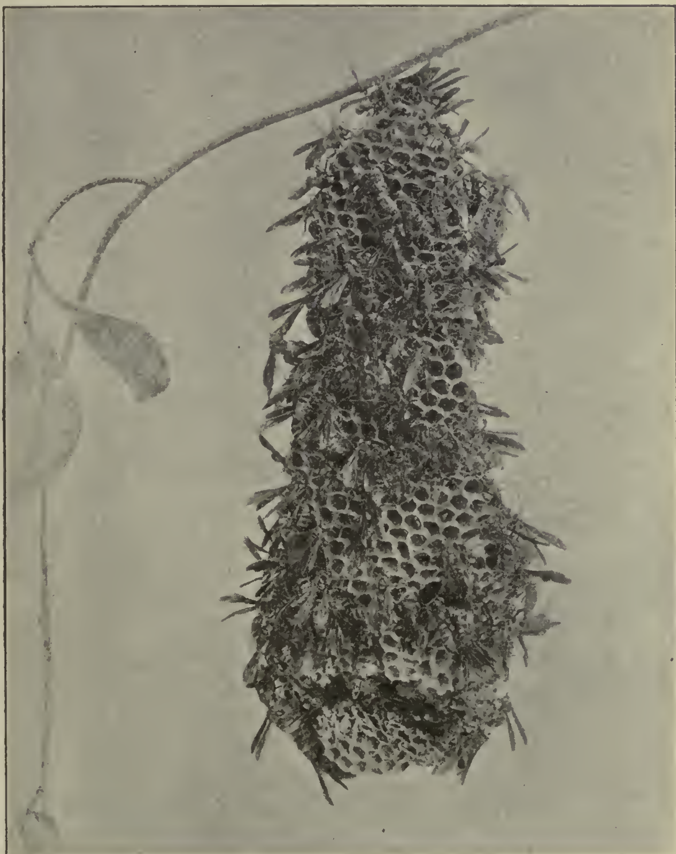

FIG. 29.—Wasps (*Polistes* (?) *lineatur*, Fabr) killed by *Cordyceps*.

cylindrical asci or sacs, each containing eight spores. These are resting spores which grow under favourable circumstances and reproduce the disease. Among the most important are the following :—

Nectria sp.	on tea.
„ *cinnabarina*	on cacao.

Nectria theobromae on cacao.
„ *jungeri* „
„ *Bainii* „
„ *camerunensis* „
„ *ditissima* on cacao, coffee, tea, and rubber.
„ *striatospora* „
„ *coffeicola* „
„ *diversispora* on cacao and rubber.
„ *funtumia* on rubber.
„ *gigantospora* „
„ *ipomoeae* on egg-plant and sweet potato.

Closely related to the genus *Nectria* is the genus *Calonectria*, containing *C. flavida* (Corda), Sacc., *C. cremea* and *C. bahiensis*, Hempel, all of which occur on the cacao, and *C. gigospora*, Massee, which occurs on the sugar cane.

Another genus of this order is the *Necosmospora*, which attacks water-melons, cotton, cow-peas, etc., in the Southern United States, and which no doubt occurs in tropical America. It has also been reported from India (see pages 98, 108, 231, 237, 241).

The fungus lives in the soil where it thrives saprophytically on the decaying organic material. In all probability it usually gains entrance to the host plant through wounds on the roots, although many believe that it can attack the healthy plants without difficulty. It is most abundant in the tracheary tissues of the xylem, but may also invade other tissues. It eventually kills the plant, and then produces a growth on the surface. Two types of conidia, micro-conidia and macro-conidia, are produced. The perithecia are superficial, scattered, flask-shaped, and often orange-coloured. The asci are cylindrical, and each contains eight spherical spores. Although this fungus as it occurs on the different hosts has few, if any destinctive characters, yet it seems impossible for it to pass from a host of one species to a host of another species. This order also includes the genus *Sphaerostilbe*, which contains *S. flavida*, Massee, of the coffee.

Epichloë is a genus the species of which occur on the grasses. The fungus attacks the grass above the ground, usually the upper part, and forms a white or tan-coloured pod-like structure around the stem or leaves, causing them to be strangled. The conidia are similar to those of the powdery mildews. As the growth approaches maturity numerous cavities, opening to the outside, are formed. In these cavities are the sacs containing the spores. This disease is common in Malay and other tropical countries.

Order 7. SPHAERIALES.—This is one of the very largest orders of fungi, and the species are the cause of numerous plant diseases, although the great majority are saprophytic. They range in habit from leaf parasites to terrestrial forms, but agree in character of the reproductive structures. The great majority grow on woody or herbaceous stems, and with but few exceptions the mycelium is in the substratum. The great majority are inconspicuous.

Species belonging to the genus *Leptosphaeria* (Fig. 30) produce leaf-spots which are irregularly distributed over the surface, and usually vary in colour with their age. When fully mature the perithecia are to be found buried in the tissues of the leaf, and projecting slightly above the surface. They are almost spherical, and contain long, slender, clavate cylindrical asci (sacs), within which are the spores. The spores are usually colourless, becoming yellowish when old. The most important tropical species of this genus is *L. sacchari*, van Breda, of the sugar-cane (page 88).

The genus *Mycosphaerella* (Fig. 31) also contains many species which cause leaf-spot diseases. These spots also vary in size and colour depending upon their age. The conidia spores are formed very early in the history of the spot, but the ascospore stage does not appear until a much later period. *M. fragariae*, (Tul.) Lindau, is the cause of a common leaf-spot disease of the strawberry in the United States, and has in all probability been introduced into the tropics. *M. stratiformans*, Cobb, of the sugar-cane (see pp. 89, 112) is well known as the leaf-splitting blight. Other fungi of this order which cause diseases are *Cytospora sacchari*, Butler, and *Trichosphaeria sacchari*, Massee, on the sugar-cane (Fig. 32); *Ustulina zonata*, (Lev.) Sacc. sp., *Venturia Speschnewii*, Sacc., *Rosellinia*

FIG. 30.—Section of cane leaf showing perithecium of *Leptosphaeria sacchari.* Also two mature asci and three mature spores. (After Cook and Horne, Bul. 7, *Estación Central Agronomica de Cuba.*)

bunodes, *R. bothrina*, Petch, *R. radiciperda*, Massee, on tea and rubber; *Anthostomella coffeae*, Del., *Rostrella coffeae* on coffee; *Sphaerella gossypina*, Atk., on cotton; *Pleospora theae*, Speschnew; *Coleroa venturioides*, Speschnew, and *Massaria theicola*, Petch, on tea; *Calospora vanillae*, Massee, of vanilla.

Order 8. PEZIZALES.—This is a very large order, in which most of the species are saprophytic. They are usually disc or cup-shaped when mature, and vary greatly in size and colour. More or less tube-shaped asci are borne within these cups, each ascus containing eight spores. The genus *Sclerotinia* contains the greatest number of parasitic species. In this genus the

FIG. 31.—*Mycosphaerella gossypina* of the cotton. Conidial stage.

cup or ascocarp arises from a sclerotium or dense mass of hyphae. This sclerotium may be developed on a living host, or it may form later. Among the most important species of this genus are *S. libertiana*, Fckl., and *S. Fuckeliana*, De Bary, which attack lettuce, cabbage, and other plants (pp. 130, 234, 236).

Order 9. LICHENS.—The lichens are probably the most remarkable plants known, since each plant is really two plants (an alga and a fungus), which have united, forming a sort of unequal partnership (symbiosis). The hyphae of the fungus are interwoven among and around the cells of the alga. The alga, because of its chlorophyll, is able to form the organic foods which are partly absorbed by the fungus. The vegetative portion of the fungus holds moisture, and secures the necessary mineral food. However, it appears

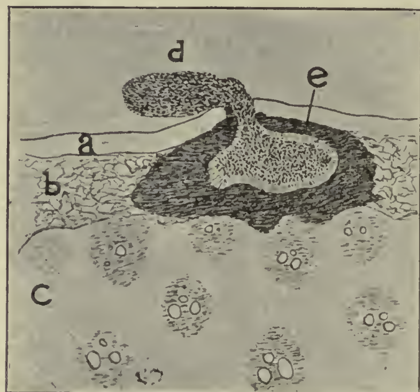

FIG. 32.—Melanconium state of *Tricosphaeria sacchari*.
(After Cook and Horne, Bul. 7, *Estación Central Agronomica de Cuba.*)

that the partnership is not equal, but that the fungus receives more from the alga than it gives in return. The lichens grow and thrive only during seasons of considerable moisture. When dry they become inactive, and remain in a resting condition until the conditions are again favourable for growth. They are sometimes quite troublesome, especially in the cacao groves.

FUNGI IMPERFECTI

Under this term we group a great number of poorly understood species. They are analogous to the conidial stages of the Ascomycetes, and some of them are doubtless the conidial forms of true Ascomycetes; but the relationship between conidial and ascosporic stages is unknown, and therefore botanists are unable to place them in their proper positions.[1] It is also probable that some species have lost their ascosporic stage, and are entirely dependent upon the conidia for perpetuation. Our lack of knowledge concerning this group makes it a very difficult study for both scientific and economic purposes.

As a matter of convenience the class has been divided into three groups or orders, the Hyphomycetes (or Moniliales), the Melanconiales, and the Sphaeropsidales.

Order 1. HYPHOMYCETES OR MONILIALES.—This is the largest order of the Fungi Imperfecti. Many of the species are probably the conidial stages of Ascomycetous fungi. It is a sort of waste-basket order in which have been thrown many fungi, of which we have an imperfect knowledge. It contains a very large number of species, the majority of which are saprophytic. It is subdivided into four families as follows :—

Family Moniliaceae, which contains many leaf parasites.

Family Dematiaceae, which includes *Cladosporium*, *Heterosporium*, *Helminthosporium*, *Cercospora*, *Macrosporium*, and *Alternaria*, all of which are abundant, and cause many very destructive diseases.

The species belonging to the genus *Cladosporium* are the cause of many diseases, although most of them are saprophytic. The diseases are usually known as "scabs." The conidia vary somewhat in form, but in general may be said to be globose or ovoid, and one to four-celled. Among the most important species are *C. carpophilum*, Thum, of the peach ; *C. fulvum*, Cke., of the tomato ; *C. brunneoatrum*, of the orange ; and *C. elegans*, Penz, and *C. citri*, B. & F., of the lemon (see pp. 119, 124, 217).

[1] An illustration of this is *Glomerella gossypii*, (Southworth) Edgerton, which was known as *Colletotrichum gossypii*, Sou., until Dr. Edgerton discovered the ascosporic stage.

The various species of the genus *Alternaria* are also the cause of many diseases. The conidia are muriform, many-celled, and borne in chains on the tips of simple or branched conidiophores. Among the most important are *A. citri* of the orange, and *A. castilloae* of the rubber.

The genus *Macrosporium* bears a close resemblance to the genus *Altenaria*, but the conidia are solitary instead of in chains. Among the most important are the *M. Solani*, E. & M., which causes the early blight of the potato and tomato (pp. 209, 217); *M. nigricaulitum*, Atk., of the cotton; *M. commune*, Rafeul, of the tea; *M. longipes*, E. & E., and *M. tabacinum*, E. & E., of the tobacco.

The species of *Cercospora* are the cause of a very large number of leaf-spot diseases, and are very common and abundant in both tropical and temperate countries. The conidia are very much elongated, slender and many-celled, and are readily recognised. Among the most important are *C. beticola*, Sacc., of the beet; *C. apii*, Fr., of the celery; *C. gossypina*, Cke., of the cotton; *C. longipes*, Butler, *C. sacchari*, (Br.) D. & H., *C. vagina*, Kr., *C. acerosa*, D. & H., and *C. kopkei*, Kr., of the cane; *C. sorghi*, E. & E., of the corn; *C. nicotianae*, E. & E., and *C. raciborskii*, of the tobacco; *C. coffeicola*, B. & C. (Fig. 33), of the coffee; *C. personata*, Ellis, of the peanut; *C. viticola*, Sacc., of the grape; *C. hibisci*, Tracy and Earle, of the Okra; *C. theae*, van Breda, of the tea; *C. bolleana* (Thum) Speg., of the fig; and many others.

The genus *Helminthosporium* also contains many parasitic species. The conidia are cylindrical or spindle-shaped, and many-celled. Among the most important are *H. heveae* of the Para rubber, *H. theae* of the tea, and a number of species on corn and other grains.

Family Stilbaceae, which are mainly saprophytic.

Family Tuberculariaceae, which contains the genus *Fusarium*, which is the cause of many severe diseases.

In the genus *Fusarium* (Fig. 34) the conidia are spindle-shaped, curved, and several-celled when matured. They are borne on the tips of the branched conidiophores. The symptoms of the disease vary with the different species. Among the most important are *Fusarium album*, Sacc., of the cacao; *F. roseum*, Link., of the fig; *F. lycopersici*, Sacc., of the tomato and egg-plant (see page 221); *F. oxysporium*, Schl.,

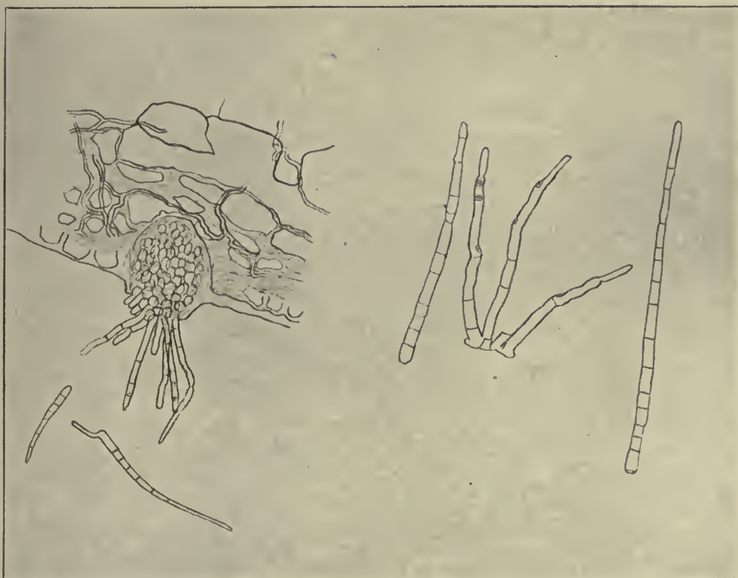

FIG. 33.—Cross section through coffee leaf showing fruiting body of *Cercospora coffeicola* and detached spores. (After Cook and Horne, Bul. 7 *Estación Central Agronomica de Cuba.*)

and *F. solani*, Mart., of the potato; *F. udium*, Butler, of the pigeon pea; and many others.

Botrytis is another genus of this order which is both parasitic and saprophytic. The most important species are *B. fascicularis*, which attacks the egg plant; *B. longibrachiata*, Oud., on tobacco; and *B. cinerea*, Pers., which is very widely distributed and attacks a very large number of plants, and is frequently the cause of considerable losses.

In the genus *Oospora* the mycelium penetrates the host, but eventually emerges to produce the chains of transparent or slightly coloured, globose, one-celled conidia. The most important disease caused by *Oospora* is the potato scab, caused by *O. scabies*, Thaxter (page 280).

The species of the genus *Ramularia* attack many plants. The conidiophores emerge from the stomata, forming tufts, and bear numerous terminal conidia. The most important diseases are the "areolate mildew"

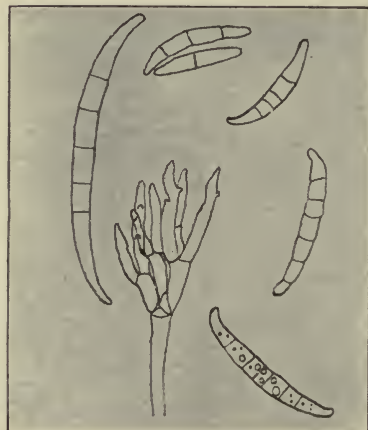

FIG. 34.—Conidiophores and spores of Fusarium species. (After Cook and Horne, Bul. 7, *Estación Central Agronomica de Cuba.*)

of the cotton, which is due to *R. areola*, Atk. (see page 112), and *R. necator*, Massee, of the cacao.

In *Piricularia* the conidia are many-celled and borne on unbranched conidiophores. The most important disease due to this genus is *P. grisea*, (Cke.) Sacc., of the rice (see page 99).

Pellicularia kaleroga, Cooke, of this order is one of the well-known fungi of the coffee; *Necator decretus*, Massee, is the cause of an important disease in the tea; *Coniothecium scabrum* is the cause of a disease on citrus fruits; *C. coffeae*, of the coffee; *Pucciniopsis caricae*, Earle, of the papaw; *Periconia pycnospora*, Fres., of the malanga.

Order 2. Melanconiales.—This order includes a small number of species in which neither asci nor pycnidia are produced. The spores are usually borne in irregular cavities without walls. The majority of the species are saprophytic, but a few are parasitic, and the cause of some of our most important and destructive plant diseases.

The diseases caused by the species belonging to *Colletotrichum* are usually known as anthracnoses. No definite pycnidia are formed, but the conidia are formed in clusters within the tissues of the plants and are at first covered by the epidermis, which eventually ruptures and allows them to escape. The conidial patches are surrounded by setae. Among the most important species are *C. lindemuthianum*, (Sacc. and Magn.) Seibner, of the bean (see page 226); *C. gossypii*, Southworth, of the cotton (see page 111); *C. gloeosporioides*, Penz., of the citrus fruits (see page 116) and avocado; *C. lagenarium*, (Pass) Ell. and Hals., of the cucumber, squash, water-melon, etc.; *C. falcatum*, Went., of the sugar-cane (see page 79); *C. coffearum*, Nack, of the coffee (see page 166); *C. incarnatum*, Zimm., of coffee and cacao; *C. camelliae*, Massee, of the tea (see page 171); *C. phomoides*, (Sacc.), Chester, of the tomato (see page 214); *C. palmarum*, of the palm; *C. nigrum*, E. and H., of the pepper (see page 224); *C. vanillae*, of the vanilla; *C. luxificum*, van Hall and Dorst, *C. brachytrichum*, Del., and *C. theobromae*, of the cacao.

The diseases caused by the species belonging to the genus *Gloeosporium* are also known as anthracnoses. The characters are very similar to those of *Colletotrichum* in that there are no true pycnidia, and that the spores are borne in patches within the tissues of the plant and beneath the epidermis, which is eventually ruptured. There are no setae as in *Colletotrichum*. The spores are colourless or salmon-coloured, unicellular, and borne singly on the tips of the conidiophores. Among the most important are *G. amygdalinum*, Brizi, of the almond; *G. coffeanum*, Del., of the coffee; *G. theae* and *G. theae sinensis*, Miyabe, of the tea; *G. musarum*, Cooke and Massee, of the banana; *G. piperatum*, E. and E., of the pepper; *G. lagenarium*, (Passer) Sacc. and Roum., *G. affine*, Sacc., and *G. bussei*, of the vanilla; an undetermined species on Yantica; *G. alborubrum*, Petch, of the rubber; and many others.

The genus *Septogloeum* resembles *Gloeosporium*, but the conidia spores are pluriseptate. It contains *S. arachidis*, Racib, which attacks the peanuts (page 232), and *S. mori*, (Lev.) Briosi and Cavara, which attacks the mulberry (page 246).

The genus *Coryneum* contains several important species. The conidia are borne beneath the epidermis of the host plant, which they eventually rupture. They are oblong or spindle-shaped, yellowish and multicellular. The most important are *C. Beijerinckii*, Oudem, of the peach; *C. mori*, Nom., of the mulberry (see page 245).

The genus *Pestalozzia* also contains several species which are the cause of diseases of certain plants. The conidia are spindle-shaped and multicellular. The median cells are brown and the terminal cells clear, with one cell at the free end carrying several cilia-like processes. The most important are *P. guepini*, Desm., which attacks *Camellia japonica*, *C. theae* (tea), magnolia, citrus, rhododendron, and hevea (see page 170); *P. palmarum*, Cooke, on the palms and tea (page 201); *P. fuscescens*, Sor., var. *saccharii*, Walker, of the cane; and an undetermined species on the cacao.

The genus *Cylindrosporium* contains many species which are the cause of plant diseases. The conidia are filamentous, sometimes slightly twisted, and embedded within the tissues of the host just beneath the epidermis, which is eventually ruptured.

Order 3. Sphaeropsidales.—This order is so named because it produces structures which resemble the perithecia produced by Sphaeriales. These structures are known as pycnidia and contain spores which develop directly from the walls and not in asci. The group is very large, and includes a number of species which cause leaf-spot diseases. It also includes several species which cause diseases of roots and twigs.

The genus *Phoma* contains many species which are the causes of important diseases. The pycnidia are single, sometimes closely collected, black and sunken in the tissues of the host plant, causing spots with rather indefinite margins. When mature they rupture the epidermis and the spores escape. The conidia are unicellular and colourless. Among the most important are *P. betae*, Frank, of the beet, *P. batatae*, E. & H., of the sweet potato, and others which are known to occur in the temperate zones, and probably occur in the tropics. Also *P. solani*, Hals., of the potato.

The species of the genus *Phyllosticta* are the cause of well-defined spots on living leaves only. The spores are colourless. Among the most important are *P. hortorum*, Speg., on the egg-plant; *P. tabaci*, Pass., on tobacco in Italy; *P. bataticola*, Ell. and Mart., on sweet potato; *P. betae*, Oud., on beets; *P. coffeicola*, Dela., of the coffee; *P. Speschnewii*, of the tea.

In the genus *Sphaeropsis* the pycnidia are black, spherical, and embedded in the tissues of the host. They finally break through the epidermis, and the spores escape through a small aperture. The spores are ovoid, oblong, unicellular, and dark-coloured. Among the diseases attributed to this genus is a leaf disease of coffee due to an undetermined species. The genus *Coniothyrium* contains the species *C. coffeae*, which has been reported on the coffee.

In the genus *Sphaeronema* the pycnidia are membranous with long beaks, and are embedded in the tissues of the host. The conidia are ovoid or oblong, unicellular, and almost colourless. In this genus we find *S. adiposum*, Butler, causing a disease on the stems of the sugar cane; *S. fimbriatum*, E. & H. (Sacc.), causing a disease of the sweet potato; and *S. album*, Petch, causing a disease on rubber.

In the genus *Hendersonia* the pycnidia are subcutaneous. Among the most important of the tropical species of this genus is *H. theicola*, Cooke, which attacks the tea, and *H. coffeae*, Del., which attacks the coffee.

In the genus *Actinonema* the pycnidia are very small, and the conidia are clear and two- or three-celled. In this genus we find *A. rosae*, (Lib.) Fr., on the rose, and many other diseases.

In the genus *Septoria* the pycnidia are very much like those of *Phyllosticta* and *Sphaeropsis*. The spores are clear, long, usually multicellular, and frequently slightly curved, and bear some resemblance to those of *Cylindrosporium*. The species of this genus are the cause of a very large number of diseases. Among the most important are *S. petroselini*, Desm., var. *apii*, Br. and Cav., of the celery; *Septoria lycopersicae*, Speg., of the tomato; *S. theae*, Cav., of the tea; *S. nicotianae*, Pat., on the tobacco.

In the genus *Diplodia* the pycnidia are small, spherical, and dark-coloured, and the conidia are two-celled when mature. In this genus we find *D. cacaoicola*, P. Henn., which causes the twig disease of the cacao (see page 180), and which also grows on the cane, mango, and other plants; *D. zebrina*, of the rubber; an undetermined species on palms; *D. vasinfecta*, Petch, which is the cause of an important disease on the tea; and *D. rapax* on the rubber.

The closely related genera *Lasiodiplodia* contains *L. theobromae*, (Pat.) Griff. and Maubl., which is the cause of an important disease of the cacao; *L. tubericola*, E. and E., on mango and cacao; and *Botryodiplodia elastica*, Petch, on the rubber.

In the genus *Vermicularia* the pycnidia are embedded among a mass of brown septate hairs. The conidia are unicellular, occasionally two-celled, and usually spindle-shaped. In this genus are found *V. ipomoearum*, Schw., of the sweet potato; *V. microchaeta*, Pass., on *Camellia japonica* in Italy; *V.*

vanillae, Del., which attacks the vanilla; and an undetermined species on *Hevea braziliensis.*

In the genus *Ascochyta* the pycnidia are embedded in very much discoloured tissues of the host plant. The conidia are ovoid or oblong, clear, and two-celled. In this genus we find the *A. nicotianae*, Pass., of the tobacco (see page 153); *A. pisi*, Lib., of the pea (page 230); *A. corticola*, and an undetermined species on the citrus fruits. The genus *Discosia*, which belongs to this order, contains *D. theae*, Cavara, which attacks the tea; and the genus *Dematophora* contains *D. necatrix*, Berlese, which attacks the tea and many other plants.

In the genus *Aschersonia* we find a number of very important and interesting species. They differ widely from the great majority under consideration in that they attack and destroy great numbers of insects which are injurious to our crops. Among the most important are *A. aleyrodis* and *A. flavocitrina*, which attack the white fly (Aleyrodes) and many scale insects of Florida and the American tropics, and *A. sclerotioides*, which attacks the scale insects.

Basidiomycetes

The class Basidiomycetes is subdivided into Hemibasidiomycetes, the Protobasidiomycetes, and Autobasidiomycetes.

Under the Hemibasidiomycetes we have the order Ustilaginales or Smuts, which are very abundant on many plants, especially the cereals, wherever grown. The fungus is first observed in the flower, leaf, or stem as small (or in the case of corn as large) tumours or nodules which are white and spongy. In a very short time these nodules become filled with great masses of black (occasionally light-coloured), greasy spores which are known as chlamydospores. Under suitable conditions these spores germinate, producing small promycelia, on which are formed the true spores or sporidia; these in turn grow, producing a mycelium which penetrates the host plant.

The species of this order may be spread in various ways; in some cases they cling to the seed, are planted, grow, and penetrate the young plant; in some cases the spores are carried by wind, insects, etc., to other host plants which are in bloom, grow and penetrate the developing seed, in which they remain dormant until the following season, or they may be carried over in the old decaying plants which are left on the field.

The order includes two families, the Ustilaginaceae and the Tilletiaceae. Under the first family are several genera, of which we will consider but one, *Ustilago*.

U. avenae, (Pers.) Jens., or the loose smut of the oats, is the most common and most destructive. It is as widely distributed as the oats themselves. The flowering plants are frequently thoroughly infested by the mycelia, which give rise to masses of black spores within the flowering glumes. These spores are scattered by the wind, and possibly to some extent by insects. They are also thoroughly mixed with the grain at harvest time. When no precautions are taken to destroy them they germinate with the germinating grain, and thus cause the infection of the young plants.

U. tritici, (Pers.) Jens., is the loose smut of the wheat, and is also very widely distributed. The life-history of this organism is practically the same as that of *U. avenae*, but it is also claimed that the maturing grain may become infected, and that the organism may thus be carried over from season to season by mycelium within the grain.

U. zeae, (Beckm.) Ung., of the corn (Fig. 44) is the cause of the large, very unsightly growths on the ears, tassels, and leaves of the plant. The spores live in the soil and in the old and decaying stalks, and infect the young and growing plants (see p. 95).

U. sacchari, Rabenb., of cane.

U. sorghi, (Link) Pass., of corn and kaffir corn.

U. segetum, (Bull) Dittm., of cereals.

In the family Tilletiaceae we will consider two genera, *Tilletia* and *Urocystis*.

T. foetans, (B. & C.) Trel., commonly known as the bunt or stinking smut of wheat. It is widely distributed throughout the wheat-growing countries. The spores are produced almost entirely within the grain, and are distributed and sown with the seed. They germinate, producing the promycelium on which are produced the sporidia, and the infection takes place through the young plants.

The Protobasidimycetes contains the order Uredinales or rusts. This order contains a greater number of parasites than any other order, many of which attack agricultural crops. The rusts are also very interesting because of their peculiar habits in attacking different hosts. These fungi have three stages, the *aecidiospores* or spring spores, the *uredo* or summer spores, and the *teleuto* or winter spores. In the spring, yellow spots occur on the leaves, and in a short time burst open, exposing great masses of spores which are borne in chains. These are the aecidiospores, which are carried to the proper host and in a short time produce mycelia which penetrate its tissues. The next is the uredospore stage of which there may be several generations. The uredospores are borne singly on the ends of aerial hyphae. The third generation is the teleutospore stage, which is the resting stage. In due time these spores germinate and produce sporidia, which in turn produce mycelium, again starting the life cycle of the fungus. In many species these stages occur on host plants from two entirely different orders, usually the aecidia upon one, and the other two stages upon another; or in some cases the fungus produces only two stages, each upon a different host; while other species are confined to a single host. Some are without aecidial stage, others without uredo stage, while still others are without the teleutospore stage.

The rusts are among the most important fungi that cause disease. While they do not as a rule completely destroy the plant, they reduce its vigour and cause a decrease in the yield. *Hemileia vastatrix*, Berk. and Br.

(see page 160), of the coffee is probably the most injurious of any of the tropical rusts.

Puccinia sorghi, Schw., and *P. purpurea*, Cooke, of corn, and *P. purpurea*, Cooke, on millet, broom corn, and Kaffir corn, are more or less common in tropical countries where these crops are grown (page 96).

Uromyces appendiculatus, Thax., attacks the beans; *U. pisi*, (Pers.) De Bary, the peas; *U. Zoffrini*, the vanilla; and *U. betae*, Frank, the beet.

Uredo scabies attacks the vanilla; *U. arachidis* is a serious pest on the peanut; *U. gossypii*, Lager, is a serious pest on cotton; *U. kuehnii*, Wakker and Went., on cane; and *U. fici*, Cast, of the fig.

Coleosporium ipomoeae, (Schw.) Burr., of the sweet potato, is also very widely distributed.

The Autobasidiomycetes, sometimes called the higher Basidiomycetes, includes the great mass of more or less fleshy fungi which are usually referred to as mushrooms, toad-stools, punks, etc. They are masses of mycelium which have assumed more or less definite forms, although extremely variable in size and shape. The great majority are saprophytic, but many of them may, under certain circumstances, assume parasitic habits. They are the cause of many diseases and wood rots.

The Auriculariales include a number of fungi which are jelly-like in character, and which may grow singly or in masses.

The Exobasidiales are always parasitic, and produce deformities of the host plant. These deformities are frequently gall-like in nature, and are composed of tissues of both host and fungus. *Exobasidium vexans*, Massee, of the tea belongs to this order (page 172).

The Hymenomycetales includes the families Thelophoraceae, Hydnaceae, Polyporeaceae, and Agariaceae.

In the Thelephoraceae the hymenial or spore-bearing surface is usually smooth and continuous. The two most important genera are *Corticium* and *Hymenochaete*, which attack many plants, especially trees. Among the most important are *C. javanicum*, Zimm., of the coffee, tea, rubber, mango, and cacao; *C. Zimmermani*, Sacc. and Sud., of the rubber; *C. lilaco-fuscum*, Berk. and Cast, of the cacao; *Hymenochateae noxia*, Berk., of the cacao and rubber; *C. theae*, on the tea; *C. vagum*, B. and C., var. *solani*, Burt., of the potato, tomato, lettuce, beet, pea, cucumber, and melon.

The family Hydnaceae is readily recognised by the hymenial surface being spread over tooth-like out-growths of the sporophore, or in some cases wart-like or plate-like out-growths. This family includes the *Irpex flava*, Klotsch, which causes a root disease of the coffee and rubber (see pp. 168, 196, 244).

The family Polyporaceae contains the great majority of the pore-bearing fungi. In these fungi the sporophore is filled with small pores opening on one surface, and these pores are lined with hymenium or spore-bearing tissues. Some are fleshy and a few are edible, but the great majority are leathery, corky, or woody. This family includes the genus *Polyporus*, which contains several species causing root-disease on the tea, cacao, and rubber; *P. obliquus* and *P. fumosus*, on the citrus trees; and undetermined species on tea and rubber. It also includes *Fomes lucidus*, (Leys) Fr., on the betel-nut palm; *F. semitostus*, Berk., on the rubber and cacao; *Poria vincta*, Berk., on the rubber; *P. hypolateritia*, Berk., and *Trametes theae* on the tea.

Agaricinaceae is the largest family, and is characterised by the spores being borne on a hymenium which is spread over lamellae or gills. It includes the common mushrooms and toadstools, many of which are edible. In this family is found the genus *Marasmius* which contains the following species: *M. sacchari*, Wakker (Fig. 35), and the var. *hawaiiensis*, Cobb, *M. plicatus*, Walker, *M. bambusinus*, Fr., which cause diseases of sugar-cane; *M. rotalis* on the roots of tea, on the cacao, and on the nutmeg; *M. semiustus*, B. and C., on the banana; *M. equicrinus*, Mull., on the cacao; *M. rotalis*, B. and Br., and *M. sarmentosus*, Fr., of the tea; *Agaricus citri* and *A. hesperidium*, of the citrus fruits;

Schizophyllum lobatus and *S. commune*, Fries, of the sugar-cane; and an undetermined species of *Crepidotus* on cacao.

Order 4. PHALLALES.—The species of this order are much more complex than any other fungi. When mature, the spore-bearing part becomes a shiny, drip-

FIG. 35.—*Marasmius sacchari* of the sugar-cane.

ping mass with a very vile odour. This odour, which has led to the common name of "stinkhorn," is especially attractive to flies, which are largely responsible for the distribution of the spores. Species belonging to the genus *Ithyphallus* are said to attack the sugar-cane in the Hawaiian Islands (page 90).

CHAPTER IV

OTHER CAUSES OF PLANT DISEASES

Slime Molds (Mycetozoa).—The organisms of this group are considered by some as the simplest of animals, and by others as the simplest of plants. The great majority are saprophytes, although a few are parasitic in habit and cause diseases of both animals and plants. When active they are protoplasmic and jelly-like. The fruiting or spore-bearing bodies are usually small, but in some few species are quite large.

The mature spores have a very close resemblance to the spores of smut. Under favourable conditions they germinate, giving rise, not to a mycelium, but to a small protoplasmic body which moves, engulfs food, and lives very much as the simplest form of animal (the amoeba). Different individuals fuse and eventually form a jelly-like mass known as a plasmodium, which may be of considerable size. These bodies are often abundant in forests where there are quantities of decaying woody materials. In time they dry up, forming the fruiting bodies. In the case of the parasitic forms, they penetrate the hosts during the amoeboid stage, stimulating the cells and causing abnormal growths, as in the case of *Plasmodiophora brassicae*, Wor., of the cabbage and related plants (page 232).

Algae.—Some of the blue green algae live in cavities in the higher plants and have assumed either a partially or completely parasitic existence. However, they are not users of manufactured foods, and do not cause diseases of great economic importance.

Other algae form patches on leaves, twigs, and branches of the plants and live partially as parasites or in such a manner as to seriously interfere with the function of the plants, as in the case of *Cephaleurus mycoidea*, Karsten, of the tea (page 174).

Seed Plants.—A number of species of seed plants have become partially or entirely parasitic upon other plants which they injure and sometimes destroy. Among the most widely distributed of these parasitic plants are the dodders or love vines (*Cuscuta*). The seeds of the dodder germinate in the soil, producing a colourless vine which, upon coming in contact with the proper host, twines round and becomes attached to it by haustorial growths. It then loses its connection with the soil and continues its existence at the expense of the host plant.

The *mistletoes* (Fig. 36) are semiparasitic and are widely distributed throughout most parts of the world. The germinating seeds of these plants send their root-like haustorial growths directly into the tissues of the host plant. These plants have well-formed leaves, contain chlorophyll and so are not entirely dependent upon the host plant for nourishment. However, they take a great deal of water and possibly some salts from the host plant, and cause dwarfed growths and malformations, and frequently cause the death of a part or all of the host plant.

The *broom rapes* are widely distributed over the earth, and many species are known to live in tropical countries. Some of them attack the agricultural crops and do considerable damage. The seeds do not germinate, in some species at least, unless they come in contact with the proper hosts. A definite union is formed between the host and parasite which can only be seen by removing the soil from the roots. Not all the roots are attached to the host, but serve the ordinary functions of nonparasitic plants (page 159).

Bacteria.—These interesting little organisms are the causes of many diseases in plants as well as in animals. They are frequently classified with fungi, the great group of plants to which they bear the closest resemblance. They do not contain chlorophyll, and therefore cannot manufacture starch like the green

FIG. 36.—Tree attacked by mistletoe. (Photo by H. H. York.)

plants, but are compelled to live upon organic compounds.

They are unicellular and very small and can be studied only with high-power microscopes. Some are spherical and known as cocci, others short and rod-like and known as bacteria, others long and rod-like are known as bacilli, while others are more or less spiral-shaped and known as spirilla. They may be separate or bound together in filaments, planes, or masses by means of a gelatinous sheath.

When the conditions are favourable they reproduce very rapidly by simple division; each cell dividing into two, and each of these dividing, etc., until a very large number are formed. When the conditions are unfavourable each cell may develop a thick wall and become a spore, which in due time under favourable conditions may give rise to a new colony.

The physiological activities of different species of bacteria are quite different. Some of them cause diseases in animals, others in plants, others are useful in certain industries, while still others hasten the decay and removal of organic waste substances. Some require air, while others live only where the air is inaccessible. Some of them produce colouring substances, some are phosphorescent, and still others produce heat.

Among the most important in agriculture are the nitrifying bacteria, which live in the soil and in the nodules on the roots of legumes. Certain bacteria take the free nitrogen of the air, which is not available for plant food, and construct proteid compounds in the nodules. In the decay of these nodules, the proteids are eventually reduced to nitrates by the action of the nitrifying bacteria, and thus become available food for higher plants. This explains in brief why leguminous plants are improvers of the soils. Many diseases of plants are due to bacteria; in some cases the disease makes itself manifest in the breaking down of the tissues, and later in the death of the plant, as in the case of the bud rot of the coco-nut, banana, etc.

Among other important bacterial diseases are those caused by *Bacillus gossypina*, Sted., of the cotton; *B. amylovorus*, of the pear; *B. solanacearum*, E. F. Smith, of the tobacco, tomato, potato, egg-plant, and pepper (pp. 210, 216, 221, 226); *B. tracheiphilus*, Smith, of the cucurbits; *B. carotovorus*, Jones, of the carrots; *Pseudomonas campestris* (Pammel) Smith, of the cabbage, etc. (page 233); *B. phaseoli*, Smith, of the beans (page 227); *B. vascularum*, of the sugar-cane; and *B. phytophthorus*, Appel, of potato.

In other cases galls or excrescences are formed on various parts of the plants, and either seriously injure or possibly destroy the plant, as in the case of the crown gall disease of many plants.

Bacteria are also frequently associated with other organisms of diseases and decay, and materially aid them in their progress. Many obscure diseases are doubtless due to these minute organisms.

There are many other plants which have this habit of attaching themselves to the roots of plants, and thus living partially or entirely as parasites. Some twining plants assume such huge proportions as to completely destroy the plants which serve them for support. Seeds of some plants are sometimes caught on other plants, produce roots which extend to the ground and eventually attain greater vigour than the support, as in the case of the palm and the ficus.

Insects may also be the cause of diseases, either directly or indirectly, and although the discussion of this subject comes more strictly within the province of the entomologist, there are some which, from the character of the injuries which they cause, may well be considered at this time. These insects are the causes of abnormal plant growths known as galls or cecidia, some of which are very complicated in both form and structure, but very few are of any great economic importance. Probably the most injurious to economic plants are the mites (belonging to the genus *Eriophyes*[1]). The mites are not true insects, but are very minute organisms, closely related to the spiders. The diseases which they cause are referred to as *phytoptosis*, rust and witches' brooms. The phytoptosis of the tomato is an enlargement of the stems, which are also covered

[1] Syn. *Phytoptus*.

with a dense coat of fine plant hairs (see page 219). The rust or russetting of the orange and lemon is also the work of a species of mites (*Eriophyes oleivonu*). Other species of mites are the cause of peculiar enlargements of stems and the formation of witches' brooms (pp. 182, 220), while still others attack the young foliage of plants, causing the formation of excessive growths of plant-hairs or the production of well-defined cecidia. When very abundant the plants are frequently conspicuous for long distances.

Insects are frequently of great assistance to fungi in their work of destruction and may therefore be considered as indirect causes of disease. Many fungi depend almost or entirely on insects to carry them from place to place, while many others depend upon the insects to make wounds by which they gain admission into the plants. In fact, many fungi cannot penetrate plants in any other manner than through wounds.

Nematodes.—An enormous number of plants suffer from the attacks of worms which are so small that it is impossible to detect them without the use of the microscope. In most cases the attack is made upon the roots of the plants but in some few cases other parts of the plants suffer. The nematode plant disease was first discovered in Europe in 1859 by Schacht. In 1871 Schmidt described the organism under the name of *Heterodera Schachtii.* In 1872 Greef described *Anguillula radicicola* which Müller transferred to *Heterodera radicicola* in 1884. Either this or a very similar species was afterwards discovered on the roots of the sugar-cane in Java and described by Treub under the name of *Heterodera javanica.* The disease has been referred to in an Agricultural paper in the United States as early as 1857, and in 1889 Dr. Neal referred the organism provisionally to *Anguillula arenaria*, but in the same year Atkinson referred the organism to *Heterodera radicicola.* It was reported from Brazil in 1878 as attacking the coffee trees and described by Golbi under the name of *Meloidogyne.* In 1897 Cobb, who has described a large number of species of nematodes, expressed the opinion that the Australian species, which he named *Tylenchus arenarius*, was identical with the species previously reported from the United States. In 1909 the same author reported *Heterodera radicicola* on the sugar-cane in Hawaii. It will be readily seen that our present knowledge of the subject is in a decidedly chaotic condition. However, it is safe to say that nematode diseases are widely distributed throughout the torrid and the two temperate zones. Dr. Ernst A. Bessey, who has recently made extensive studies upon this subject has sent me an unpublished list of more than three hundred plants on which the disease is known to occur. From a number of published lists which are before me, I have made the following incomplete list which will indicate the wide range of host plants which suffer to a greater or less degree from this pest :—

Peach . . .	Amygdalus persica
Fig . . .	Ficus carica
Grape . . .	Vitis vinifera (several varieties)
Tea . . .	Thea sineusis
Potato . . .	Solanum tuberosum
Egg-plant . .	,, melongenum
Tomato . .	Lycopersicum esculentum
Cotton . . .	Gossypium herbaceum
Okra . . .	Hibiscus esculentus
Coffee-weed . .	Cassia obtusifolia
Cow pea . . .	Dolichos Catjang
Bean . . .	Phaseolus vulgaris
Japan Clover . .	Lespedeza striata
Sweet Clover . .	Melilotus alba
Morning Glory .	Ipomea sp. (several)
Poke Berry . .	Phytolacca decandra
Sunflower . .	Helianthus annuus
Water-melon . .	Citrullus vulgaris
Beet . . .	Beta vulgaris
Careless Weed .	Amaranthus retroflexus
Corn . . .	Zea Mays
Cabbage . . .	Brassica oleracea
Turnip . . .	,, rapa
Rutabaga . .	,, campestris rutabaga
Parsnip . . .	Pastinaca sativa
Lettuce . . .	Lactuca sativa

Shepherd's Purse .	Capsella bursa-pastoris
Blackberry . .	Rubus villosus
Dog Fennel . .	Eupatorium foeniculaceum
Cypress Vine . .	Quamoclit vulgaris
Purslane . . .	Portulaca oleracea
Cassava . . .	Jatropha manihot
Pea-nut . . .	Arachis hypogaea
Petunia . . .	Petunia sp.
Begonia . . .	Begonia sp.
Dahlia . . .	Dahlia sp.
Citrus Fruits . .	Citrus aurantium, etc.
Plum . . .	Prunus myrobalanus
,, . . .	,, domesticus
Mulberry . .	Morus sp.
Walnut . . .	Juglans cinerea
Pecan . . .	Carya olivaeformis
Almond . . .	Prunus communis
Tobacco . . .	Nicotiana tabacum
Rose . .	Rosa sp.
Violet . . .	Viola sp.
Sugar-cane . .	Saccharum officinale
Banana . . .	Musa sp.

Although the present state of our knowledge of this subject is decidedly chaotic and confusing, it is not impossible to give a general and somewhat popular discussion. The disease is not serious upon all species of plants, but it is, no doubt, injurious to some extent in all cases. In many instances the plants show no external evidences whatever of the presence of the nematodes, while in others the plants become unhealthy and die with no apparent cause. However, an examination of the roots of the plants will reveal a greater or less number of galls, which if sectioned and examined under a microscope will be found to contain many of these little worms. The number and character of the galls varies largely with the host plants and the number of worms in the soil. However, the galls on plants with fleshy roots like the beet are frequently very large, while the galls on the plants with fibrous roots are much smaller. In some instances the galls are so small as to be scarcely noticeable.

It must be kept in mind that galls are frequently produced by other organisms. One of the most common of these is the *Plasmodiophora brassicae*, Wor. (p. 232) which causes the well known "club root" upon cabbage, turnip, and many other plants belonging to the family Cruciferae. The galls which are so abundant on the family Leguminoseae are caused by the nitrogen-fixing bacteria (*Bacterium radicicola*), which are beneficial to plant growth. *B. tumefaciens* (Smith and Townsend) is the cause of the so-called crown-gall, which has proved so destructive to many plants, especially the family Rosaceae, in many parts of the world. Insects are also the cause of gall-formations on the roots of many plants.

Upon cutting a nematode gall and examining the cut surface with a hand-lens, a great number of very small bodies will be found imbedded in the abnormal mass of root tissue. A more critical examination with a compound microscope will show that all the tissues of the root have been deformed, and that these small bodies contain one or more of the worms. It is probable that the young worms usually attack the young roots, and no doubt the variation in the character of the deformity depends not only on the host plants but upon the number of worms and the age of the roots at the time of attack. The distortion of the roots, especially those parts through which the food substances of the plant pass, seriously interferes with the normal functions of the plant. Furthermore, these diseased roots eventually die and decay, even though the plant continues to live, and form a most excellent source for infection by root-inhabiting fungi. The upper parts of the plants also become weakened and more susceptible to the attacks of various fungi.

The worms of *H. radicicola* are usually hatched within the tissues of the old galls and work their way between the cells or through the ducts to new parts of the same plant, or to other plants. By the use of a spear-like organ in the head they puncture the younger portions of the root, often the root-hairs, and gain entrance and become embedded in the tissues. This irritation causes an increased and irregular growth of the root which results in the formation of the gall. The worms make some increase in length, and a very great increase in diameter, becoming spindle-shaped and finally club-shaped, the head being the small end. The males undergo another transformation, becoming slender, which enables them to travel through the tissues of the gall until they reach the females, with which they copulate, and then perish. After copulation the females develop eggs from which the next generation of worms is hatched. Stone and Smith give the length of life of males as four weeks and of females as six weeks.

ENVIRONMENT AND FUNCTIONAL OR PHYSIOLOGICAL DISEASES

Many diseases are not due to any of the specific organisms which have been discussed, but to the fact that the plants are grown under unfavourable conditions. Plants which are grown under such conditions lack vigour and vitality and cannot make maximum growths or produce the desired abundance of grain, fruit, or vegetable, they are also far more susceptible to the attacks of fungi, bacteria, etc., than plants that are in a normally healthy condition. The factors which may be unfavourable to plant growth are, soil, moisture, temperature, gas, and smoke.

The soil may be suitable to certain classes of plants and unfavourable to others. Of course, it is conceded that the soil must contain the necessary food elements which are essential for plant growth, but frequently the soil fulfils this condition and yet for some unexplainable reason the plants will not thrive as they should. New soils may be well suited to certain crops and very unsatisfactory for others, which if grown in these conditions are not only poor but also subject to other diseases.

Soils which have been kept continuously in one crop for years may eventually become unproductive, even when supplied with an abundance of commercial fertilizers. In these cases the unproductiveness is not due to lack of food material but to some other factors which have been brought about by the repeated planting of the same crop, and the character of the fertilizers used. This condition is especially noticeable in the vegetable-growing districts. The cause may be attributed to malnutrition, and the symptoms will vary largely with the crop and the various factors involved; in general they are—(*a*) a retardation of growth or dwarfing of the plant, which will reduce its crop or result in death; (*b*) variations in colour, which interfere with the physiological activities of the plants; (*c*) malformation or dying of the roots, which interfere with the feeding of the plants. The characters of the soil will no doubt vary in different countries, but in general it will be found to be excessively acid and deficient in humus and in nitrifying bacteria.

The moisture content of both soil and air is an important factor. Different classes of plants demand different amounts of water in the soil. Some plants may die for lack of water while others may die because of too much water, even in the same soil. In either case, but especially the latter, the plant is weakened and subject to the attack of disease-producing organisms. This secondary attack is frequently mistaken for the original cause and treatment applied without success.

Unfavourable temperature is also a factor in decreasing the vitality of the plant, and this factor is very frequently combined with moisture content of the air.

Gas and smoke around manufacturing and smelter works are among the causes for injury and possibly the death of plants.

In addition to these, there are many maladies of plants that are so imperfectly understood that we group them under the general term of physiological disease.

Among the most important of these so-called physiological or functional diseases is the **mosaic** or **calico** disease, so common on tobacco, tomatoes, and related solanaceous plants. This disease has been demonstrated to be due to an enzyme within the cells of the plant.

A number of diseases are clustered under the general term of **yellows**. Some few of these diseases have been found to be due to bacteria, but far the greater number are due to unknown causes.

Chlorosis is another term under which many diseases of both known and unknown causes are frequently grouped. It always means the loss or rather the lack of the normal amount of chlorophyll in the plant, and may be a disease or symptom of a disease. In the former it is usually due to the character of the soil, frequently the lack of iron, or the presence of injurious quantities of soluble salts. In the latter it usually indicates a root disease, due either to fungi or insects. However, chlorosis may be due to some cause other than any of those mentioned.

CHAPTER V

SUGAR-CANE

Red Rot or **Smut** (*Colletotrichum falcatum*,[1] Went) (Fig. 37).—This is one of the most severe of the known diseases of the sugar-cane. It was first described from Java by Went in 1893. It attacks the stems and works on the inside of the plant, and so cannot be detected until the disease is well advanced. The first external evidences of disease are the drooping, withering, and finally yellowing of the upper leaves. This is followed by a similar wilting of the entire crown, and finally the whole stool shows indications of disease and dies. When not severe the eyes frequently die and blacken and the dead areas extend out from the nodes. Upon splitting a diseased cane during the early stages of the disease it will be found that the fibro-vascular bundles near the base are reddish in colour. However, the presence of a red colour in the fibro-vascular bundles is not necessarily an indication of this disease, since the colour may be due to any one of many other causes. As the disease advances the red colour spreads to the surrounding tissues and irregular discoloured blotches are formed, which may be reddish or yellowish or white with red margins. These white areas with red margins are a positive proof of the disease.

An examination of the diseased tissues with a microscope will reveal more or less mycelial threads of a fungus, or if the diseased canes are split and put in a

[1] This organism is also said to be the cause of a root disease, but some authors claim that this is not true.

moist chamber, the fungus will develop readily and be easily recognized. There is considerable difference of opinion as to the fungus that causes this disease, but after looking over the literature carefully the writer has decided to refer it to *Colletotrichum falcatum*, Went, although not sure that this is correct. Massee and certain other writers believe that the disease is due to *Trichosphaeria sacchari*, Massee, which is also supposed to be the cause of the "rind" disease in the West Indies (see page 81). Other writers insist that the real cause is *C. falcatum*, and that the *T. sacchari*, Massee, follows as a secondary fungus.

FIG. 37.—Sugar-cane affected with red rot. (Photo by C. W. Edgerton.)

The diseased canes are frequently found to be injured by insects, especially borers, and no doubt these wounds facilitate the entrance of the fungus, which in turn does much more damage than the insects themselves.

Some writers insist that this fungus is more strictly saprophytic than parasitic, and that it cannot attack healthy canes. Others say that it cannot attack mature canes except through wounds, but that it can attack young plants. However, the young canes are usually protected by the leaf-sheaths. In some places the fungus is said to grow on the dead canes only and the disease is not known.

It is widely distributed throughout the sugar-growing countries of the world, and in fact it is extremely doubtful if there are any sugar-growing districts where it does not exist, although it may be much more destructive in some places than others. It occurs in the West Indies where it is known as "red rot," and in Java where it is known as "red smut," although it is not caused by a smut fungus and must not be confused with Ustilagineae. It is also known in Queensland, Barbadoes, India, Hawaii, Madagascar, and the United States.

The character of the treatment depends somewhat on the severity of the disease and its behaviour in the locality in which it is destructive.

First of all, great care should be taken to use none but healthy stock for planting, and if possible nothing but immune varieties should be used. Second, the old fragments of stalks and leaves and other rubbish on which the fungus is known to be growing saprophytically should be destroyed if the conditions of cane culture in that locality make such treatment practical and profitable.

The "**Rind Disease**" (*Trichosphaeria sacchari*, Massee, or *Melanconium sacchari*,[1] Massee) (Fig. 38) is a stem disease which first attracts attention by a premature yellowing and drying-up of the leaves. This is followed by the death of the entire plant. Some of the joints of the diseased canes show dark discoloured patches which indicate the presence of the fungus. These areas become sunken and of a dull yellow colour, and finally the entire cane becomes discoloured and brown and light in weight. Eventually small black eruptions come through the surface, and are sometimes prolonged into curved black thread-like structures which

[1] Other synonyms are:—*Strumella sacchari*, Cooke, from Queensland; *Coniothyrium malasporium*, Sacc., from Porto Rico; *Trullula sacchari*, E. & E.

are more or less kinky. These are the fruiting bodies. They are mucilaginous or jelly-like, and contain great quantities of spores. In localities of great humidity, the thread-like structures are not formed, but the spores

FIG. 38.—Sugar-cane affected with "rind disease."

form black, shiny masses on the surfaces of the cane at the points of discharge.

These spores are carried in various ways, but primarily by the insects and by the wind. When placed under suitable conditions, they germinate readily, infect the new plants, and soon give rise to the disease in new locations. There are two well-recognised stages in the reproduction of this fungus :—

Stage 1.—The *conidia*, which are two kinds, the macroconidia and microconidia. Both are borne from the same filaments and near a wound, as black velvety patches. The microspores are the smaller of the two.

Stage 2. — *Ascigerous*, which occurs as minute, black, hairy perithecia on dead, more or less decayed canes.

This fungus grows abundantly on dead canes and also on bruised fruits, such as banana and pineapple, and so has abundant opportunity to perpetuate itself from season to season. There is some difference of opinion as to whether it can or cannot penetrate healthy uninjured plants, but there can be no doubt that the insects greatly facilitate the infection by carrying the spores, and by making wounds through which the organism gains access to the interior of the plant. It is especially destructive on the cuttings, which it attacks through the wounds and prevents germination. It has been suggested that the fungus may be of saprophytic ancestry, but that it readily adapts itself and becomes parasitic.

Mr. Howard[1] believes that it cannot pass through the nodes, but is confined to the internode in which the inoculation takes place.

Mr. E. J. Butler does not believe that this fungus is responsible for the disease, but that the true cause is *Colletotrichum falcatum*, and that *T. sacchari* is secondary in importance, growing only on the weak or unhealthy canes, especially those which have been infected with *C. falcatum*. However, according to our present knowledge, *T. sacchari* has a much wider distribution than *C. falcatum*, but further investigations may show that their ranges coincide. At the present time it is known in the Southern United States, West Indies, British Guiana, Antigua, Mauritius, India,

[1] Howard, "Sugar-Cane Diseases in the West Indies," *Ann. of Bot.*, March 1903.

Borneo, Tonquin, Java, Argentina, Queensland, and the Hawaiian islands.

The nature of the disease is such that the only remedies that can be recommended at this time are such cultivation as will insure healthy plants, the burning of refuse and the sterilization of cuttings by dipping in weak Bordeaux mixture.

FIG. 39. — Sugar - cane affected with "pine-apple," disease. (Photo by C. W. Edgerton.)

The **Pineapple Disease** (*Thielaviopsis ethacetica*, Went) (Fig. 39).—This is a stem disease which originates in the cuttings for planting and frequently prevents them from growing. The plants which do succeed in growing from these diseased cuttings are usually diseased. The diseased plants are not conspicuous during the early periods of this disease, in fact, they frequently cannot be separated by the external appearance from the healthy plants. However, the interior becomes filled with the fungus, which produces an abundance of sooty black spores. No perfect stage of this fungus is known.

This fungus is primarily saprophytic, but readily becomes parasitic when it gains entrance through a wound. It thus readily attacks the cuttings which are made for plantings, causing the cut surface to become blackish in colour. When these diseased cuttings are split open they show red or cinnamon colour, and if the disease is well advanced they show large black blotches with red margins. In this condition they give a characteristic odour of pineapples, therefore the name. Many of these diseased cuttings die without germination, while many of those which do germinate die later, or produce weak, unprofitable plants.

The disease is especially destructive on the island of Java, and also occurs in Bengal, Southern United States, West Indies, Mauritius, British Guiana, and the Hawaiian Islands.

It grows readily on the pineapple and many kinds of plants, and is no doubt frequently carried by insects and gains entrance to the host plant through the wounds which they make.

Care should be taken to select healthy plants for cuttings. These should be cut carefully with clean knives, and the cut surfaces dipped in Bordeaux mixture.

Went believes that Massee has confused this fungus with *Trichosphaeria sacchari*, and that the macro- and microconidia of *T. sacchari* are identical with *T. ethacetica*. Howard also believes that *T. sacchari* and *T. ethacetica* are identical.

The **Cacao Disease** (*Diplodia cacaoicola*, P. Henn.).—This is a stem disease caused by a fungus which is said to grow on the dead branches of the cacao (*Theobroma cacao*).

The fungus is both saprophytic and parasitic on the canes, causing them to become shrunken and wrinkled longitudinally. Elongated blisters containing spores are formed in rows on the surface of the canes.

These blisters burst and the spores exude in strings. In appearance they somewhat resemble the *melanconium* stage of *Trichosphaeria sacchari*, Massee (see p. 81). In dry weather the spores form a black crust over the surface of the cane. The disease was first reported from the German colony of Kamerun in West Africa, but has since been reported from Bengal and the West Indies. Destruction of the debris in both cane-fields and cacao-groves is the only effectual remedy.

Iliau (*Gnomonia iliau*,[1] Lyon).—This disease is peculiar to Hawaii and is the cause of heavy losses. It was first described by Cobb, who was inclined to believe that it was largely due to a lepidopterous larvae,

[1] *Melanconium iliau.*

but Lyon has more recently proved it to be due to a fungus which attacks the young shoots, "binding the leaf-bases into a tight, unyielding jacket about the stem." The outer leaves become dry and the entire shoot eventually dies. The dead leaf-sheaths are always pinkish-brown, and the rind of the developing stalk a deep bluish-gray. The fungus has two stages, the perfect stage known as *Gnomonia iliau*, which is not common, and the *Melanconium* stage which is very abundant, especially in cool damp weather. The spores of the perfect stage are carried by the wind and those of the latter stage are probably carried by water. The disease can be controlled to some extent by early planting and by good cultivation.

In addition to the preceding diseases which may be considered the most important stem diseases of this very important crop, we also find a number of diseases which, although doing only a slight amount of damage, may develop into serious pests at any time. They are is follows :—

Cytospora sacchari, Butler, is a fungus causing a stem disease which occurs in Bengal and Madras. It is very similar to and very easily mistaken for the *Melanconium* stage of *Tricosphaeria sacchari*.

Black Rot (*Sphaeronaema adiposum*, Butler).—Occurs in Bengal and causes dusky red streaks in the interior of the stems.

Schizophyllum lobatum is a wound-parasite in Java. *S. commune*, Fries, has been reported on stems of sugar-cane in the West Indies. It is also said to be a parasite on the mulberry tree.

The Sooty Mould (*Capnodium* sp.).—This is not a disease but is mentioned in this connection because it is frequently mistaken for one. It is a black fungus growing superficially in the honey-dew which is exuded by mealy bugs (*Aleyrodes*). It does not penetrate the plant, but when abundant it does interfere with the physiological function of the plant by shutting off the light, although not so severe on the cane as on some other plants. Allied species of this same fungus occur on mango, peepul, coffee, tea, orange, lemon, and other plants.

Smut.—*Ustilago sacchari*, Rabenhorst, or smut of Bengal and Trinidad, is another stem disease which causes the tip of the plant to be developed into a long whip-like, much curved shoot, which may be several feet in length and is a dusty black, due to the development of the spores. As a rule it is not serious. It also occurs on the wild *Saccharum spontaneum*.

Rust.—A rust due to *Uredo Kuehnii*, Wakker and Went, occurs on the leaves of the sugar-cane in Java.

Gumming.—This disease has been reported from several cane-growing districts of the world, but the cause has not been determined. The tops of the plants die, and in most cases the base of the arrow is found to be decayed, and the disease frequently becomes severe before it is recognised. Upon splitting the stalk the cavities are found to be filled with a foul-smelling substance and the tissues discoloured. Fresh cuts bleed, producing a yellow liquid of the consistency of honey which oozes from the ends of the fibres. The characters of the gumming plants depend very much on the length of time the plant has been diseased. The drops of gum frequently run together, and contain bacteria, which may be the cause of the disease.

The disease is spread in the cuttings. Fortunately many of these cuttings do not grow at all, and when they do are usually tardy and make stunted plants.

The disease can be controlled by care in the selection of seed plants, the use of clean cuttings, good drainage, destruction of rubbish, rotation of crops, and the selection of resistant varieties.

Calonectria gigaspora, Massee.—Has been reported from Trinidad as growing in the borer wounds of the sugar-cane. It is very doubtful if it is of any importance.

Although the **leaf diseases** are not so destructive as the stem and root diseases, yet they interfere with the physiological function of the plants, and no doubt

FIG. 40.—Leaves of sugar-cane affected with ring-spot disease.

greatly reduce their vitality and therefore their productiveness.

Ring-Spot Disease of the Leaves (*Leptosphaeria* *sacchari*, van Breda) (Fig. 40).—This, like many other leaf-spot diseases of plants, causes its greatest injury by reducing the leaf and thus weakening the vitality of the plants, but does not kill. The spots are more or less oval, and 3 to 5 mm. wide when measured across the leaf, and 5 to 15 mm. when measured in the opposite direction. The tissue of the spot is dead, grayish, and surrounded by a narrow brown or reddish ring. When fully matured, minute black points appear. These are the fruiting bodies (perithecia) which are buried in the leaf and project slightly above the surface. They are almost spherical and about 140 mm. in diameter. They contain long, slender, clavate-cylindrical sacs (asci), which contain the spores. The disease occurs in India, Singapore, Java, Borneo, and the West Indies.

Leaf-splitting Diseases.—These diseases are due to one or more species of the genus *Mycosphaerella*, and are known in the Hawaiian and Fiji Islands where they cause considerable loss. The first appearance of the disease is in the discolorations near the tips of the outer leaves. In a short time light-coloured stripes appear between the fibro-vascular bundles. At first they are narrower than the green stripes, but gradually become wider. In time the leaves become dry and whitish, and begin to split. A careful examination at this time will show small semi-spherical black bodies embedded just below the surface of the leaf. A more careful examination with the microscope shows these bodies to be filled with the spores of the fungus, which are discharged through a small opening, and serve to infect other plants. The disease is very conspicuous and very destructive. The affected shoots should be cut and burned before the spores are ripe.

Leaf-Spot. — The brown leaf-spot (*Cercospora longipes*, Butler) attacks the young leaves causing narrow oval spots, about $\frac{1}{8}$ inch in diameter, which are clearly visible on both surfaces by the reddish colour. As they grow older they increase in size, are brown in the centre, surrounded by red and a yellow zone. The spores are borne in the brown mass in the centre. The leaf gradually dries up. Other similar leaf-spots of less importance are the eye-spot (*C. sacchari*, Br. de H.) of Hawaii and Java; the red spot (*C. vaginae*, Kr.) of Java, India, and West Indies; the black spot (*C. acerosum*, D. and H.) of Java, and (*C. kopkei*, Kr.) of Java, and the yellow leaf-spot (*Pestalozzia fuscescens*, Sor., var. *sacchari*, Wakker) of Java.

Wither Tip.—This is a leaf disease which has been reported from Hawaii by Cobb. It is not very serious and appears only at intervals. It is most abundant on the blades, causing them to die from the tip backwards. The blades lose their colour on the tips and in streaks which vary from $\frac{1}{8}$ inch to nearly half the width of the leaf. Finally the entire leaf is dead with the exception of the midrib. One of the most characteristic features of the disease is the abrupt contrast between the dead and living part of the leaf. The disease is apparently due to an undetermined fungus.

The term **root disease** is somewhat general, since it no doubt includes root diseases which have many different causes. Some of the most important of these diseases have been very ably discussed by Prof. N. A. Cobb,[1] from whose work much of the information here given has been drawn. They are the most destructive of the known diseases of the cane, partly because they are more or less obscure for a considerable period, and partly because their location makes it especially difficult to apply any satisfactory remedy economically.

Ithyphallus (Fig. 41) is a fungus which is said to be the cause of one of the most important root diseases known, although it is not so widespread as some others. The injury to the root system is not so apparent to the observer, unless it is studied with the aid of the microscope. However, as the new shoots come through the ground they are found to be covered with masses of the white mycelium of the fungus. If this mycelium is

[1] "Fungus Maladies of the Sugar-cane," Bul. 5, *Experiment Station of the Hawaiian Sugar Planters' Association. Div. of Plant Pathology and Physiology.*

very abundant it gradually smothers and kills these young shoots, gains strength and vigour, and spreads to other young shoots. Eventually it gives rise to more or less spherical or egg-shaped sporophores or fruiting structures. The period of growth for this mycelium is comparatively long, requiring from one to two and a half years. However, when this mass of mycelium has reached its maturity, the formation

FIG. 41.—Mature specimen of *Ithyphallus*. (After Cobb, Bul. 5, *Hawaiian Sugar Planters' Agricultural Experiment Station.*)

of the sporophores requires only three or four hours. The sporophores rapidly increase in size, and break through the ground during the early hours of the morning. When matured they are 4 or 5 centimeters in height, and about 1 centimeter in diameter. The spores are carried by means of the wind, flies, and other insects. The members of the group to which this species belongs are commonly called stinkhorns, because of their offensive odour and their peculiar shape.

Remedy.—Mr. Cobb has suggested the use of lime, at the rate of $1\frac{1}{2}$ tons per acre, as the most satisfactory remedy. The rubbish should first be burned from the land, thus removing the greater part of the disease excepting in the old stubble. The lime should then be applied along the rows so as to reach the greater part of the affected plants. This treatment will also be beneficial in combating other fungi.

An *Ithyphallus* has been reported on the sugar-cane in Java, and stinkhorns are found in the cane-fields of Louisiana, but their economic importance is as yet unknown.

Marasmius.—Probably the most widespread of the root diseases is due to various species of fungus known as *Marasmius.* When this disease attacks the cane the growth is retarded and the stools are weak in both size and number of canes. However, many affected stools are found which contain some dwarfed canes, and others which show no indications whatever of the disease. The leaf-sheaths when dead do not fall but adhere firmly to the canes, and when pulled apart they are found to be cemented and matted together by a mass of whitish mycelium. The canes are light in weight and can be pulled with ease because of the lack of roots. When cut open in the early stages of this disease the fibro-vascular bundles are reddish, and later numerous cavities are formed which contain the mycelium of the fungus. The roots are also covered with mycelium of the same character.

The organisms which cause this disease belong to the toadstools or mushrooms, which constitute a group of the higher fungi (see page 65). They are saprophytic on the dead canes and parasitic on the living plants. The most common method of distribution is from plant to plant through the soil, or from the dead and decayed parts by the growth of the mycelium. However, when the climatic conditions are favourable the fruiting bodies are formed. They appear as small, somewhat spherical masses of mycelium, which later spread out into the characteristic toadstool form, on the underside of which are the gills bearing the spores. They are usually about $\frac{3}{4}$ inch in diameter, but may be larger.

The most widespread species is *M. sacchari*,[1]

FIG. 42.—Sugar-cane affected with *Marasmius sacchari*. (Photo by W. T. Horne.)

Wakker (Figs. 42, 43), which occurs in Java and the

[1] This fungus is said to also occur on Guinea corn, imphee, and sweet potatoes, in the Barbadoes.

West Indies. *M. sacchari*, var., *hawaiiensii*, Cobb, occurs in Hawaii, *M. plicatus*, Wakker, in the United

FIG. 43.—Sugar-cane affected with *Marasmius sacchari*. (Photo by W. T. Horne.)

States, and *M. bambusinus*, Fr., on the fallen canes in Cuba; and an undetermined species has been reported from the Barbados, St. Vincent, St. Lucia, Dominica, Montserrat, Antigua, St. Kitts, and Nevis.

Some workers have expressed doubt as to whether these fungi are the causes of the diseases attributed to them. A more thorough knowledge of this group of fungi will doubtless reveal a much larger number of species, and extend the range of those already known.

The disease may be held in check by careful cultivation and drainage, by the selection of healthy plants, by developing immune varieties, by destroying the waste material left on the fields, and by rotation of crops, or resting the lands. The success of any method, however, will depend in a great measure on the methods of cultivation followed in the locality.

Root Galls.—The nematode root-galls have been reported in the sugar-cane from various parts of the world, and they are frequently the cause of very great losses (page 71).

CORN, ETC.

While corn is not strictly a tropical plant, and in fact does not reach its highest development in the tropics, it is grown for local consumption, and its diseases must be taken into consideration.

Smut.—One of the most common and widespread diseases of corn is the smut (*Ustilago zeae* or *U. maydis*). This disease may occur as swellings on any part of the plant above ground, but is most common on ears and tassel. The affected parts become transformed into an unsightly mass of moist, spongy fungus tissue (Fig. 44), which eventually becomes dry and extremely light and fragile. This condition is well known to every one familiar with growing corn. The fungus contains an enormous number of spores which are readily distributed by the wind. It can also maintain itself in old stalks left in the fields, and produce spores which pass directly to the young and growing crops the following season.

It cannot be prevented by any known treatment of the seed as in the case with some other smuts. Where very troublesome, the diseased stalks should be cut and burned as soon as the disease is detected. When the disease is not sufficiently troublesome to necessitate this treatment it is always advisable to rake and burn the old stalks before planting a new crop.

A smut (*Ustilago sorghi*, (Link) Pass), also attacks the Kaffir corn in Cuba, and probably occurs on other cereals. It completely destroys the grain, leaving only a black dust. (See treatment for smut, page 280).

Mildew.—A mildew which is due to *Peronospora*

FIG. 44.—Ear of corn destroyed by smut. (After Cook and Horne, Bul. 7, *Estación Central Agronomica de Cuba.*)

maydis, Racib., has been reported from Java. It attacks the young plants, causing them to lose colour, droop, and die. It is supposed to exist on some of the native grasses from which it passes to the young corn.

Rust.—Corn is also subject to two well-known rusts (*Puccinia sorghi*, Schw. and *P. purpurea*, Cooke), but they do comparatively little damage, and there is no effective method of preventing them. When abundant they cause the leaves to dry prematurely and thus reduce their value for feed.

P. purpurea, Cooke, also attacks many other related plants such as Kaffir corn, broom corn, millet, etc., and when serious reduces their feed value.

Other Diseases.—*Cerospora sorghi*, E. & E., also attacks some of these plants, producing a leaf-spot and thus reducing their feed value.

Grain Moulds are prevalent on crops which have close heads when grown in damp climates. The author found the Kaffir corn and pearl millets in Cuba suffered seriously from this trouble at about the ripening time. It appeared that the trouble was due primarily to *Fusarium* sp., and *Helminthosporium* sp.

There is no treatment for these grain moulds, but wherever these crops prove profitable in moist climates it may be possible to breed varieties with loose heads which will not retain the moisture.

OTHER CEREALS AND FORAGE CROPS

Sclerospora Graminicola.[1]—This is the cause of a common disease in the East Indies. It occurs on *Pennisetum typhoideum* (bayro or jowar) (Fig. 45), but it is not serious except on low, ill-drained land where it may become epidemic. It deforms the ears wholly or in part into loose green heads of small, twisted leaves. The mycelium occurs in these deformed parts, and also in other parts. The conidiophores are produced from mycelium in the normal leaves only, and project from the stomata of the leaf. The area over which they are borne is readily recognised by a whitish streak down the leaf. These conidia germinate readily in water, and give rise to from three to twelve, or even more zoospores by which the fungus spreads. The oogonia are produced later in the parenchyma of both the foliage leaves and the deformed parts of the plant.

This disease also occurs on various species of *Setaria italica*, and on *Euchlaena luxurianana* in Poona and Japan.

[1] "Some Diseases of Cereals caused by *Sclerospora graminicola*," E. J. Butler, vol. ii. 1 (Bot. ser.) 1907, *Memoir of the Department of Agriculture of India.*

PIGEON PEA

Wilt.—This disease, which has been reported from India, was first attributed by Butler to a *Nectria* which he found on the stems, and it has also been attributed to a

FIG. 45.—Ears of *Pennisetum typhoideum* affected by *Sclerospora graminicola*. (After Butler, *Memoirs of the Department of Agriculture in India*, Botany Series, No. 1.)

variety of *Necosmospora vasinfecta* (Atk.) Smith, which is said to cause a similar disease of the cotton, but as a result of later investigations Butler has determined it to be due to a *Fusarium* which he has described under the name of *F. udium*. It is a soil parasite which probably gains entrance to the plants through wounds, plugs up the tracheary tissues, thus interfering with the free circulation of water, causing the plants to wilt, and frequently results in death. It is especially severe on seedlings. Mr. Butler, who has made extensive investigations on this disease is of the opinion that it cannot be controlled by any method other than the development of immune varieties.

DISEASES OF RICE[1]

Blast (Italian, *brusone*; Japanese, *imochibyo*) (Figs. 46, 47) is the most serious disease of rice. It has been studied in Japan, Italy, Russia, and North America, and probably occurs wherever rice is grown. On account of its obscure and protean character it usually is not popularly recognised as a disease, but the damage is attributed to weather or soil conditions, bad seed, or bad water. It commonly occurs in epidemics, culminating in a series of "bad years," followed by a series of years in which only mild or local attacks occur. No locality where it has once occurred appears to ever become entirely free from it. Definite accounts exist of its occurrence in Japan at least two hundred years ago, and in Italy as early as 1560; probably it has existed from very ancient times. From the standpoint of the amount of loss it causes, it undoubtedly ranks with the grain rusts as one of the most serious plant diseases of the world.

Cause and Symptoms.—Blast is caused by the parasitism of a fungus which has been called *Piricularia oryzae*, Br. & Cav. The correct name of the fungus is still somewhat in doubt, as it is apparently identical with the fungi *Dactylaria parisitans*, Cav., and *Piricularia grisea*, (Cke.) Sacc., both of which occur on various grasses. This fungus may occur upon any part of the rice plant except possibly the roots, and at any age, thus producing the most diverse effects.

In its most typical and disastrous form, blast is a

[1] This discussion of the diseases of rice was written by Dr. Haven Metcalf of the United States Bureau of Plant Industry.

disease of the joints of the stalk. Beginning as a very small spot on the sheath-node (the thickened turgid bright green ring at the base of every leaf-sheath, just

FIG. 46.—Rice affected with the blast disease.

1, Diseased leaf; 2, diseased ear; 3, conidiophores and spores; 4, germinating spores in water; 5, formation of chlamidiospores.

above the true joint of the stem), the tissue gradually dies until the stalk at this point is partially or completely killed. A brownish coloration spreads up the sheath, usually for about an inch, and for perhaps a half-inch below. A section cut through the stalk shows the presence of the dark mycelium of the above-named fungus. In consequence of this slow cutting-off of the stalk at the joint the parts above slowly die, and the stalk may break off entirely, especially when it is the

Fig. 47.—Germinating rice grain affected with the blast disease.

first (leafless) joint below the head that is affected. Any or all joints may become diseased at any stage in the development of the plant, from the period before the head is shot out until the grains are mature. The grains may thus be completely filled out, partially filled out, or not filled at all, according to the time when the attack of the disease occurs. Obviously, a late attack causes the least loss. The dead top of the plant may present the most varied appearance, according to the weather conditions and the length of time that it is exposed to the weather, and to the growth of saprophytic organisms. It may appear bleached, blackened, discoloured in various ways, or merely withered. Below the lowest affected node the plant is healthy, and abundant normal suckers are put up from the roots.

Commonly also the leaves are similarly invaded by the fungus at the point where the leaf-blade joins the sheath, and the blades break off. In America the leaf-blades themselves are less frequently affected, but in Japan, Italy, and Russia this appears to be a serious form of the disease. The writer has seen but one serious outbreak of the leaf-spot form of the disease; this was in South Carolina, in June, on rice about two feet high. Ordinarily the leaf-spots are not definite in appearance or size, but appear as irregular, often confluent, dead patches; but fairly discreet, black-margined, or zonated spots are also sometimes seen, resembling quite strongly the *Piricularia* spots on grasses of the genus *Panicum*. The fungus occasionally produces its lesions on the leaf-sheaths and internodes, often following a wound, and very commonly occurs, in late attacks, on the rhachis and pedicels of the head, and even on the glumes of the grains. Finally, the fungus readily attacks the seedling, girdling it at the point where it emerges from the seed. Probably this is the cause of much greater loss than is realized; and many a failure of stand is undoubtedly due to this, rather than to poor seed or bad water.

The Fungus. — It will thus be seen that the symptoms of the disease are neither conspicuous nor characteristic; indeed the only dependable diagnostic symptom is the presence of the mycelium. Where the spores can be found at all on the surface of any diseased spot, they are both numerous and conspicuous, but being fugacious in any case, they are often hard to find. If a diseased portion of the plant is placed in slightly damp air (*e.g.* in a petri dish with a single layer of damp filter paper over the bottom), the spores may develop, but more frequently only contaminating organisms appear. The most reliable method of isolation is to drop 3 mm. thick slices of a diseased lower node region into a petri dish containing 1 per cent of Agar-agar in water (with no nutrient added). This substratum appears to furnish the proper degree of moisture, and is unfavourable to the growth of contaminating organisms. In general the fungus grows poorly in culture and produces spores sparingly, but some strains are exceptional in this regard. When the conidia germinate they quickly produce chlamydospores, which, in contact with any hard substance, assume the character of appressoria. The chlamydospores are long-lived, surviving at least twenty months in a dry condition. Artificial inoculations with conidia are very easily made; the conidia, however, rarely survive over three months.

Conditions Favouring the Disease.—All writers appear to agree that nitrogenous fertilizers strongly predispose to the disease. This appears to have been recognised in Japan 200 years ago. In America, land that is rested, either dry or under water, or newly cleared land, is especially subject to the disease. This relation has not yet been explained or clearly correlated with any structural character of the rice.

Certain writers have assumed definite environmental relations of cold, heat, fog, irrigation conditions, etc., but upon this point there is no general agreement. Dry land rice is in general as seriously affected as irrigated rice.

Relation to Varieties.—Varieties vary greatly in their susceptibility to blast, but there is no agreement as to what type of plant is immune. According to Farneti, the loss of resistance in Bertone rice was correlated with some decrease in mechanical and thickening tissue. No variety has yet been proved to be absolutely immune, but some varieties are highly resistant. In America the three leading varieties, Gold, Kiushu, and Honduras, are all highly susceptible, and in order named; Gold, the finest variety, being the most seriously affected.

In Italy great progress has been made in introducing resistant varieties. Several of these, notably Chinese, Lencino, Birmania, and Vialone Nero, are very successfully grown. Experience to date indicates, however, that all varieties tend to lose their resistance after about two to twenty years of cultivation in the same locality. Twelve of these varieties introduced into America in 1908 have so far proved ill adapted to the climate of the Gulf and Atlantic coasts, although growing well in California, where the culture of rice is just being introduced. In Japan, according to Kawakami, the most resistant varieties are Bungo, Kawase, Sekitori, and Kanieji.

Possible Methods of Control. — Spraying once or twice with Bordeaux mixture, just as the head is emerging from the sheath, has successfully prevented the most serious form of joint and "neck" blast. Probably a sticky Bordeaux would do better, but the ordinary Bordeaux sticks to the head, neck, ligule, and joint regions, although not to the general surface of the plant. But it is not practicable to spray a field crop like rice.

Farneti recommends seed selection by a specific-gravity method involving the use of a 1 per cent copper sulphate solution which, at the same time, separates the grains by weight, disinfects their surfaces, and separates most weed seeds. This treatment appears to be based upon the theory that blast is transmitted at least in part by seed, which seems probable but has not been clearly demonstrated.

Special local conditions sometimes admit of special methods. Heavy nitrogenous fertilizing may be reduced or omitted, always with beneficial effect; in certain localities the substitution of non-nitrogenous fertilizers may be possible. Lime has been used with local success in America and in Russia. There is room for unlimited experiment on the fertilization of rice soils, as local conditions vary greatly. Where it is the custom to rest land, and especially under water, the situation may be helped somewhat by omitting this practice and cropping continuously.

However, it is evident that for the future the greatest dependence must be placed upon the discovery of immune or highly resistant varieties. The fact that this has already been accomplished in a large measure for Italy, augurs well for other countries and conditions.

Other Diseases. — Compared with blast, all other diseases of rice are inconsequential. But a few may be mentioned: Smut, caused by the fungus *Tilletia horrida*, Tak., is probably the most serious of the minor diseases. It is a native of Japan, and has been introduced into America. Presumably it is amenable to the same seed-treatment that is used in preventing smut of other grains.

Lump smut, caused by *Ustilaginoidea virens*, (Cke.) Tak., is also a native of Japan, and has been introduced into America. Individual grains become swollen and malformed, presenting an appearance analogous to ergot. In Japan this disease is regarded as a symbol of a luxuriant crop, rather than a cause of loss; and apparently not enough grain is ever affected to do serious harm. The disease is very conspicuous.

The fungus *Sclerotium oryzae*, Catt., apparently causes a stem rot under water, although the parasitism of the fungus has not been demonstrated by inoculations. This disease occurs locally in Italy and America.

A disease of rice spoken of as straight-head, or sterile-head, is apparently increasingly common in the Gulf States. The grains simply fail to fill; in consequence the heads stand erect. The plant appears normal otherwise. The cause is unknown.

Various apparently malnutrition diseases are reported. Many of these have doubtless been confused with blast. The best known of these, called "rust" in South Carolina, from the rusty appearance of the leaves, is controlled in one locality at least by the application by kainit, 400 lbs. to the acre.

COTTON

Cotton is one of the most important tropical and semi-tropical crops. It is subject to a great number of diseases, many of which are no doubt as widely distributed as the plant itself. Some of the diseases mentioned here have not been reported from tropical countries, but no doubt many of them are in the tropics and will be reported at some future time, while others may be introduced at any time. It is therefore very important that they should be considered in a work of this kind.

Damping Off; Sore Shin; Seedling Rot.—The seedlings of cotton, and also of many other plants, frequently suffer from a disease which causes the stem to wilt, fall over, and die. In short, the diseased plants behave in the same manner as tobacco, vegetables, and many other plants when grown in seed-beds.

The young cotton plants, when attacked with this disease, rot at or near the surface of the ground. Sometimes this is a soft rot which works very rapidly and results in the early death of the plants. This is the well known "damping off or seedling rot." In other cases it starts as an ulcer or sore on one side of the plant, just below the surface of the ground, works slowly, and shows a reddish brown colour. The ulcer gradually deepens, sometimes extending into the vascular system. This is known as sore shin, and is not necessarily fatal to the plants. If the ulcer is superficial the plant usually recovers and many of them live, even when the ulcer has penetrated the vascular tissues. *Pythium Debaryanum*, Hesse, *Glomerella gossypii*, (Southworth) Edg., and *Rhizoctonia* sp., are responsible for most of the "damping off" troubles and seedling diseases in general, but it has not been demonstrated that they are the cause of these diseases of the cotton.

Older plants frequently suffer from the "sore shin" disease, which may be due to the same organism as the "damping off" or "sore shin" referred to above. However, the plants being older are also stronger and better able to resist the organisms of disease.

When these diseases become troublesome, the crops

FIG. 48.—Cotton plant affected with wilt. (Photo by H. R. Fulton.)

should be rotated. Liming has been recommended for acid soils.

Cotton Wilt; Frenching; Blackheart; Blackrot.—This disease should be known as the wilt (Fig. 48), since it is very similar in its general characters to the wilt diseases which occur on many other plants. It is one of the most severe and widespread diseases of the cotton.

It was first attributed by Atkinson to *Fusarium vasinfectum*, but E. F. Smith afterwards found what he believed to be the perfect stage of the fungus, and described it under the name of *Necosmospora vasinfecta*.[1] It evidently enters roots through wounds. It penetrates to the fibro-vascular bundles of the plant where it grows rapidly, producing an abundant mycelium and spreads into the stem. In a short time it plugs the ducts of the bundles, and interferes with the transmission of water from the roots to the upper parts of the plant. The effect of this cutting off of the supply of water is the same as a prolonged drought, and the leaves usually wilt, dry, and fall. In most cases the wilting takes place very rapidly, but in some cases the leaves dry very slowly and then fall. Occasionally only a part of the plant dies.

In some cases the disease causes a dwarfed growth but does not kill the plant. However, it can be readily detected by splitting the stem which, if affected, will show a dark discoloration of the normally white internal tissues.

The disease is subject to great variations. It usually starts with a yellowing of the edges, or between the larger ribs of the lower leaves. These discoloured parts may become white but later turn brown, die, and fall. This condition spreads over the entire plant, sometimes slowly and sometimes rapidly.

The fungus produces an abundance of spores both in the soil and upon the old dead leaves. These spores will retain their vitality in the soil for very long periods of time, and may be carried to other localities in a great many different ways.

This is one of the most widely distributed diseases of the cotton. It is very common throughout the cotton-growing districts of the United States, and has been

[1] The organism causing the wilt of the cow-pea and the water-melon are so similar to the organism which causes the wilt of the cotton that it is impossible to distinguish them. Although these organisms are so much alike they will not transmit the disease from one crop to another. The okra is also attacked by a fungus which causes a similar disease.

reported from the East Indies, but Butler, who has made the most recent investigations on this subject, is of the opinion that *N. vasinfecta* is not the cause of the wilt disease upon any of these plants or upon the cotton. He believes *N. vasinfecta* to be a soil saprophite, and that these diseases are due to *Fusaria* whose perfect stages are as yet undetermined.

The nature of this organism is such that no direct treatment can be given. The diseased plants should be destroyed as soon as they begin to wilt if possible. If not possible to do this the old and dead plants should be burned at the close of the season. When the disease is very severe the crops should be rotated, and the fields kept in some other crop for as long a period as practical. Fertilizers suitable to the development of strong healthy plants should be used. However, the most satisfactory remedy up to the present time has been the development of resistant varieties. These have proved especially successful in the United States.

Black Rust; Yellow Leaf Blight; Mosaic Disease.—This is one of the most interesting and most complex diseases of the cotton, and in the United States it is by far the most important. It is the result of a number of factors, primarily the soil and the climate, which, if unfavourable, so weaken the plants as to make them easy victims of any one or more of the following fungi: *Macrosporium nigricaulitum*, Atk., *Alternaria* sp., *Mycosphaerella gossypina*, Atk., and *Glomerella gossypii*, (Southworth) Edg.

The disease is most common on old soils which have been in cotton for many years. Unfavourable soil, accompanied by an unfavourable season, results in a heavy loss. The character and progress of the disease varies greatly with the weather conditions. In most cases the leaves turn yellow in irregular areas, producing a mottled or mosaic effect, the parts next to the veins being better nourished, retaining the green colour the longest. Another condition is that in which a drought is followed by warm rains. The mosaic condition is not so prominent, but the leaves have a tendency to become black and to fall quickly. In either case the plants are very much weakened, and become an easy prey to the fungi already mentioned. In fact, the fungi are already at work before the discolorations are complete.

It will be readily seen that the important factor in the control of this trouble, or combination of troubles, is to produce strong, vigorous plants. Such plants will not suffer materially from any of the fungi mentioned. The use of potash fertilizers has given most excellent results in the southern part of the United States.

Anthracnose of the Stem. — This characteristic anthracnose or rot disease is due to the fungus *Glomerella gossypii*, (Southworth) Edg. It attacks the stem, leaves, and bolls, but does not cause the characteristic cankers. The spots or points of attack are at first of a dull, reddish-brown colour, and are slightly depressed. As they approach maturity they enlarge, the spores are formed in great abundance, and give them the dirty grey or pinkish colour. The spores are carried in various ways, and the disease spreads very rapidly. It is very severe in plants which have become weakened from some other cause. Wounded plants are especially susceptible, and the spores frequently enter through the scars which are left by the fallen leaves. It also attacks the young plants at or just below the surface of the ground, causing them to wither and die in the same manner as when attacked by the "damping off" organisms. This early attack of the young plants is no doubt due to the spores being carried over with the seed.

The best precaution against this disease is to get seed, if possible, from the fields which are not affected, or to select seed from plants which are clean. At the same time the debris from the old fields should be burned, and the crops should be rotated so as to put clean seed on the clean fields.

Anthracnose of the Boll.[1]—This disease is due to the fungus *Glomerella gossypii* (Fig. 49), which has been previously mentioned. It attacks various parts of the plant throughout its entire life, from seedling to maturity. When it attacks the bolls, they usually lose their green colour, and frequently become a dull red or bronze. In case the boll is near maturity it may

Fig. 49.—Cotton balls affected with anthracnose. (Photo by C. W. Edgerton.)

be able to complete its growth, ripen and open in the normal manner without much injury. However, if the fungus attacks the boll early it causes a premature dying of the diseased parts of the carpels, and therefore an unequal growth which causes them to crack open and expose the immature lint to the weather. Of course this immature lint is a poor grade, and the greater part of it decays. In case it is sufficiently

[1] Syn. *Collctotrichum gossypii*, Southworth. This fungus is well known in the United States, and has been reported from South Africa.

mature not to rot, it is usually difficult to pick. The disease is quite common in both the United States and the West Indies, the annual loss ranging from 10 per cent to 50 per cent.

Leaf Blight.—This disease is due to the *Cercospora* stage of the fungus *Mycosphaerella gossypina*, Atk,[1] which occurs on the leaves of the plant causing the characteristic *Cercospora* leaf-spot (Fig. 50). The spots are small, whitish, of dead tissue, and are surrounded by a rather indefinite reddish border. During the fall and winter the *Sphaerella* or perfect stage can be found in very great abundance. The disease may attack plants at any stage of their development, but when unaccompanied by other troubles it causes very little damage. It is widely distributed throughout the United States and the West Indies, and no doubt occurs in other places from which it has not been reported.

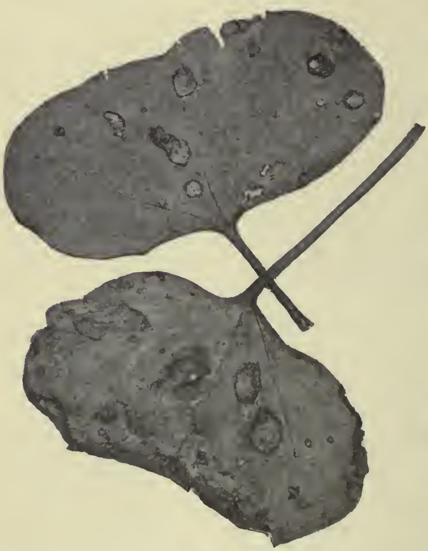

FIG. 50.—Cotton leaves affected with leaf blight. (After Cook and Horne, *Prime Informe Anual de la Estación Central Agronomica de Cuba.*)

Mildew. — This disease is caused by the fungus known as *Ramularia areola*, Atk. It does not appear until the fall, when it may be found in the angles formed by the veinlets. It causes well defined, irregular, small, translucent, or light green-coloured or yellow-tinted areas, which are most conspicuous on the

[1] The organism was first described under the name *Cercospora gossypina*, Cke., but later studies proved it to be the *Cercospora* stage of *Mycosphaerella gossypina.*

under side of the leaf. A little later in the season, the formation of the conidiophores on the under surface gives the white frosty effect. It is most common on cotton growing in low, moist land, and causes a premature falling of the leaves. In general it does not do much damage, but occasionally causes considerable loss by reducing the leaf surface of the plant. It is common in the United States and in the West Indies, and has been reported from the Transvaal.

Angular Leaf-Spot.—Clear watery spots are sometimes formed at the angles of the veins or along the sides of the large veins and ribs. These spots contain millions of bacteria, but there is some difference of opinion as to whether the disease is due to the bacteria or is a physiological condition which has been taken advantage of by these organisms. As the disease advances the tissues become dry and dead and frequently break into holes.

Cotton Boll Rot.—This is a disease which causes considerable loss by rotting the unripe bolls. It has been known in the United States since the earlier part of the last century, but its cause is as yet not fully decided upon. Stedman made a study of it and attributed the cause to a bacterium which he described under the name *Bacillus gossypina*, but his results have not been fully confirmed. It works on the strongest plants and in the richest land, and is most severe during wet weather.

In 1897 Professor C. F. Baker made some studies of this disease in Alabama, and came to the conclusion that the primary cause was one of the small leaf-hoppers, commonly known in the Southern United States as "sharp-shooters." These little insects not only cause injuries by puncturing the bolls but they facilitate the entrance of numerous fungi. Professor Baker's investigation demonstrates the presence of three species of *Bacillus*, and *Colletotrichum gossypii*, *Fusarium* sp., *Altenaria* sp., *Rhinotrichum macrosporum*, Farlow, and *R. tenellum*, B. & C.

This disease is well worthy of a thorough investigation. In the meantime it has been recommended that in districts where this disease is prevalent, the planters should avoid varieties which make excessive growths, use well-drained land, leave abundant space for cultivation and free circulation of air, and use acid phosphate only for fertilization.

Another bacterial disease, caused by *Bacillus malvacearum*, is said to be very destructive to the Egyptian and Sea Island Cotton in Nyassaland.

Shedding of Bolls.—The cotton crop in the United States frequently suffers from a premature shedding of the bolls. This may be due to fungus and insect injuries, but is more probably due to any one of a number of non-organic causes, such as character of the soil, fertilizers, rainfall, etc. It must be studied separately in each cotton-growing country.

Cotton Rust.—This is a true rust caused by the fungus *Uredo gossypii*,[1] Lager. It occurs on all parts of the green plant, spreading from the older parts to the new leaves as rapidly as they are formed. On the upper side of the leaf it produces small rounded, or angular, purplish brown spots. The spores are borne in pustules just beneath the epidermis, which finally ruptures and sets them free. These pustules are far more abundant on the under than on the upper surface of the leaf.

Rust was first reported from Ecquador, and is very abundant in the United States and the West Indies. It is much more severe on the strictly tropical varieties than on those grown in the semi-tropical and temperate zones. The varieties grown in the Southern United States are partially immune, even when grown in the West Indies.

The destruction of the rubbish from the fields, and such cultivation and fertilization as will result in vigorous plants, will do much to control the trouble. It is also wise to avoid the badly affected plants when selecting the seed.

[1] Syn. Uredo of *Kuehneola gossypii*, Arthur.

Black Boll.—This disease has been reported from Montserrat and Antigua, but the cause is not definitely known. The inner part of the boll decays near the base, the seeds swell up and the lint is destroyed. The bolls drop without opening.

Texas Root Rot.—This disease is not known except in the south-western part of the United States, but may be carried to other places at any time. It starts by causing a few of the plants to wilt and die very suddenly, usually near blossoming, but occasionally when small. The disease spreads to neighbouring plants, and is most severe in hot, wet weather. The disease is due to a fungus known as *Ozonium omnivorum*, Shear, which attacks the roots and which is always found on the top roots of the diseased plants. The roots are shrunken and have depressed spots with reddish borders. The fungus is white, becoming brown or yellow and finally producing sclerotia. The lint of the diseased plants is also modified, being larger and with fewer spirals than the lint from normal plants. The fungus persists in the soil which precludes direct treatment. It can be controlled by rotating the crops and by selecting seeds from immune plants.

Root Knots.—These peculiar growths are due to the attacks of the nematodes (page 71). When few and scattered they do not cause much damage, but when abundant they reduce the vitality of the plants and frequently cause death. Fortunately the cotton is not so seriously affected as many other crops. However, they cause injuries which are points for infection by many fungi, especially *Neocosmospora vasinfecta*, and thereby are the indirect cause of very great losses.

Unfortunately many of our soil-improving plants, such as cow-peas, are also subject to the attacks of these pests, and so cannot be used as rotation crops where the soil has become infected. The grasses and small grain are known not to harbour this pest and, therefore, can be used as rotation crops. However, both the cotton and the grasses and small grain are hard on the land which usually needs a legume crop to give the necessary improvement for a return to cotton.

Nematodes on the cotton are well known in the United States and the West Indies, and probably have a much wider distribution.

CITRUS FRUITS

The citrus fruits are both tropical and subtropical,

FIG. 51.—Lemon twigs affected with wither tip, *Colletotrichum gloeosporioides*.

and the most important diseases to which they are subject appear to be as widespread as the hosts.

Wither Tip; Leaf-Spot; Lemon Spot; Canker; and Anthracnose.—This disease (Figs. 51, 52), which is known by so many names, is probably the most destructive fungus disease known to the citrus fruits. It is due to the fungus, *Colletotrichum gloeosporioides*,[1] Penzig. It attacks the lime, lemon, orange, pomelo, and probably

[1] *Colletotrichum gloeosporioides*, Penzig. Syn. *Vermicularia gloeosporioides*, Penzig; *Phyllosticta adusta*, E. & M.; *Colletotrichum adustum*, Ell.

all varieties and species of citrus, but the lime is the greatest sufferer. In fact, some of the workers who have been studying this disease have expressed to the writer the opinion that the organism is a true parasite on the limes only, and that it does not attack other varieties of citrus fruits when they are in perfect health. However, there can be no doubt that trees which are weakened from other causes are extremely susceptible

FIG. 52.—Limes affected with anthracnose, *Colletotrichum gloesporioides.*

to attacks of this disease. Furthermore, the writer is led by his correspondence to believe that the virulence of this organism varies in different citrus-growing districts of the world. The character of the disease also varies somewhat on the different species and varieties. It is found upon trees of all ages, from seedlings in the seed beds to the mature trees. It usually appears first on the tips and edges of the young leaves, and frequently on the petiole, the axil of the leaf forming a good place for the lodgment of the spores. The parts attacked become light green in colour and eventually brown. The light brown or nearly black acervuli or fruiting bodies are next formed upon either side of the leaf. The leaves wither and die, and the disease gradually travels back along the new growth causing the characteristic "wither-tip." These injured parts frequently break and hang lifeless, having much the appearance of having been cut by insects. Young trees are sometimes entirely defoliated in this manner. It can readily be distinguished from the blight by the fact that the leaves do not wilt, and from the dieback, by the absence of dark excrescences, of gum pockets, and multiple buds.

The opening blossoms expose the stigma, which is the most vulnerable point of the plant. The blossoms and young fruit which are attacked in this manner fall very early, and frequently the entire tree is left fruitless. If the bloom escapes, the young fruits may be attacked at almost any period of their development. They sometimes have the appearance of having been bitten by insects and usually fall very early. When about half grown the fruit becomes more resistant to disease and either throws it off entirely or forms a corky scar over the surface. However, the fully matured fruits are frequently attacked as the result of abrasions in handling, through which the fungi gain entrance. In these cases the fruits may be entirely destroyed or their value may be greatly reduced. Infected fruits, which show no indications of the disease, are frequently shipped but develop the disease before they can be put on the retail market. This is especially true of the lemons.

It has a very wide distribution, having been reported from the United States, Cuba, Porto Rico, Jamaica, Brazil, Mexico, Australia,[1] Italy, and Malta. In all probability it occurs in all citrus-growing countries of the world, although it may be very much more severe in some places than in others.

The diseased fruits, leaves, and twigs should be

[1] Another anthracnose of Australia is caused by *Phoma citricarpa*, M'Alpine.

removed and burned. Spray with Bordeaux mixture, until the fruit is near maturity, and then use the ammoniacal solution of copper carbonate. Lastly, spray the fruit just before gathering, or wash after gathering with potassium sulphide wash or ammoniacal solution of copper carbonate to prevent rot before marketing.

FIG. 53.—Leaves of lemon affected with scab, *Cladosporium citri*.

The character of the treatment must be varied in accordance with climate and local conditions.

Scab.—This disease (Fig. 53) is due to the fungus *Cladosporium citri*, B. & F., and occurs abundantly on the sour orange, lemon, mandarin, pomelo, rather sparingly on the sweet orange, shaddock, and other citrus fruits. It has been reported from Cuba, Porto Rico, Hawaii, Japan, Australia, and the United States, but no doubt has a much wider distribution. It is much worse in moist than in dry climates. It is most common on the leaves of the lemon which become very much roughened by corky elevations on the upper surface, accompanied by corresponding depressions on the lower surface. So abundant does the fungus become that the leaves are frequently distorted and prevented from fully performing their normal functions. When the fruit is attacked it becomes very much roughened, and its market value is very greatly reduced.

It is sometimes quite serious on nursery stock, stunting the seedlings before they can be budded.

The disease can be controlled by spraying with Bordeaux mixture.

Gum Disease; Gummosis; Mal Di Gomma; Foot Rot; Collar Rot.—This is the most common and widespread disease of the orange. It was first reported from the Azores in 1832, but is now known in the orange-growing districts of southern Europe, West Indies, Bahamas, United States, Hawaii, Australia, and probably in all other orange-growing regions. Of course, its wide distribution gives rise to a very large number of names. In 1878 Professor Giovonni Briozi expressed an opinion that it was the result of the fungus *Fusarium limonii*, but did not produce positive proof. Borg, as a result of his studies in Malta, expressed the opinion that it was due to *Agaricus citri* growing on the roots, but there is nothing in other countries to confirm this view. Savastano and Maymone say that it is due to (1) a bacterium (probably *B. gummi*), (2) a breaking down of cellular tissue due to excessive formation of sap, and (3) to external causes such as wounds. For the present at least, we must consider it a physiological disease which may arise from one or more of several causes, such as unfavourable soil, poor drainage, improper fertilization, and mechanical injury.

It is possible, and in fact probable, that the above names may represent several diseases, which for want of definite information have been classed as one. It is also possible that some other supposedly distinct diseases are in reality forms of gummosis.

This disease is most common about the crown of the trees, but frequently extends up the trunk and downward along the roots. There is first an exudation of gum followed by a brownish coloration and sometimes an odour similar to decaying oranges. In Cuba a peculiar gumming of the twigs has also been observed. The most satisfactory remedies consist in careful cultivation, the removal of the soil from about the crown of the tree so as to admit of thorough aeration, generous and uniform supply of water, cutting away of the diseased parts, and painting with a solution of equal parts of crude carbolic acid and water, and then covering the wounds with wax. The sour orange seems to be the most resistant variety, and budding on sour orange or other resistant stock is to be encouraged.

Blight.—This is one of the most puzzling of the leaf diseases of the orange. It is very common and very destructive in Florida, and has been reported from Cuba. No specific organism has been discovered, and we are therefore compelled to consider it a physiological disease. The leaves wilt and finally fall, in some cases rapidly and in others very slowly. In some cases it originates in a part of the tree and gradually spreads over the entire tree. It is very frequently associated with other diseases, especially the anthracnose, which complicates the diagnosis.

With our present meagre knowledge of the disease and its cause, the only remedy that can be suggested is to pull out and burn all diseased trees.

Mottled Leaf.—This disease has given some trouble in California. It appears to be a physiological trouble caused by the roots penetrating an unfavourable subsoil.

Dieback or Exanthema.—This is one of the most serious diseases of the citrus fruits in Florida, and has given some trouble in California. It has also been reported from Australia and Hawaii, and is said to occur in Cuba, but if so, it is no doubt frequently confused with a dieback which is due to grubs and drought. It attacks citrus trees of all varieties and ages; The diseased trees make an exceptionally vigorous growth early in the season and produce a number of deep green coloured water sprouts. This condition is followed by a characteristic dying back of the tips, formation of rusty spots on the leaves and twigs, and multiplication of buds in the leaf axils, and frequently the formation of more or less gum. The leaves may fall or may hang on the tree indefinitely. When bearing trees are suffering from this disease, the fruits begin to fall when about one-third grown. This premature falling is accompanied by a lighter colour, followed by reddish brown specking or irregular blotching and splitting of the fruits. Gum is also formed either on the surface or in the core.

This appears to be a physiological disease which may be due to an excess of ammonia in the soil or fertilizers, to improper soils, to poor drainage, or to an underlying impervious soil. The treatment must be in accordance with the conditions causing the trouble. Some of the more recent but unpublished studies on this disease indicate that it may be a form of gummosis.

Other parasitic fungi, which have been reported as of some economic importance, on the citrus fruits, are *Diplodia aurantii*, Catt., and *Pleospora hesperidearum*, Catt.; *Septoria limoriam*, Passe., and *S. sicula*, Penz., on ripe fruits in Italy.

Orange Tree Canker.—This disease, which is due to *Didymella citri*, Noack, attacks the branches, causing depressions of the bark followed by longitudinal and transverse cracks with thickened margins. The black pycnidia are produced within these wounds. The disease has been reported from Brazil.

Sooty Mould.—This trouble is due to a fungus known as *Capnodium citricolum*, M'Alpine,[1] which occurs in the southern part of the United States, California,

[1] This disease has been described as due to *Meliola camelliae*, (Catt.) Sacc., but more recent studies indicate that it should be placed in the genus *Capnodium*.

Hawaii, Australia, Southern Europe, and no doubt in many other countries where the citrus fruits are grown. It is known by many common names, such as "morfea," "fumago," "Nero," and "mal di cenere" in Italy; "sooty mould" in the United States; "sooty mould," "fumagine," "black mildew," and "black blight" in Australia. *C. stellatum*, Bernard, has been reported on the citrus fruits in the Dutch East Indies.

These fungi are not parasitic upon the orange, but are saprophytes belonging to the pyrenomycetes, and living upon the honey-dew which is exuded by many insects belonging to the families *Aleyrodidae*, *Coccidae*, and *Aphididae*. These insects occur not only upon the orange but upon many other plants. The fungus grows rapidly and covers the leaves, stems, or fruits with masses of black mycelium. In fact, it is frequently so abundant that the trees have the appearance of being painted black. While the fungus does not feed upon the tree itself it covers the parts so completely that the leaves are prevented from performing their normal functions, and reduces the vitality and productiveness of the plant. It also seriously injures the fruit for market. Since this disease, if it can be called a disease, is dependent on the insect, the treatment should be one that will destroy the insects.

Melanose.—This disease has been reported from Florida, Australia, and Cuba. It occurs on the leaves, fruit, and twigs, producing small brownish-black elongated spots. The leaves fall rapidly, and the normal functions of the trees are greatly reduced. No organism has been found which will account for the disease, but it responds readily to treatment with weak Bordeaux. The first spraying should be given before the trees bloom, and the other applications about once a month until the fruit is well formed. The use of potash manure, and the avoidance of fertilisers rich in nitrogen, has been recommended.

Lichens.—These plants frequently grow abundantly over the trunk and branches of the trees, and sometimes on the leaves. They are not parasitic, but prevent the plants from performing their ordinary physiological functions. This is especially common where trees are planted too close together or are not properly pruned. Proper planting and care will in the great majority of cases remove the necessity for treatment, but where it is a serious factor it may be controlled by spraying or washing the trunks and branches with strong Bordeaux or by painting with the following mixture: dissolve 4 pounds soap in 10 gallons water, by boiling, and while still hot add 4 pints crude carbolic acid.

Epiphytes.—These plants frequently become attached to the trees, and while not directly injurious, are unsightly and frequently very annoying. They should be removed by hand, and the trunks or branches washed or sprayed with a 4 per cent to 6 per cent solution of copper sulphate or rosin compound.

Scaly Bark or Nail-head Rust.—This is a disease of the bark of the tree and the rind of the fruit of the sweet orange, and has caused rather heavy losses in Florida. It is due to a very small fungus known as *Cladosporium herbarium*, Lk., var., *citricolum*, Lk. On the young branches the disease appears as circular or oval spots about $\frac{1}{6}$ to $\frac{1}{2}$ inch in diameter, slightly elevated and of a rusty colour. As the disease advances these spots become brittle, crack lengthwise, and eventually break, thus giving a scale-like effect. In some cases these spots are so numerous as to unite. On the larger stems and trunk patches of rough shaggy bark are produced.

On the fruit the disease appears as brown sunken spots or rings, which are at first yellowish or reddish-brown, but eventually become dark. As the bark cracks and flakes off, it gives openings for the entrance of the wither-tip fungus (*Colletotrichum gloeosporioides*), and finally causes the death of the affected part. The disease is frequently confused with gummosis and melanose. It can be controlled by grafting on immune varieties, by heading back the trees, by painting the bark with carbolineum, or by spraying five or six times with Bordeaux mixture. A somewhat similar disease, which may or may not prove to be the same, occurs in California and Arizona.

Yellows.—This disease, which is a yellowing of the foliage, has been reported from Arizona. It is not understood, and is supposed to be due to physiological causes.

Canker.—This is a bark disease which has been reported from Brazil by Noack. It is caused by the fungus *Didymella citri*, Noack, and appears first as a depression of the bark, followed by a cracking, and finally producing an open wound. The fruits of the fungus are borne in this wound. All diseased parts should be cut and burned as soon as detected.

Chlorosis.—This disease is a yellowing or whitening of the leaves, due to a reduction of the chlorophyll. It may be due to any one of many causes, such as the presence of grubs or fungi on the roots, poor drainage, drought, or a soil which is deficient in the necessary food materials. However, it is frequently difficult to discover any cause whatever, and the presence of parasites which may attack the weakened tree is often confusing to both the grower and the botanist. Of course, the fruit production of the tree is reduced or entirely destroyed, and the death of the plant frequently results. In Malta this disease is said by Borg to be accompanied by an enormous production of bloom, but that these blossoms are usually poorly developed. He also says that the diseased trees sometimes produce an abundance of very small fruit which never matures. As the disease progresses unhealthy, yellowish shoots come from the base of the trunk. Where no specified cause can be discovered, good cultivation and fertilization will frequently restore the trees to their normal condition. The fertilizers should usually contain a small amount of sulphate of iron.

Fleshy Fungi.—The large fleshy fungi are no doubt the cause of some troubles on the citrus trees, especially in localities where the orchards and surroundings are not well kept. However, they may cause trouble in orchards under the very best cultural conditions. Most of these organisms are primarily saprophytic, growing on dead twigs, old stumps and debris either in or near the orchard. They gain entrance to the tree through wounds, and may grow for long periods of time and the tree may die before the organism appears on the surface as sporophores, or fruiting bodies. Borg has reported *Polyporus obliquus*, which he says is a true parasite, and *P. fumosus* from Malta. They kill their hosts in from three to five years. He also reports *Agaricus citri* and *A. hesperiduum* as saprophytic on rotten roots, and expresses the opinion that they may have some connection with the gummosis.

Root Rots.—Root rots, which are due to various causes, are more or less common, and have been reported in one form or another from practically all citrus-growing districts of the world. In most cases they can be traced directly to poorly-drained soil, improper planting, or poor cultivation.

Any of these causes will be accelerated by various root fungi, which are especially severe on weak trees. They usually cause a chlorosis or yellowing of the leaves, which eventually fall; and if the cause is not removed the tree finally dies. Kirk has reported a serious root rot of the lemon and citron in New Zealand. The leaves show the usual symptoms, the growth is arrested, flowers are produced in great abundance, and a heavy crop may be produced for several years. The fruits become smaller from year to year, and finally fail to ripen. The small roots or rootlets decay, the epidermis flakes from the larger roots, which finally decay. The collar softens and rots, giving off a vile odour. The decay may extend a foot above the collar and the bark fall away in fragments. If the rot travels longitudinally the tree may live for many years, but if the trunk is girdled, death results very quickly. It is due to cold soil, excessive moisture, and too deep planting.

He also reports another root decay, due to *Lycoperdon* sp., which is evidenced by the usual symptoms in the foliage, and which kills the trees in a very short time.

Borg reports *Rhizoctonia violacea* as being destructive in Malta on the roots of the citrus trees, which are grown in low, clay soil.

Polystictus hirsutus, Fries, has been reported on limes in Dominica; but it cannot be said positively whether it is or is not parasitic.

Fruit Rots.—The rots of the citrus fruits are due to the attacks of the various species of *Penicillium* (Fig.

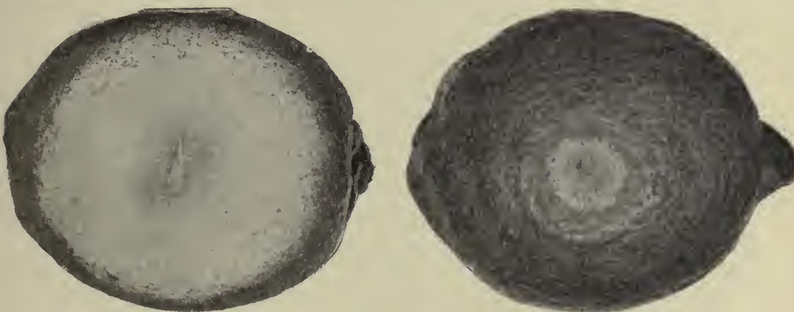

FIG. 54.—Lemons affected with *Penicillium* rot. (Photo by W. T. Horne.)

54), among the most important of which are *P. italicum*, Wehmer, *P. glaucum*, Link.[1] The species of this genus are mostly saprophytic in nature. It has been demonstrated that the fruits rarely if ever rot unless the spore of the fungus gains admission through injuries in the epidermis. These roots may be held in check in three ways, viz.: by preventing the spores from entering the fruits, by using care in picking and handling, and by refrigeration and destruction of the diseased fruits.

There is also a black rot of the orange which has been reported from Arizona. It is due to *Alternaria citri*, Pierce, which gains entrance to the fruits in the same manner as the *Penicillia*, and must be combated in the same way.

[1] Syn. *P. digitatum*, (Fr.) Sacc., and *P. olivaceum*.

Still another rot has been reported from Cuba. It attacks the fruit from the blossom end, frequently while still on the trees. The cause is as yet undetermined.

A splitting of the fruits, which is said to be due to excessive moisture, has been reported from Italy.

Brown Fruit Rot.—This disease (Fig. 55), which is due to a fungus, has been described by R. E. Smith as *Pythiacystis citrophthora*, and is the cause of heavy

FIG. 55.—Lemon affected with brown fruit rot. (Photo by W. T. Horne.)

losses in California. It is especially severe on the lemons, but also attacks other citrus fruits. It can be found on the fruits in the orchards and packing houses, but is most destructive on the fruit after packing. It first appears as a brownish or purplish discoloration of the rind, which is lighter on the green than on the ripe fruits, and is equally severe on weak and vigorous fruits. It spreads rapidly from fruit to fruit, and is also characterised by a peculiar odour, and by the presence of small flies which are attracted to it. It is usually followed by a growth of *Penicillium*.

The disease is most abundant in the orchards during wet weather, and on heavy soils. It can be controlled to some extent by rectifying the unfavourable conditions of the soil, but is best controlled in the packing houses by the use of a disinfectant in the washer: one pint of formalin to 1250 gallons of water or one pound of permanganate of potash or copper sulphate to 625 gallons of water.

Black Rot.—This disease or fruit rot has been reported from South Africa by Mr. I. B. Pole Evans, and the organism causing it described by him under the name of *Diplodia natalensis*. He describes the disease as follows:—

The first evidence of disease is a translucent or watery appearance of the rind, usually around the stalk end of the fruit. This is quickly followed by a softening and gradual brown discoloration of the affected tissue. The brown discoloration, when it has once appeared, spreads very rapidly, and uniformly over the whole fruit, which then becomes distinctly sticky to handle, while at the same time a greenish-brown liquid exudes from it where it comes into contact with anything on which it is resting. Very soon after this a dark olive-green to black discoloration appears at the stalk end, and from thence encroaches over the whole fruit until it is converted into a black mummified mass with a very crinkled and shrivelled surface.

Fruit in this condition left exposed to the dry atmosphere soon dries out, and remains indefinitely a hard body exceedingly light in weight, but retaining to a considerable extent its original form and shape. The loss of weight in the fruit can be detected almost as soon as the brown discoloration appears. When a dry lemon is cut open the whole of the pulp has been absorbed, and nothing remains but a dark fibrous mass of tissue.

The pips and radiating septa are usually covered with a dull greyish growth. On examining the lateral black discoloration more closely with the naked eye or with a hand lens, it is seen to be due to the formation of a number of small dark patches under the epidermis of the rind. As these dark masses increase in number they run one into another and coalesce, so that the whole surface takes on a homogeneous dark colour.

If affected fruit is kept under moist conditions, a very different state of affairs occurs. The surface very soon becomes studded with innumerable tufts of hyphae, at first greyish-olive in appearance, but which later on turns darker coloured, and then eventually completely invests the fruits with a dark felt-like mycelial growth.

In addition to the diseases given in this chapter, D. M'Alpine in his *Fungus Diseases of the Citrus Trees in Australia, and their Treatment*, has described the following diseases and the organisms causing them. They are—

False Melanose . . .	Cladosporium bruneo-atrum.
Black Scurf . . .	Coniothecium scabrum.
Root Rot of Lemon . .	Phoma omnivora.
Wither Tip	Phoma omnivora.
Lemon Bark Blotch . .	Ascochyta corticola.

He also gives technical descriptions of a number of other fungi which occur on the citrus fruits, but which are of little economic importance.

Cottony Mould of Lemons.—This storage rot, which is quite common in California, is due to an undetermined species of *Sclerotinia*. The infections occur in the orchards, and the fungus develops in storage, forming a dense, white cottony mass of mycelium, which spreads very rapidly. It penetrates the fruit, producing black sclerotia on the interior. The ascosporic stage is developed from these sclerotia, and these spores can infect either fruit or the cover crop. The fungus is also said to live saprophytically on dead vegetable matter on the ground or parasitically on the twigs of both oranges and lemons. It is believed that the most common source of infection is from the cover crops. Probably the best method of combating this organism will be the washing of the fruit with a good disinfectant.

PINE APPLE

Rot.—The young plants will sometimes rot unless allowed to dry for eight or ten days before setting. This is doubtless due to the attack from soil fungi, which readily enter the fresh wounds and find suitable foods for growth.

Wilt.—This disease causes a loss of colour, the plant gradually turning from green to red, then yellow, then brown, and finally withering. The discoloration begins at the tip, and is accompanied by a drooping of the plant. The fruits are none or are very poor, and ripen prematurely. The disease appears to be due to a mycelium which infests the roots and rots them. It is said to be readily transmitted from the parent to the new plants. Recent studies indicate that it may be due entirely to the use of certain fertilizers.

The disease may be held in check by using nothing but healthy stock. In case of an outbreak, pull and burn the diseased plants, and treat the soil from which the plants were pulled with lime. Fertilize the plants well, and thus enable them to resist the disease.

The Spike or Long Leaf.—This disease is well known in Porto Rico and Florida. At first the leaves are long and slender, but as the disease progresses they assume the form of rod-like bundles. In severe cases the central leaves do not unfold. Usually no fruit is produced, but whenever formed it is small and worthless. The disease originates through the use of too much acid phosphate. When plants are once affected the disease character is readily transmitted through the slips. The grower should always select healthy plants for setting. Use dried blood, bone meal, or other organic fertilizer. If necessary to use acid phosphate the grower should also use 300 or 400 pounds of lime per acre shortly afterwards.

Leaf Spot.—This has been reported as troublesome in Porto Rico, and may be introduced into other places at any time. It first appears as small brownish spots $\frac{1}{8}$ to $\frac{1}{4}$ inch in diameter. They increase in size, become oval, lose colour in centre, but maintain a brown border. They are frequently on the edge of the leaf. Although this leaf disease is not considered serious, a number of the leaves die. It can be controlled by good cultivation and drainage.

Tangle Foot.—This disease is common in Florida and the West Indies. The leaves turn yellow, beginning at the tip, wilt, and eventually dry up. Examination of the roots shows that they are wound or twisted into a more or less compact mass. The cause of this disease is unknown, but probably due in most cases to poor preparation of the soil.

Blight. — This disease has been reported from Australia, and when better understood may prove to be the same as the disease previously described under the name of wilt. The diseased plants are described as being stunted, turning yellowish, and finally drying up, dying, and rotting. The disease is due to a fungus which attacks the roots, causing the tips to be pale brown instead of white.

Sun Scald.—This is due to the plant bending so that one side of the fruit is unduly exposed to the sun, and also to the moisture which adheres unevenly to the surface. The scald is followed by a rotting of the fruit.

Black Heart or **Core Rot.**—This is a disease in which the fruits ripen unevenly. Black patches occur in the pulp, and it is finally entirely destroyed. The disease is due to a fungus, probably *Penicillium* sp.; but it is thought that the lack of food or improper fertilizer may prove an aggravating factor. It occurs in the West Indies and other tropical countries.

Heart Rot.—This disease has been reported from Cape of Good Hope. It occurs as a blackening of the heart or central axis, frequently through its entire length. It is a physiological disease which is said to be due to excessive moisture. A similar trouble has been reported from the United States.

Fruit Rot.—A fruit rot, due to an undetermined species of *Diplodia*, has been reported from the West Indies. The organism enters through the cut end of the fruit stalks, and penetrates the surrounding pulp tissue. The perithecia appear under the rind as small black spots. Fruit rots have been reported as due to the following organisms: *Thielaviopsis ethacetica*, Went., *Trichosphaeria sacchari*, *Diplodia* sp., *Peni-*

cillium sp., *Aspergillus* sp., *Fusarium* sp., *Eurotium* sp., and a yeast-like organism. The most important of these is said to be *Thielaviopsis ethacetica*[1] (page 44), which is said to attack both ripe and unripe fruit in the field and in storage, causing a soft rot, and also causing a base rot of the crown and a leaf spot through wound infections in the field.

Great care should be used in the cutting and packing, and the cut surfaces should be covered with wax. Recent experiments in the United States Department of Agriculture have demonstrated if the fruits are subjected to fumes of formaldehyde gas (1200 cc. of formalin to 1000 cubic feet of space) for one half hour, the ravages of the fungus can be controlled without injuring the fruit.

PAPAW

Leaf Spot. — The tropical papaw (*Carica papaya*) is attacked in the West Indies by a leaf-spot fungus, *Pucciniopsis caricae*, Earle. It occurs as small black masses on the under sides of the leaves, and causes them to become yellow and fall. It is not destructive, but is sometimes quite severe on seedlings.

BANANA

Bud Rots.—The most serious diseases of the bananas are the bud rots, which are more or less prevalent in various parts of the world. They are not well understood, and it is by no means certain that they are the same. Dr. Delacroix describes such a disease on the Chinese banana (*Musca Cavendishi*) near Alexandria, in Egypt. Other bananas are also attacked, but do not suffer so severely. The disease usually appears on the young plants first, and always on the young leaves and core. The diseased parts become brown, the tissues disorganize and become putrid, and finally die. The

[1] Syn. *Thielaviopsis paradoxa, Sporoschisma paradoxum, Chalara paradoxa.*

disease usually begins in March, and is very destructive in from three to four months. The plants also suffer from nematodes; but whether they, or a bacterium which is present in the putrid parts is the cause, is as yet undecided. Nitrate of soda, applied at the rate of 200 kil. to the hectare, is said to be very beneficial.

Bud rots have been reported from Cuba, Jamaica, Trinidad, Dutch Guiana, and Central America. The one in Trinidad has been investigated by Mr. J. B. Rorer, and proved to be due to *Bacillus musae*, Rorer. It is very probable that the bud rots of the other American tropics are due to the same cause, but this has not been demonstrated.

Since writing the above, Mr. Ed. Essid has published a paper, giving the results of experiments which indicate that the disease is due to *Ustilaginoidella musaeperda*. It is very important that Mr. Essid's experiments should be duplicated by workers in the American tropics.

Surinam Disease.—This disease, which is also known as "bigie footoe" or "Elephantiasis," occurs in Surinam, and is said to occur in Columbia, but is of no great economic importance. It has been investigated by Mr. Essid, who attributed it to *Ustilaginoidella oedipigera*. He describes it as follows:—

> The disease manifests itself by a very often enormous distension of the base of the stem—this is why it was called "bigie footoe" or *Elephantiasis*. In some cases it may not be apparent, but generally a kind of sloughing takes place, caused by the transverse rupturing of the leaf-bases along the line of insertion. The leaves then wither; the withering has nothing striking about it; it is the ordinary fading away of dying leaves.

Banana Leaf Blight.—This disease is quite prevalent in certain localities in Jamaica. It first appears as a brownish discoloration of the fibro-vascular bundles in the veins and midribs of the leaves. The entire leaf blackens and the petiole undergoes a rot, which extends into the stem. The terminal bud does not suffer at first, but the plants are stunted and do not produce fruit. The disease is undoubtedly contagious, and probably bacterial. It stunts the growth of the plants, and spreads slowly throughout the plantation. The Central American blight, which may or may not be the same as the above, is said to have caused the abandonment of 15,000 to 20,000 acres in Panama, and to have caused much greater loss in other Central American countries.

Wilt.—A wilt which is said to be caused by a species of the *Sphaeropsideae* has been reported from Porto Rico, but the information concerning it is very meagre. The leaves become more or less covered with yellow spots, in the centre of which are clusters of minute dots or fruit bodies. The plant wilts, but may live for a long time.

Fruit Rot.—A fruit rot has been reported from Trinidad, but its cause has not been demonstrated. The leaves shrivel, the base of the petiole rots, and finally the fruits are attacked by the rot. A number of organisms have been found, and among them the nematodes, which may prove to be the primary cause.

Ripe Fruit Rot.—A ripe fruit rot (Fig. 56) due to *Gloeosporium musarum*, Cke. and Massee, is very common throughout the American tropics, and is frequently seen on the over-ripe fruits in the northern markets. It has also been reported from Queensland, Australia, and reports also indicate its presence in South East Africa. Thus far, it has not proved severe.

Fig. 56.—Banana affected with ripe fruit rot.

Fruit Scabs.—These scabs have been reported from

Australia, Fiji Islands, Sandwich Islands, the United States, and the West Indies. The fruits become more or less discoloured and cracked. The cause has not been determined. A similar disease has been reported for fruit from Portuguese East Africa. Mr. Evans of the Transvaal says that it " gives the rind a very rough and warty appearance," and that " it is due to an abnormal enlargement and growth of the lenticels on the skin of the fruit, though the actual cause underlying this is yet to be determined.

Brown Spot.—Mr. Evans also reports this disease, which he describes as follows :—

> Externally the fruit appears quite healthy, but on removal from the rind and cutting the soft pulp across, little brown masses of tissue are encountered, which are of a tougher and drier consistency than the surrounding parts. These spots remind one of the necrotic areas found in apples suffering from Bitter Pit. No organism has been detected in connection with the disease, and it appears to be due entirely to abnormal physiological action.

The writer has occasionally observed a similar condition, with the exception that the masses were not brown, in the Cuban bananas.

Root Diseases.—Root diseases have been reported from various parts of the world, but the data is decidedly indefinite. *Marasmius semiustus*, B. & C., has been reported from the West Indies and Trinidad, and is supposed to occur in other parts of the world. It also attacks the leaves, stems, flowers, and fruits, frequently causing the flower buds to decay before emerging from the shoot. Ordinarily it is not severe, but a disease which was probably due to this fungus was very destructive in the Fiji Islands about 1889. The only satisfactory remedy is the destruction of the diseased plants by burning.

Nematodes.—These pests have been reported from Trinidad, Costa Rica, Hawaii, and probably occur in many other places.

MANGO

Bloom Blight.—This disease is due to *Gloeosporium mangiferae*, which attacks the opening blossoms, causing them to turn black, dry up, and fall. The young shoots may also wither and die. This disease is said to be quite severe in Hawaii. It can be controlled by two applications of Bordeaux at intervals of two weeks.

A species of *Lasiodiplodia*, which was apparently *L. tubericola*, E. & E., has been found on the fruits of the mango (*Mangifera indica*) in the Washington, D.C., U.S.A., market. The fruit was supposed to have come from Florida, but no definite information was obtained.

Black Blight.—This is not a true disease, but a case of where a fungus *Capnodium mangiferum*,[1] Cooke and Broome, growing on the secretions of plant lice, produces a mould so dense that it interferes with the proper physiological functions of the plant. If possible, the plant lice should be kept in check. One of the most satisfactory remedies is the Bordeaux-resin spray mixture.

Corticium javanicum, Zimm., has been reported on the mango in Java.

Lasiodiplodia tubericola, E. T. E., is said to cause a disease of the fruits in San Domingo.

AVOCADO

Anthracnose.—This disease is due to *Colletotrichum gloeosporioides*, Penz., which also attacks the citrus fruits (see page 116). It causes a heavy loss of foliage, and consequently weakens the tree. It also attacks the fruit, causing a complete loss if the fruit is young, and spotting and cracking if the fruit is near maturity at the time of the infection.

A disease supposed to be due to a *Gloeosporium* attacks the leaves of the avocado in Hawaii, causing them to become a rusty brown and fall. It also attacks the flowers, twigs, and branches, causing a dieback,

[1] Syn. *Dimerosporium mangiferum*, Cooke.

which is frequently fatal to the tree. Further study may prove this also to be the *C. gloeosporioides*.

FIG

Rust.—This disease (Fig. 57) is due to a true rust fungus, *Uredo fici*,[1] Cast., which attacks the leaves, producing numerous rust-red spots on the under surface and causing the leaves to fall. This disease is very common in Southern United States and West Indies, and when severe the trees will not bear fruit of any consequence. It can be controlled by repeated sprayings with Bordeaux mixture.

FIG. 57.—Leaf of fig affected with rust, *Uredo fici*. (Photo by C. W. Edgerton.)

Leaf Blight.—This disease is caused by the fungus *Cercospora bolleana*, (Thuem.) Speg., and appears as leaf spots. It can be controlled by the use of Bordeaux mixture.

Yellow Rust.—This is not a true rust, but a disease due to *Fusarium roseum*, Link. It is more or less common in Cuba and the Southern United States. It attacks the leaves, causing yellowish spots which break and fall, thus giving the plant a very ragged and unsightly appearance.

[1] Syn. *Phykapsora fici*, Arthur.

Canker.—This disease is due to the fungus *Libertella ulcerata*, Massee, but is not severe except where figs are grown under glass. The disease causes the formation of small radiating cracks which eventually form large cankers, destroying both bark and cambium. If the canker completely girdles the tree or branch, all that part beyond the canker dies and is soon covered with the fruit of the fungus, which oozes out as numerous hair-like processes. These processes consist of spores, held together by a gelatinous substance which dries and becomes hard, but softens in water and is readily scattered.

Fig. 58.—Twigs of fig affected with *Tubercularia fici*. (Photo by C. W. Edgerton.)

Another canker has recently been reported from Louisiana, U.S.A., and described by Edgerton (Fig. 58) as due to *Tubercularia fici*. Mr. Edgerton describes it as follows :—

The disease is characterised by the shrinking and drying out of the tissue surrounding a fruit scar, accompanied by an increased growth of the healthy surrounding tissue, and followed later by a dropping out of the dead part, leaving an open wound in the branch. The cankers are perfectly characterised at all stages in their development. At first, the tissue surrounding a fruit scar turns slightly darker in colour and shrinks. Frequently at this time these cankers or lesions will show a number of small pink spots on their surface, which are in reality the fruiting pustules of the fungus which causes the disease. While this diseased portion is small at first, it gradually spreads out in all directions until the branch may be from one-half to two-thirds girdled. Rarely does the disease entirely girdle the branch, because the latter generally dies before the disease has progressed that far. However, if the twig is not more than half girdled, it generally is not killed, and so the scars of cankers may be seen on branches of all sizes.

In the healthy tissue surrounding the canker, generally there is an increased growth, so that in many cases from a short distance away the canker has the appearance of a knot on the branch. The tree tries to heal over the wound caused by the canker, but is never very successful in doing it. Scavenger beetles and a number of saprophytic fungi and bacteria get into the dead wood of the canker and prevent the healing over of the wound.

A longitudinal section of a cankered branch shows that the fungus which causes the disease has penetrated and killed the bark, cambium, and part of the wood.

The fungus seems to gain an entrance to the fig branch in the fruit scar alone, and this infection takes place within less than a year after the development of the fruit. However, as the fungus is not a rapid grower, the canker does not appear for several months after it has really gained entrance to the host tissue.

The fungus forms cushions of pseudoparenchymatous tissue on the surface of the cankers, these sometimes beginning their development underneath some of the layers of cells of the host, and finally breaking through and sometimes forming directly on the surface. These cushions are very irregular in shape and size. Sometimes the surface is rounded and smooth, and sometimes it is very irregular. On these cushions on small narrow conidiophores, the small, elliptical, hyaline spores are developed, these being cut off singly from the ends of the conidiophores. At the time the spores are developing, the pustules are a light pink in colour.

It is believed that the disease can be controlled by frequently cutting and burning the diseased twigs so as to destroy them before the fungus comes to fruit.

Limb Blight.—This disease (Fig. 59) is caused by the fungus known as *Corticium laetum*, Karsten. It gains entrance to the plant through twigs which have been killed by insects and spreads to the living parts. It is characterised by a wilting of the leaves, accompanied or preceded by the bright-coloured fruiting layer. It is reported from the southern part of the United

Fig. 59.—Limb blight of fig, *Corticium laetum*. (Photo by C. W. Edgerton.)

States, and should be treated in the same manner as the canker.

Fruit Rot.—An anthracnose rot (Fig. 60), occurring throughout the southern part of the United States, is caused by an organism which Stevens and Hall have described under the name of *Colletotrichum carica*, but which Edgerton believes to be due to *Glomerella* *rufomaculans* (Clinton) Sacc., the bitter-rot organism of the apple. The rotten spots are sometimes circular, sunken, and usually covered with a white mycelium on which is eventually produced numerous salmon-pink coloured spores. Frequently the entire fruit is destroyed. In cases where the fruits are attacked when quite young, they become dry and hang on the tree for a year or more, thus becoming a source of infection for the next crop. The disease can be controlled to some extent by destroying the diseased fruit and the mummies, and by pruning out and burning the dead twigs; spraying with Bordeaux mixture will be profitable in localities where the rainfall is not too great.

FIG. 60.—Fruit rot of the fig, *Glomerella rufomaculans*. (Photo by C. W. Edgerton.)

Another fruit rot is due to *Botrytis cinerea*, Pers., but is not of much importance except where the figs are grown under glass.

Soft Rot.—This disease (Fig. 61) is due to *Rhizopus nigricans*, which is also the cause of the rot of the sweet potato and many other plants. It attacks the ripe fruit, causing it to rot, and producing the characteristic black mould. It is especially common in wet seasons, and is disseminated by means of the wind, rainfall, and insects. It is especially severe on the thin-skinned varieties. There is no very satisfactory way of controlling it, but frequent picking of the fruit and protection against insects may reduce its ravages to some extent.

Leaf-Spot.—This disease is due to a *Cercospora*, probably *C. fici*, Heald and Wolf. On the upper side of the leaf the centre of the spot is light brown and the margin dark or purplish brown. On the lower side it is more of a uniform brown colour. The spots may be round or irregular in shape. It is of very slight importance, and when occurring alone would not necessitate treatment. When occurring in connection with other parasitic fungi, it would undoubtedly be reduced by the use of the Bordeaux mixture with profit.

Dieback of Twigs.—This disease has been reported from the southern part of the United States. It is of

Fig. 61.—Soft rot of the fig, *Rhizopus nigricans*. (Photo by C. W. Edgerton.)

very little importance and seems to be associated with other fungus pests.

Nematodes.—These little pests which are troublesome on so many plants, attack the fig, and are the cause of considerable loss in the sandy soils (see page 71).

Root Diseases.—*Dematophora necatrix*, Hartig, attacks the roots of the fig in the southern United States, causing a loss of foliage, and finally kills the trees. The diseased trees should be removed and burned.

Rosellinia sp. has been reported as attacking the roots of *Ficus dubia* and other plants in Singapore, India.

GUAVA

Fruit Rot.—This disease is due to *Glomerella psidii* (G. Del.) Sheldon, and is more or less common in the West Indies, Florida, and California. The disease first appears as brown decaying spots which are finally covered with mass of salmon-coloured spores. The fruit gradually rots, becomes wrinkled and shrunken.

OLIVE[1]

The olive tree grows well within the tropics, but appears to be productive only in rather dry countries. It has attained its principal commercial importance in regions having a marked winter season. About 16° F. is its limit of endurance of cold. Within its proper climate it is a very rugged and resistant tree, enduring extremes of heat, drought, soil poverty, and neglect. It will not bear abundant crops, however, without fairly good soil, good cultivation, regular pruning, and, except in the most favoured spots, some irrigation.

Olive Knot (*Bacterium savastanoi*, E. F. Smith).—Olive knot is also known as tuberculosis of the olive, rogna in Italy, gale in France, and by several other names. It probably occurs throughout the Mediterranean olive-growing districts, and has been observed at several points in California. It is said to be of little importance in the more extremely hot and arid regions where olives are grown.

So far as is known, no variety is immune. In California the San Diego Mission is considered to be somewhat resistant. This and the Manzanillo are among the most popular for making ripe pickles, which are regarded as the most profitable product of the olive in the United States. Some of the smaller varieties, which are used almost exclusively for making olive oil, are very susceptible. The Nevadillo appears to be one of the worst in this respect.

[1] Prepared by Prof. Wm. T. Horne of the University of California.

The disease appears as conspicuous swellings on the trunk, limbs, twigs, or leaves. These swellings are irregularly hemispherical or flattened on top, or nearly spherical where they occur on twigs. About the end of the first season's growth they crack from the top and often become deeply fissured with the segments strongly diverging. They are from a few millimetres to four centimetres or more in diameter. Sometimes several knots become confluent and cover a considerable area. This is particularly liable to occur on a wound or on the large natural swellings at the base of the tree. The majority of the knots on twigs occur on leaf scars. Many appear about old injuries. On the trunk or limbs, knots are particularly liable to occur on the callus or thickened bark about an injury.

The knots are at first firm and fleshy, but the interior soon becomes woody; after maturity the outside dries and becomes hard also. There may be abnormal growth formed within the fissures of an old knot or at the side of it.

The injury to the tree consists in killing or spoiling areas of conducting tissue of cortex and sapwood. When many knots develop in a limb and die, the transportation of water and food materials may be impeded, and the limb itself die. Trees may collapse and die in the same way. However, the disease is not usually fatal to the tree for many years.

The development of the knots is directly caused by the presence within the cortex of the tree of a specific bacterium, *Bacterium savastanoi*, E. F. Smith.[1] It has been repeatedly shown that when a living culture of this bacterium is introduced into the bark of an actively growing olive tree the characteristic knot appears.

The manner in which the specific bacterium which causes the disease is carried from the knots and intro-

[1] See *Bulletin* No. 131, iv. *Bureau of Plant Industry, United States Department of Agriculture*, for very full technical discussion. The organism has generally been referred to *Bacillus oleae* (Arc.) Trev., but the name has been based on so much confusion and error that Dr. Smith has rejected this name and given a new one.

duced into the bark of another tree is not known. Careful field studies in California have failed to connect any insect or other agent with its transfer. Apparently it must be carried in some purely accidental way since isolated trees are often affected among healthy ones. Also the disease may remain without apparent extension for a considerable time.

Remedies.—The University of California recommends the cutting of all knots from the trunk and limbs with a strong knife or with a chisel and mallet, and painting the wounds with a strong antiseptic. All the knots should be pruned out from the smaller twigs. Much foliage must not be removed in summer, but in winter the trees may be very severely pruned. A spray of Bordeaux or other good fungicide should be given in winter or early spring, using care to cover the trunk and limbs.

It is believed that this will prove effective and practical for the more resistant varieties since the olive tree, growing under favourable conditions, is benefited by regular and generous pruning.

Fungus Root Rot (*Armillaria mellea*, (Vahl.) Quel.).—*Armillaria mellea*, or a very closely related fungus, is rather common in California on many fruit and ornamental trees. The fungus penetrates the living bark of the roots and spreads out as fan-shaped, felty, white mycelium, which rapidly kills the tissue. Where the fungus pushes out into the soil, it assumes the form of smooth black strands a little smaller than the lead in a lead pencil. In December groups of large smoky or tan-coloured toadstools are formed near the affected trees. The fungus passes along the roots from one tree to another, making a gradually enlarging area in the orchard.

Remedies.—Olives succumb more slowly to this disease than citrus fruits or stone fruits, but all affected trees will probably die. All diseased trees should be dug out and as many of the affected roots as possible brought to the surface and burned. The land should be planted to some annual crop for a number of years. It is believed that pear trees are immune, and may be planted in the affected areas.

Olive Leaf-Spot (*Cycloconium oleaginum*).—This is a rather common disease, but is not known to be of enough importance to justify the use of remedial measures. Rotting of the fruit sometimes causes considerable loss. It is probably due to various causes and is thought to be largely a seasonal or local effect on certain varieties.

CHAPTER VI

TOBACCO

THE tobacco is a plant which is not strictly tropical: in fact, it thrives far into the temperate zones. Many of the diseases to which it is subject are common in both the temperate and tropical regions, while others may have a more restricted area. However, with our present knowledge of the troubles of tropical plants, it is desirable to give the full list of diseases to which the crop is subject.

Seed-Bed Rot.—All growers of tobacco fully recognise the desirability of securing good healthy plants, and all are fully aware of the great losses which sometimes occur in the seed beds. The young and tender plants of the seed bed, well watered and growing close together in rich soil, form a most excellent place for the growth and spread of fungus diseases. Under these conditions the young plants are attacked by the well-known "damping-off" which destroys very large numbers. There are a number of fungi which thrive under the above conditions and cause the damping-off of the young plants (see p. 29), but the observations of the writer lead to the belief that the *Rhizoctonia* is the most important in the West Indies.

It was and is still the practice in many places to select virgin soil for the seed beds, and then sterilize by building a large fire on the place where the bed is to be made. In some tobacco-growing districts those beds are made in the mountains, partly because of the lower temperature, partly because of the available virgin soil, and the necessary plant growth for the fire, and frequently because of a superstitious belief that mountain-grown plants are better than those grown in the lowlands. However, it is not necessary to use the above antique and crude methods to protect the seed beds from this disease. The soil can be thoroughly sterilized by the use of hot water, formalin, or Bordeaux. Of course it must be remembered that the beds are always subject to reinfection by sticks and other vegetable matter remaining in the soil, which may contain and protect the organism, and also by the foreign material which may be carried in by wind and insects, or the workmen's tools, shoes, etc.

The hot-water method consists in first preparing the beds as for sowing, and then thoroughly soaking them with boiling water. The water should be boiling hot and used in considerable quantity.

The formalin method consists in mixing two pounds of formalin in fifty gallons of water, and applying to the seed beds at the rate of fifty gallons to each forty-eight square feet of surface. If possible, the soil should then be covered with burlap, or some similar material for forty-eight hours in order to prevent rapid evaporation. It should then be thoroughly aired for several days before sowing.

The Bordeaux mixture method consists in treating both beds and plants with the mixture, whenever the trouble appears. Always give the treatment as soon as there is the least sign of the disease, and thus prevent its getting well started. Enough Bordeaux should be used to thoroughly wet the plants and surface of the soil. Care should be taken to use an excess of lime or the plants will be killed by the mixture. Plants treated by this mixture are easily injured by drying, and therefore should be well watered while under treatment (Fig. 62).

Root Rot.—A root rot which attacks tobacco, violets, peas, and many other plants has been reported from Western Europe, extending from England to Italy, and from Northern and Eastern United States as far south as North Carolina. Although it has not been reported from tropical countries, its character is such that the writer sees no reason why it should not appear in some of the tobacco-growing districts of the tropics, at any time, and for that reason this discussion is given. Its wide range of host plants increases the danger of transmitting it from place to place, and makes it much more difficult to combat.

The disease is due to a fungus, *Thielavia basicola*, Zopf. (page 47), which produces an abundant inter-

Fig. 62.—Tobacco seed bed. (Photo by W. T. Horne.)

The left half of the bed on untreated soil and most of the plants killed by "damping off" fungi. The right half sterilized soil.

cellular septate branching mycelium which somewhat resembles the mycelium of *Rhizoctonia*. The roots of the diseased plants are abnormal, and so weak that when the plant is pulled up, they are frequently torn off, leaving nothing but the stub. New roots are frequently formed above the point of injury, and the plant may continue to make a stunted growth or may die. The roots may be rough and brown, and the inner tissues are frequently red in colour. The disease is most severe in the seed beds, and appears to thrive best where the drainage is poor and the soil alkaline in character.

The seed beds should be treated as for other seed-bed rots, care should be used in selecting nothing but healthy plants for planting, and the fields should be well drained.

Paluppu.—This is a root disease of Dumbara which is caused by an undetermined species of *Fusarium.* The stem becomes discoloured at the base and the leaves dry up, the plant undergoes a premature ripening and eventually dies. The plants should be destroyed, and it has been recommended that lime be used on the soil from which they are taken.

Fig. 63.—Tobacco plants affected with nematodes.

Nematodes. — These pests attack the tobacco in common with many other plants on which they live. They have been reported from the United States, the West Indies, and Hawaii, and since they are so widely distributed, they no doubt attack the crop in many other places. The extent of their injuries is somewhat questionable; the writer has examined many plants in Cuba which had an abundance of the galls (Fig. 63) on the roots but an apparently healthy top. However, in Porto Rico, they are said to be the cause of considerable trouble in the seed beds. While the difficulties in controlling them in the fields may be very great, they can doubtless be controlled in the seed beds by the use of carbon bisulphide, followed by a free areation of the land before sowing the seed, or, where practical, by the use of heat.

Mosaic Disease; Calico, or Mottled Top.—This very peculiar and interesting disease is widely distributed throughout the tobacco-growing districts of the world. The leaves of the diseased plants show irregular light and dark green areas, which may be pronounced or scarcely noticeable. The disease may also cause irregular thickenings in different parts of the leaves, and may cause pronounced twistings or deformities. The diseased leaves are not suitable for cigar wrappers, and have a poorer burning quality and aroma than healthy leaves, but the natives of some parts of India are said to prefer them to the normal leaves.

It has been demonstrated that it is not due to a specific organism as at first supposed, but is a true physiological or functional disease. Dr. Woods, of the United States Department of Agriculture, has made extensive studies of this disease and claims that it is due to an "excessive quantity or excessive activity" of an oxidizing enzyme in the diseased cells. This enzyme interferes with the formation of sugar, and thus retards the growth of the plants. Dr. Woods was also able to produce the disease artificially by breaking the top of actively growing plants at any stage of their existence. By the same method he was also able to produce the disease in tomatoes, potatoes, petunias, English violets, and pokeweed (*Phytolacca decandra*), and other plants.

It is a well-established fact that the disease can be transmitted from plant to plant by touch, and it is well known that the labourers are frequently the cause of its spread, and it is probably carried by insects which frequent the plants. It is generally believed that it is very slightly influenced by the character of the soil or fertilizers, but excessive nitrates are said to favour its development. In India it is also said not to occur on newly-cleared jungle lands. It is not transmitted through the seeds, but on general principles it is inadvisable to use seeds from unhealthy plants.

The only satisfactory remedies are preventative measures, such as careful preparation and care of the seed beds, the selection of clean healthy plants, careful field cultivation, care in handling, and so far as possible protection from insects.

Leaf Spots.—Tobacco, like most plants, is affected with various fungi which attack the leaves and produce spots, and since the leaves are the commercial parts, injuries are much more serious on the tobacco than on most plants. The amount of injury due to these causes depends upon the season; being much greater in a very wet than in a relatively dry season.

The following are among the most important:—

(*a*) *Cercospora nicotianae*, E. and E., is one of the leaf-spot fungi which is quite common in the West Indies and the United States, Ceylon, and Sumatra. It is more prevalent on the lower than on the upper leaves, due to the fact that the upper leaves are better aerated and receive more sun while the lower leaves retain the moisture. It is more troublesome in the Western than in the Eastern Hemisphere.

(*b*) *Cercospora raciborskii* occurs in Queensland, Ceylon, and Java, and behaves in much the same manner as the preceding, while an undetermined species has been reported from Dumbara as causing a leaf disease locally known as "pulli."

(*c*) *Ascochyta nicotianae*, Pass, is another of these leaf-spot diseases which occurs in the West Indies, but is not so severe as *C. nicotianae.*

(*d*) *Macrosporium tabacinum*, E. and E., is the cause of a leaf-spot known as "white speck." It causes small, circular, rusty red or brown spots which later develop ashy-coloured centres.

(*e*) *Macrosporium longipes*, E. and E., causes the "brown spot," which can be readily distinguished from the above by concentric markings.

(*f*) *Septoria nicotianae*, Pat., is the cause of a leaf-spot disease which has been reported from Jamaica. It is known as the frog-eye, and appears as concentrically zoned brown spots which finally become white.

The only remedial or precautionary measures that can be taken to advantage, are the protection of the plants in the seed beds, with Bordeaux mixture if necessary, and to transplant none but healthy plants. A single diseased plant may cause the serious injury of a great many.

Mildews.—Both the powdery mildew (*Erysiphe communis* (Wallr.), Lev.) and the downy mildew (*Phytophthora nicotianae*, De Haan) are reported from Java and Australia, and probably have a much wider distribution.

Either the same or a different species of *Erysiphe* has been reported as being a very severe pest in Dumbara, where it is known by the local names of "Ash" or "Alu" or "Sambal." It attacks the lower leaves and gradually works upwards, completely covering them with a white mycelial and conidial growth which gives them the appearance of being covered with ash. The leaves become dry but retain their ash character even after curing. Unfortunately the disease also attacks the tomato, red pumpkin, seedling tamarind, and many other plants, both cultivated and wild, which increases the difficulties in combating it. It can doubtless be controlled to some extent by the use of such spraying mixtures as the ammoniacal copper carbonate solution or some other preparation which does not stain the leaves.

Peronospora nicotianae, Speg., is the cause of another mildew which has been reported from Queensland and California. It forms dirty, greyish violet tufts on the under surface of the leaves. It can be controlled by the use of Bordeaux mixture.

Granville Tobacco Wilt.—There have been reported a number of serious outbreaks of this disease in the United States, and Dr. E. F. Smith says that "if it continues at its present rate of progress, tobacco-growing in the infected districts will become impossible within a few years, and if it should extend to all the tobacco-growing sections of the United States this industry will be destroyed." The disease has also been reported from Sumatra by Hunger, from Cuba by Horne, and may exist in other places, not only on the tobacco but upon related plants.

The foliage of the diseased plants (Figs. 64, 65) wilts, the veins darken, and longitudinal dark stripes are formed on the stems. The fibro-vascular bundles of the stems and leaves are stained brown and contain an enormous number of *Bacterium solanacearum*, E. F. Smith, which is the cause of the disease. The organisms will live in the soil for many years and will also attack potatoes, tomatoes, egg plants, and peppers, and related plants, causing the characteristic wilt just described.

The most common method of infection is no doubt through wounds in the roots, and it is greatly facilitated by the nematodes. When soil becomes infected with the disease it should not be used for any Solanaceous crop for many years. Prevent the infection of clean districts by not bringing seed, tools, or soil from infected areas. If the outbreak is slight, burn all the infected plants, and disinfect the soil if possible.

Curing-house Troubles.—The curing-house troubles vary somewhat in different countries. They are usually, if not always, due to the action of certain fungi and bacteria, which reach their highest development in those countries where the climatic conditions are favourable. This class of diseases is not well understood, but among the most important is the stem rot which is due to *Botrytis longibrachiata*, Oud., which causes white velvet-like mould on the stems and veins of the leaves, and finally a decay of these affected parts and drying of the other parts. The fungus matures and produces spores on this decayed material, which should be

FIG. 64.—Tobacco field destroyed by Granville tobacco wilt. (Photo by Dr. F. L. Stevens.)

collected and burned, and the house disinfected with Bordeaux to prevent the spread of the disease.

It would undoubtedly be wise to disinfect the tobacco houses before the tobacco is put into them. It

FIG. 65.—Tobacco plant affected by Granville tobacco wilt. (After Stevens and Hall, *Diseases of Economic Plants.*)

has been suggested by Selby of Ohio that one pound of formalin in 30 gallons of water would make a suitable preparation for this purpose. It could be introduced as a fine spray and would destroy all the fungi and bacteria, after which a thorough airing would remove it entirely.

Fig. 66.—Tobacco plants affected with broom rape. (After Cook and Horne, Bul. 1, *Estación Central Agronomica de Cuba.*)

Broom Rapes.—These are flowering plants (Figs. 66,

FIG. 67.—Tobacco plants affected with broom rape.
(After Cook and Horne, Bul. 1, *Estación Central Agronomica de Cuba.*)

67) which attack the tobacco and many other plants (hemp, tomato, turnip, rape, cabbage, cotton, etc.).

They are true parasites; they do not contain chlorophyll and therefore cannot elaborate their own food. Soon after germination of the seed the young plants attach themselves to the host plants from which they draw their nourishment and cause a reduction in the vigour of the plant, and frequently the death. *Orobanche cernua* occurs on the tobacco in India, and *O. ramosa* in Japan, India, Egypt, Europe, the United States, and Cuba. These two species attack many other plants as well as tobacco, and there are many other species which do not attack the tobacco but do attack other plants.

The seeds do not germinate unless brought into contact with the roots of the host plants, and many remain in the soil for long periods of time without germinating.

The plants should be destroyed during the cultivation of the crop so as to prevent their maturing seeds. Care should be taken that the tobacco seed is free from impurities.

COFFEE

Rust (*Hemileia vastatrix*, Berkeley and Broome).—This is by far the most destructive disease known on the coffee.[1] The leaves become more or less covered with orange red spots and eventually wither and drop. Parts, and frequently the entire plants, die. The disease reaches its highest development during the rainy season. During the dry season the tree is invaded by superficial mycelial threads, which enter the stomata and feed upon the parenchyma, although but very little external evidence of the disease is to be seen at this time. However, there are a few of the characteristic red spots to be seen at any season of the year, and with the opening of the rainy season these spots become very abundant. They first appear as slightly transparent discolorations which are not easily

[1] This fungus is now believed to have spread to the coffee from some Rubiaceous plant of little or no importance.

seen unless the leaf is held to the light. As the spot increases in size it assumes a faint yellow colour, and finally the under side is covered with a bright yellow dust which soon becomes a bright orange colour. The spots now vary in size, but are circular in shape except where they coalesce. Although the infections occur on the young leaves, the spots do not develop until the leaves are older. They are usually most numerous near the apex. In June and July the disease becomes most severe, and thousands of spots in all stages are visible, each producing great numbers of spores. Many of the young shoots perish, and the berries are poor or worthless. The severity of the disease depends somewhat on the weather, but there is very little cessation until the dry season sets in. The spores are produced in great abundance in the orange-red spots, and are carried by the wind or insects to the young leaves where they germinate within about twelve hours and penetrate the leaves through the stomata. The young leaves, being much more tender and retaining moisture on the surface much longer than the older ones, are much more susceptible to the attacks of the fungus. It is said that each spot will give rise to about 159,000 spores per day, and that as many as 60 or 70 spots will be borne on a single leaf. It is claimed that the spores from the fallen leaves will not germinate, and therefore their removal will not be of any consequence in checking the ravages of the disease. The spores are said to be easily killed by spraying with tobacco water and Bordeaux.[1]

The disease is very widely distributed throughout the coffee-growing regions of the old world, having been reported from Burma, Ceylon, India, Tonkin, China, Coorg, Malay, Phillipines, Natal, Transvaal, East Africa, Malacca, Sumatra, Java, Fiji, Singapore, Samoa, Mauritius, Madagascar. It has also been reported from some of the American tropics, but the writer is reason-

[1] This fungus is sometimes attacked by another fungus, *Aspergillis* sp., and also by the larva of some insect.

ably satisfied that it does not exist in the Western Hemisphere, but that it has been confused with the disease which will be considered next. This fungus also grows upon many other plants, but has not been reported on the wild *Coffea arabica* or *C. liberica* in their native habitat, and it is therefore supposed to have originated on some jungle plant not native to the original home of the coffee and passed to the coffee upon its introduction into the home of fungus.

The *Gardeners' Chronicle* (6th March 1909, p. 153) says:

> A new species discovered growing wild on the shores of the Oubanghi, Central Africa, by Mr. Dyboneski, and named *C. congensis*, which has been grown since 1903 in the botanical garden at Ivoloina, has so far remained free from disease (*Hemileia*). Its market value is said to be fully equal to that of the best qualities of Arabian coffee. While the present crop of *C. congensis* has not suffered from the disease, *C. arabica*, planted at the same time, has been entirely destroyed.

Mancha de Hierro or Viruela.—This is sometimes called the American coffee disease, and is due to the fungus *Sphaerostilbe flavida*,[1] Massee. *Mancha de Hierro* is a name referring to the rusty iron colour of the spots which the fungus produces on the leaves, and "viruela" means "small-pox," and is suggestive of the appearance of the disease on the leaves of the plants. It is, without doubt, the most severe disease of the coffees in the Western Hemisphere, and rivals the *Hemileia vastatrix* of the old world for which it has sometimes been mistaken.

It appears on the leaves as scattered circular whitish spots, equally prominent on both surfaces, and about $\frac{1}{4}$ inch in diameter. The leaves soon turn yellow and fall, and sometimes the attack is so severe that the trees are defoliated within a month. In fact, the trees are often seen loaded with fruit but entirely defoliated.

On the young shoots the spots are whitish and usually elongated. They become dry, crack, and the

[1] Syn. *Pistillina flavida*, Speg.

fragments of bark break away in flakes, leaving the brown wood exposed. On the berries these spots are usually whitish and almost circular.

In fruiting (conidial form) the fungus produces yellowish pin-like structures which stand at right angles to the surface and bear the conidiophores. This fungus was first described by Cooke as *Stilbum flavidum*, with *Stilbella flavida*, Lindau, as a variant. But Massee has found the perfect or ascigerous stage and described it as *Sphaerostilbe flavida*, Massee ("Coffee Disease of the New World," in *Kew Bull. Misc. Inf.* 1909, No. 8).

It is frequently confused with mancha, which is due to a small moth, *Cemiostoma coffeella*, and which is distributed throughout the greater part, and possibly all of the coffee-growing countries of America. The disease also occurs on other plants than the coffee, and this increases the difficulty in controlling it. It has been reported from Central America, Colombia, Venezuela, Dutch Guiana, Brazil, Porto Rico, Dominica, Mexico, Trinidad, and Jamaica.

This disease is most destructive where the shade is excessive, and the removal of the excessive shade growths so as to allow access of sunlight and air is the only practical remedy. Cutting out and burning of the diseased parts and spraying with Bordeaux mixture will prove helpful if the conditions are such as to make this treatment profitable.

Leaf Spots.—The most important of these diseases is one due to *Cercospora coffeicola*,[1] B. & C., which attacks the leaves and fruits (Figs. 33, 68, 69), causing large blotches, which at first are visible only on the upper surface. They are dark brown at first becoming greyish above and clear below. The centres of these blotches become dead and bear the spores. It causes the leaves to fall, thus reducing the vitality of the plant and preventing the proper maturity of the berries. It attacks the twigs and also the berries which fall before

[1] *Ramularia goeldiana*, Sacc., which has been reported from Brazil, is probably the same as *C. coffeicola*.

ripening. In some countries it is said to be very destructive, while in others it causes very slight damage.

FIG. 68.—Coffee leaves affected with leaf spots, *Cercospora coffeicola.* (After Cook and Horne, Bul. 3, *Estación Central Agronomica de Cuba.*)

It has been reported from the Dutch East Indies, Mexico, Cuba, Jamaica, Trinidad, and Brazil, and probably occurs in many other coffee-growing countries.

The disease can be controlled by Bordeaux mixture, but the profitableness of this treatment will depend on the seriousness of the attack, the price of labour, etc.

Another leaf disease, which is known as the "brown-eyed disease,"[1] has been reported from Brazil, Guade-

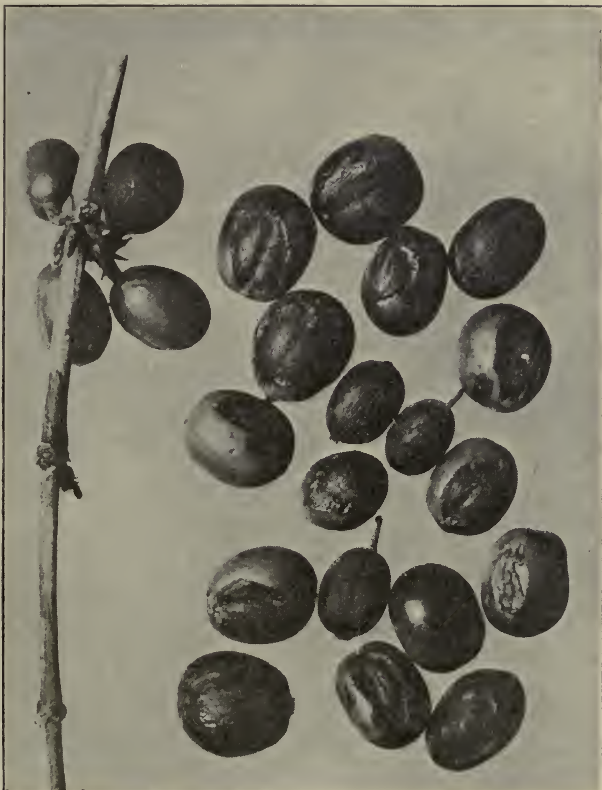

FIG. 69.—Coffee berries affected with spot, *Cercospora coffeicola*. (After Cook and Horne, Bul. 3, *Estación Central Agronomica de Cuba.*)

loupe, Jamaica, Gautemala, Cuba, and Hawaii, but probably has a much wider distribution. It has been described as follows by Noack, who made his studies in Brazil :—

The disease produced by this fungus is called the brown-

[1] This disease may be the same as *C. coffeicola*.

eyed disease on account of the brown spots formed on the leaves. As a rule these are round or oval, on the lower surface clear brown, on the upper surface dark brown. In the centre the spots are lighter in colour and greyish. The margin is sharply defined on the upper surface, dark brown or reddish, generally slightly raised, the surface often marked by fine concentric striae. Frequently several spots unite. The nerves of the leaves do not prevent their spreading. The average diameter of the spots at the centre of the leaf is one-fifth of an inch. The largest are about one-third of an inch. If a leaf is badly affected it appears more or less brown. The formation of the spots begins on the upper surface of the leaves. The spots are at first without a sharp marginal line and are scarcely visible on the under surface. The fungus not only occurs on the leaves, but on the half-formed cherry little dark spots appear which multiply and spread until finally about half the cherry becomes brown and dried.

There are other leaf-spot fungi which cause more or less trouble in different localities. In most cases these diseases are not of sufficient importance to cause serious loss, and so attract little or no attention. Among the most important is *Colletotrichum coffeanum*, Noack. It has been reported from Porto Rico, but apparently does very little damage. *Gloeosporium coffeanum*, Delacroix, has been reported from Reunion and Madagascar. *Anthostomella coffeae*, Delacroix, *Hendersonia coffeae*, Delacroix, and *Rhabdospora coffeae*, Delacroix, have been reported from Mexico.

Leaf Rot or Black Rot.—This disease was first reported from India but is now prevalent in Jamaica, Trinidad, Venezuela, and Porto Rico. It is due to a fungus, *Pellicularia koleroga*,[1] Cooke, which grows on the surface of the stems, leaves, and berries, but does not penetrate. At first it appears as a smooth, thin, whitish film which spreads, finally covering the new parts with a slimy, gelatinous substance, causing the leaves and berries to turn black, rot, and fall. The berries frequently fall in clusters. No remedy has been

[1] Cooke says that *Erysiphe scandens* of Venezuela is the same as *P. koleroga*. The same or a very similar disease in Venezuela is known by the common name of "Candelillo."

reported for this disease, but it can doubtless be held in check to some extent by the burning of diseased parts and the use of Bordeaux mixture.

Capnodium coffeae,[1] Pat., in Martinique, Venezuela, and Ecuador, and *C. braziliense* in Puttem, Brazil, are somewhat similar in their general appearance to *P. koleroga*, but are not so severe. As stated in other connections the *Capnodiums* are not parasitic on the plants but live saprophytically on the excretions of insects.

Stem Disease.—This disease is due to *Necator decretus*, Massee, which is one of the imperfect fungi. It is an internal parasite, which bursts through the epidermus of the young shoots, producing minute eye-like reddish or orange-coloured spots, which soon become gelatinous. The spores are produced in these gelatinous spots. The disease usually starts at the tips of the shoots and works downward. It has been reported from Singapore, Malacca, and the Straits Settlements. The only satisfactory remedy is to prune and burn the diseased parts. It also attacks the tea.

Another stem disease, which also attacks the fruit is due to *Corticium javanicum*, Zimm. It is a serious disease in the East Indies and Java. This fungus also attacks tea, cacao, and the Para and Castilloa rubber plants (see page 64).

Another stem disease has been reported from Jamaica, Natal, and Java. It is a bark canker and is said to be caused by *Rostrella coffeae*. Although widely distributed it is not a serious pest. It causes the leaves to wilt and become yellow, the young bark to become brown and the tissues brown or black. It is a wound parasite and is more severe on the young than on the old growths. It travels in both directions from the point of attack. All diseased parts should be cut and burned and the wounds painted to prevent new infections.

Another bark canker of the stems is caused by

[1] *Triposporium Garrneri.*

Nectria ditissima, Tull., which also attacks tea, etc. (see page 46).

Foot Disease.—A foot disease, due to *Euryachora liberica*, Oud., has been reported from Java. It attacks the base of the tree, producing a stroma just beneath the bark which eventually causes a splitting of the bark. The diseased plants should be dug out and burned, and new plants should not be set in the place from which the old ones were dug.

Root Diseases.—There are, no doubt, a number of root diseases, which are frequently referred to in the literature, but which are very imperfectly understood. However, it appears to the writer that many of these diseases have their origin in the saprophytic fungi, which develop on the decaying roots of other trees and then spread to the coffee, on which they become parasitic. At least one of these root parasites has been determined as *Irpex flavus*, Klotsch, which is one of the Hydraceous fungi. It has been reported from Malacca.

Another of these root diseases is known as the leaf blight, although it is quite different from that class of diseases usually referred to as leaf blights. It is known in Porto Rico, and is due to a fungus (*Sclerotium*) which attacks the roots, causing a decay. It gradually ascends the trunk, forming brownish or black mycelial threads, and later a thick mass over the surface of the leaves. The base of the leaf turns brown.

Another root disease which has been reported from Guatemala is due to a fungus which has been described by D'Herelle as *Phothora vastatrix.* The mycelium penetrates and clogs the sieve tubes, destroys the cambium, spreads upwards, and finally causes the death of the tree. The disease is at first detected by a cracking of the bark near the ground. The exposed wood is black and the disease at this time can usually be traced three or four feet above the ground. The disease may run for two years before the plant dies. After the death of the plant, the perithecia can be found beneath the dead bark. This disease also attacks trees used for coffee shade (Cuxil and Pateno). Free liming of the soil and planting and pruning to permit free circulation of air and sunlight have been recommended.

Delacroix reports another root disease from Guadeloupe. He believes it to be due to either *Dematophora* sp. or to *Rosellinia* sp. An undetermined species of *Helosis* has been reported from Sumatra.

The so-called **Tap Root** disease is not caused by fungi, but is due to Nematodes. The symptoms vary with the age of the trees. On old trees the leaves and young twigs turn yellowish-green and shrivel, the young shoots blacken and wilt. This may last for many months before the death of the plant. Trees four to six years of age may have a healthy appearance and suddenly collapse. The tap-roots are much swollen, the bark is thick and water-soaked. The worms are in the cork cells. The small roots are irregular and knotty. Saprophytic fungi are usually present, especially if the trees have been diseased for some time. The trees rarely recover. The disease has been reported from various parts of the West Indies, Central and South America, and Java, and is, no doubt, very widely distributed in the Western Hemisphere. However, it may very readily be confused with diseases which are due to other causes.

Other fungi which are reported as occurring on the coffee are: *Polyporus flavus*, on the roots in Guatemala; *Phyllosticta coffeicola*, Speg.; *Coniothyrium coffeae*, *Colletotrichum incarnatum*, Zimm.; and *Cephaleuros virescens*, Kunze, is said to attack the Liberian coffee.

Parasitic Phanerogams.—Coffee is subject to the attacks of phanerogams which are more or less similar in their character and mode of attack to the mistletoes. Some of the most common are:—

Loranthus orinocensis, Spr.
Loranthus avicularis, Mart. } in Venezuela.
Loranthus parviflorus, See.
Loranthus brasiliensis in Brazil.

Loranthus pentandrus in India.
Struthanthus marginatus, Desr.
Phoradendron crassifolium, (Pohl.) Eichl.

TEA

Grey Blight.—This disease is due to the fungus *Pestalozzia guepini*,[1] Desmaz. This very destructive and most common fungus blight first appears as small greyish spots on the upper surface of the older leaves, which increase in size and finally coalesce, thus forming large irregular blotches which frequently cover the greater part of the leaf. The blotches are grey, bounded by a dark line, and when mature are sprinkled with black fruiting bodies. The leaves finally assume a blistered or swollen appearance, and eventually the cuticle over these blisters bursts, usually forming a triangular figure Y and allowing the greater number of conidia to escape. The spores are carried by the wind, and for that reason frequently start on one side and gradually spread over the entire plant. The disease frequently starts on one side of a number of plants in a definite area, and gradually spreads in the direction of the prevailing winds. The fungus may attack the petiole or base of the leaf, causing it to turn brown and fall without showing the distinctive character of the disease. It sometimes causes an epidemic, and at other times attacks only the weakened plants. It is most severe on poorly-drained sour land, and its spread is facilitated by the presence of the red spider. The disease has been reported from Europe, United States, India, Assam, Ceylon, New Zealand, Australia, and other places. It is probably very widely distributed throughout the tea-growing countries. It also attacks *Camellia* and *Rhododendron* in India, *Citrus* and *Magnolia* in the United States, *Niphoblous* in New Zealand, and *Amphitomia* in Queensland. The most

[1] *Pestalozzia guepini*, Desmaz. Synonyms—*Pestalozzia inquinans*, Karst.; *Pestalozzia camelliae*, Pass.; *Coryneum camelliae*, Mass.; *Hendersonia theicola*, Cke.

satisfactory remedy is to cut and burn the affected parts as soon as the disease appears.

A leaf spot very closely resembling the grey blight is caused by *Guignardia thea*, Bernard.

Pestalozzia palmarum, Cooke, is a disease of the Coco-nut which is said to attack the tea.

Brown Blight.—This disease is due to the fungus *Colletotrichum camelliae*, Massee, and is especially severe in the seed gardens. It originates on the upper surface of the leaf, as yellowish brown spots which gradually increase in size, often extending to the edge of the leaf. When the leaf is held to the light a yellowish band is seen round the affected area, due to the spreading of the mycelium into the healthy tissues area of the leaf, which loses its green colour. The central parts of the spots often break out leaving ragged perforations. The fungus produces the characteristic Colletotrichum spores, which are readily carried by the wind.

This disease has been reported from Ceylon, Assam, and South India. It has no doubt frequently been confused with the grey blight, and since it attacks the younger parts of the plant, some planters have been inclined to look upon it as being more severe. This disease should be treated in the same manner as the grey blight. A very fine spray of Bordeaux mixture will also prove advantageous.

Rim Blight or Marginal Corrosion.—This is a combination of the grey and the brown blights, and is much more severe than either of the above. It causes the leaves to shrivel and turn brown, beginning at the edges. It should be treated as recommended for the grey and brown blights.

Blister Blight or White Blister.—This disease has been reported from India. It has been described by Watt and Mann as follows :—

It first appears as a minute pale brown or pinkish spot on the upper surface of the leaf. This enlarges in size, mostly in a perfectly circular manner, gradually becomes depressed into a pit about the size to admit the tip of the little finger, is smooth, polished, and glistening, as if coated with honey-dew. On the under side of the leaf there is a corresponding swelling which is pure white, woolly, and soft, but quite dry. As it advances, numerous blisters appear on the same leaf and even coalesce into large patches. They also occur on the young shoots, and cause much destruction of the stalk. In time the blisters change colour, become brown, and ultimately black. The shoots next wither, and the entire block of tea may then look, in May or June, as if the blast from a furnace had passed over it and killed every shoot and leaf.

The disease is caused by *Exobasidium vexans*, Massee, a fungus whose delicate mycelium penetrates the cells of the diseased parts, and after growing for some time, concentrates at the points where the blisters are formed, breaks through the surface and produces the abundance of two-celled conidia spores, thus causing the white, woolly, and soft character previously mentioned. The minute oval basidiospores are produced later and in pairs. It spreads from the leaves to the young stems, which it frequently girdles and kills. It is said to be most abundant on the unpruned plants. All plants should be carefully pruned, and the prunings and diseased parts burned. Spraying with Bordeaux mixture will undoubtedly prove helpful, but since it discolours the foliage it cannot be used near picking time. In spraying, great care should be used to spray the under surface of the leaves.

Shot Hole.—This disease is due to *Cercospora*, sp., and has been reported from India. It appears on the older leaves, causing small, brown, circular spots which resemble the injuries of the mosquito blight. It has not proved serious.

Black Fungi, and Soot Blight.—Black masses of fungi are frequently found on the surface of the leaves, especially those near citrus groves, or near the jungles. The most common of these soot blights is *Capnodium footii*, Berkeley and Desmaz., which lives on the secretions of certain scale insects. It is purely saprophytic, and its only injuries are due to interference with the physiological activities of the plant.

Thread Blight or Wither Blight.—This disease is caused by *Stilbum nanum*, Massee, and is one of the most destructive of the diseases of the tea. It kills the branches and frequently the entire tree. It is due to the fungus which grows both internally and externally. Internally it is at first most abundant in the cambium, but later passes inward to the tracheary tissues, causing the wood to turn brown. The mycelia also grow outward through the bark and spread over the surface, forming a sterile, felted mass which is most abundant on the under side of the branches and leaves. Near the margin of these patches it breaks up into irregular branched slender strands, many of them not thicker than a common thread. It is these small threads that pass to the leaves, forming a very delicate pattern. The fungus rarely forms fruit, and then only on old rotten branches which have fallen to the ground. The fruit is in the form of small pin-like structures of a pale yellow colour; they are numerous and very small, and give the appearance of a velvety or hairy mass. Since it produces only conidia spores, it is possible that it may be the conidial stage of some higher fungus. It is probable that this fungus, like many others, travels underground from plant to plant, and enters the host through the roots. It is quite common and destructive in India. This disease also attacks the mango, the sapodilla plum (*Acleras sapota*), and many other plants both cultivated and wild. The diseased parts should be cut and burned; trenches may be dug and limed to prevent the underground spread of the fungus. The use of Bordeaux mixture is also said to have given good results in checking the fungus.

Copper Blight.—This disease, which is due to *Laestadia theae*, has been reported from India. It attacks the older leaves, causing irregular copper-coloured spots on the upper surface which finally cover the entire leaf, and give a copper colour to both surfaces. In its advanced stages, the pycnidia appear as very small black spots. Removal and burning of diseased leaves and spraying with

Bordeaux mixture have been suggested as possible remedies.

Leaf Felt.—This disease has been reported as attacking the leaves of *Thea assamica* in Java. It is due to a fungus, *Hypochnus theae*, Bernard, which appears as a thin slightly reddish mass of mycelium on the twigs and under sides of the leaves. It is not a true parasite, but when abundant interferes with the physiological functions of the plant. It can be controlled by spraying with Bordeaux mixture.

Red Rust, White Blight, or "Leprosy."—This is one of the most widely distributed and most destructive diseases of the tea. It is due to a lichen *Cephaleurus mycoidea*,[1] Karsten, which occurs on both stems and leaves attacked, and produces spores by which it spreads to other plants. When the fungal element unites with the alga, it produces a true lichen containing the ascigerus fruit. It penetrates the stems of the diseased plants and proves very destructive. This disease also occurs on *Camellia japonica*, *Cinnamomum iners*, *Colathea metallica*, *Pandanus* sp., *Albizzia stipulata*, *Tephrosia candida*, and many other plants.

A very similar disease has been described by Ward,[2] who believes that it may be the same as or closely related to *Cephaleurus mycoidea*. It attacks plants with hard persistent leaves such as *Coffeae liberica*, *Ixora* sp., *Thea* sp., *Memecylon* sp., *Eugenia* sp., *Anona* sp., *Elaeagnus* sp., *Magnolia* sp., *Citrus* sp., *Duria* sp., *Sideroxylon* sp., *Quassia* sp., and *Michelia* sp., in which it produces orange-red circular or stellate patches which become green or grey-greenish, then whitish or grey and finally glistening white, shining circular or irregular branched groups. Eventually the fruiting bodies appear in these greyish patches as

[1] Synonyms—*Mycoidea parasitica*, Cunningham; *Cephaleurus virescens*, Kunze.

[2] H. Marshall Ward, "On the Structure, Development, and Life-history of a Tropical Epiphyllus Lichen." (*Strigula complanata*, Fée, *fide* Rev. J. M. Crombie). *Trans. Lond. Linn. Soc.* (2nd. ser.) *Botany* (1881, 1887), vol. lxxxviii. pp. 87-119.

black dots. The alga appears first, causing the red spots referred to above. It makes a depression in the leaf but does not penetrate the epidermis, as is said to be the case with *Cephaleurus mycoidea*. It reproduces by means of zoospores, which are especially abundant in the rainy season.

In its second stage the alga is attacked by a fungus, which results in the death of the alga if young, but if well advanced, in the formation of a lichen. It fruits abundantly by means of conidia, pycnidia, and perithecia. In the lichen stage it becomes fused with the cuticle of the host plant, and in some cases pierces the cuticle, but it cannot be considered strictly parasitic. Its greatest injury is due to the reduction of light, and thus the interference with the physiological activities of the host plant.

The injuries may be reduced by proper drainage of the land, and fertilization, and by cutting and burning the diseased parts. The dead wood should not be allowed to remain on the plant. *C. minimus*, Karsten, is a similar organism which attacks and causes considerable injury to *Zizyphus jujuba*.

Canker.—This disease is caused by the fungus *Nectria ditissima* which lives just below the bark of the stems. It gains entrance through wounds and spreads in both directions from the point of attack, finally coming to the surface through ruptures in the bark and producing an abundance of spores which are carried by the wind and by insects. This disease is well known in various parts of the world, attacking the apple, the cocoa, the coffee, and the cinchona. All diseased parts should be cut and burned, and all wounds should be painted with tar, white lead, or other disinfectant.

Horse-Hair Blight.—This is a fungus disease caused by *Marasmius sarmentosus*, Berk. It has been reported from India, where it also attacks the *Terminalia tomentosa* and other jungle trees. The plants become covered with masses of fungi which resemble horse hair.

M. rotalis, another of these horse-hair blights, occurs on tea, nutmeg, and cocoa (see page 65).

Darjeeling Stem Blight.—This disease, which is very imperfectly understood, is referred to by Watt and Mann as follows :—

In the higher parts of the Darjeeling district there will be noticed in almost every garden, a number of bushes dying from the centre, apparently without reason. It has never been noticed below 4000 feet, and appears often in isolated bushes all over the property. In some gardens it is one of the most serious blights on the place. On cutting one of the stems which is dying the centre of the wood appears to be turning black, and this appearance, we are informed by Dr. Butler, is due to a fungus attacking the stem. It demands much more investigation, however, before it can be named, or a remedy recommended with any certainty. In the meantime, all that can be done is to cut out the stems affected below the part discoloured, and paint the stump with Stockholm tar. This is one of the blights which most urgently demand further investigation.

Internal Stem Disease.—This disease has been reported from India, and has been described by Petch under the name of *Massaria theicola.* The disease may cause the death of a part or of the entire tree, and may be very slow or very rapid. The diseased plants have very much the appearance of suffering from drought. The fungus usually attacks the tree some distance above the ground, and may work both upward and downward. It is very probable that it enters the host plants through wounds. It is strictly an internal parasite, does not attack the roots, does not cause a decay of the wood, and is most severe in dry weather. Petch's description is as follows :—

If the bark over this discoloured wood is lightly scraped, it will be found to be quite black internally, and if very thin layers are cut off, minute white circular patches may be detected with the help of a hand-lens. These white patches are the contents of the perithecia, the fructification of the fungus.

The fungus lives almost entirely in the wood of the bush, only fructification being formed in the bark. The hyphae are violet, black when fresh, and are the discoloration already noted. They advance along the vessels of the wood, and, as these are the channels by which the water ascends, the hyphae stop the supply of water either by filling the tubes or by perforating the cross walls.

In most respects, this disease bears a close resemblance to the "Internal root rot" of Assam. This attacked young bushes, usually not until after the first pruning. There was nothing externally to indicate the cause of death. The leaves of the plants took on a yellow appearance in which the network of the veins was very prominently seen, and they then began to die off branch by branch. Though the effects are exactly the same, the fungus is said to be different from the Ceylon species. The latter is an ascigerous fungus *Massaria theicola,* while the former is *Diplodia vasinfecta*, a non-ascigerous species.

All diseased parts should be pruned and burned, and the wounds painted with tar or other protective substance. If the attack is severe, the stems should be painted or sprayed thoroughly with Bordeaux mixture.

Bark Disease.—*Corticium Zimmermanii*, Sacc. & Syd., and *C. javanicum*, Zimm., are the causes of severe bark diseases (see page 64).

Root or Stump Fungus.—There are a great many fungi which cause diseases of the roots of tea and other plants. Two or more species of *Rosellinia* have been reported from India and Ceylon, one of which is *R. bunodes*, and another is probably *R. radiciperda*, Massee, attacking the tea, camphor, and other plants. They are most abundant on recently cleared forest land. The leaves of the diseased plants wither and turn brown and the tree gradually dies within about two weeks. Examination of the roots will show them to be covered with a brown incrustation, under which will be found the delicate, white mycelial threads of the fungus. The hyphae penetrate the cortex and form white, star-shaped growths on the wood. When the tree is dead the mycelium appears above the ground and covers the lower part of the stem with a black velvety coating and produces millions of conidia spores. It is doubtful if this fungus can germinate on a living root, but after starting on decaying material it can readily spread to the living tissues. The destruction of stumps, roots, and decaying material in general will be helpful in controlling this disease. Trenching and liming are also said to be helpful. Young plants should never be set where others have died from this disease.

Since writing the above Petch has reported *R. bothrina* as occurring on tea and other plants in India. It spreads from the roots and stumps and frequently will not grow on related plants.

Internal Root Rot.—This disease has been reported from Assam, and is due to *Diplodia vasinfecta*, Petch. Like most root diseases, it first attracts attention by a discoloration of the leaves, which become yellow and fall, followed by the death of the tree. The fungus lives within the roots and seldom comes to the surface. The fruits are rarely formed. It is supposed to be carried by the seeds.

Up-Country Root Disease.—This disease has been reported from India, and is due to *Poria hypolateritia*, Berk. Petch describes it as follows:—

> This fructification forms a white or pinkish patch, studded with minute holes, extending for several inches over the stems, or even surface of the soil. Beneath the comparatively soft white tissues is a red horny layer which gives the fungus its distinctive name. This red layer is often formed inside decaying stumps, and may be taken as a sure sign of the presence of this fungus when no real fructification is to be found. This fungus appears to be common on dead logs in the up-country jungles.

Low-Country Root Disease.—This disease has been reported from India, and is due to an undescribed species of *Ustulina*.[1] The mycelium works between the wood and the bark, forming white or yellowish fan-shaped patches which become black on the edge when they come in contact with a crack in the bark. A cross section of the root shows numerous irregular black lines. The sporophores are formed on the lower part of the trunk and protrude from cracks in the bark. They

[1] This is probably *U. zonata*, a fungus which also occurs on pomolo and coco-nut, although it is probably saprophytic on the latter.

originate as white swollen cushions, and spread over the surface as flattened plates. When mature, these plates are grey in colour, concentrically zoned, and marked with minute black dots. They lie close to the stem, and are attacked at one point only, the point of origin. The under surface is black, and the entire structure is hard and brittle. Two kinds of spores are produced.

Other Root Diseases. — *Hymenochaete noxia* and *Botryodiplodia theobromae* are also the causes of important root diseases. There are also many other root diseases which are imperfectly understood, among which is the white root, said to be caused by an undetermined species of *Polyporus*.

Other Diseases. — Other fungi which have been reported on the tea are—

ON LEAVES—

Pestalozzia palmarum, Cooke.
Hendersonia theicola, Cooke.
Septoria theae, Cavara.
Cercospora theae, Van Breda.
Discosia, Cavara.
Phyllosticta, Speschnew.
Macrophoma, Speschnew.
Helminthosporium theae, Bernard.
Guignardia theae, Bernard.
Stilbellum theae, Bernard.
Macrosporium commune, Raban.
Pleospora theae, Speschnew.
Coleroa venturioides, Speschnew.
Chaetophoma Penzigi, Sacc.
Venturia Speschnewii, Sacc.
Gloesporium theae, Zimm.
Gloesporium thea-sinensis, Minyake.

ON STEM—

Stilbum nanum, Massee.
Corticium javanicum, Zimm.
Corticium theae.
Necator decretus, Massee.

ON ROOTS—

Trametes theae, Zimm.
Dematophora necatrix, Berlese.
Protomyces theae, Zimm.
Hymenochaetae sp. (probably *H. noxia*).
Rosellinia bothrina, Petch.

Loranthus.—This plant has been reported as severe in the gardens in India. Its general character, behaviour, and the results of its attacks are very similar to the mistletoe. The diseased branches should be cut off and the wounds painted.

Lichens and Mosses.—These are very troublesome where the drainage is poor and the shade too dense. They not only interfere with the growth of the plants, but furnish a harbour for insects. The gardens should be carefully drained, and the plants so cared for as to give free circulation of air.

Nematodes.—These pests attack the tea and are very destructive, especially on the seedlings. The nature of the disease is practically the same as that on other plants.

CACAO

Brown Rot.—This disease has been attributed to a number of organisms, but according to the latest authority it is due to *Thyridaria tarda*,[1] Bancroft. It originates as a circular brown patch on the pod, usually at the ends or along one of the grooves, but most frequently at the basal end. It spreads rapidly, and the pod turns brown and rots. The rapidity of the spread depends on the ripeness of the fruit, which usually falls in from six to ten days from date of the first attack. When the spots are about the size of a penny, small circular wounds are seen near the centre which give rise to the greyish brown mycelium.

The fungus enters wounds with great readiness, and bruised fruits are much more susceptible than the healthy ones. It is usually very abundant on the old

[1] *Botryodiplodia theobromae*, Pat. (1892); *Macrophoma vestita*, Prill et Del. (1894); *Diplodia cacaoicola*, P. Henn. (1895); *Lasiodiplodia nigra*, Appel and Laub. (1896); *Lasiodiplodia theobromae*, (Pat.) Grill and Maubl. (1909); *Diplodia rapax*, Massee (1909); *Botryodiplodia elasticae*, Petch (1910); *Thyridaria tarda*, Bancroft (1911).

Jonge and Drost report that this organism in culture produces *Diplodia*, *Lasiodiplodia*, or *Chaetodiplodia* characters, dependent upon circumstances, and conclude that the generic name *Diplodia* should be maintained.

According to Bancroft, the ascigerous stage which occurs on dead wood determines the fungus as *Thyridaria tarda*, and the two pycnidial stages should be known as *Diplodia* and *Cytospora*.

hulls of the breaking-ground, and sometimes spreads to the beans, which it completely destroys. All diseased fruits, the old husks, and also the prunings should be burned or buried in order to prevent the spread of the disease.

The disease is now known in Jamaica, St. Lucia, Vincent, Martinique, Granada, Trinidad, Barbadoes, St. Thomé, Ecuador, San Domingo, Brazil, West Africa, Cameroons, French Congo, East Federated Malay States, East Indies, Ceylon, Java, and the Philippines. It also attacks the Para rubber, mango, papaw, tea, sugar-cane, and many other tropical plants.

In Trinidad it is said to be associated with *Nectria theobromae*, Massee, and this may also be true in other places. A similar disease is said to occur in Brazil, but may prove to be identical. This disease should not be confused with the rusty or mahogany colour of the fruits, which is said to be due to thrip injuries, but which does not penetrate beyond the rind.

Dieback.—This disease is due to the same fungus as the brown rot. It causes the young twigs, and frequently the larger branches, to die in both directions from the point of infection. The first evidence of the disease is in the dying of the tip, but the disease continues to work backward, and may eventually reach the trunk. The progress of the disease on the trunk is accompanied by the death of other branches due to the interference of the fungus with the conduction of water. New shoots are put out back of the disease, and in case the disease is checked by natural or other causes one of these shoots may produce a branch. Although infection usually occurs in the branches, the trunk and lateral roots may also serve as points of infection. When several of the top branches are infected the disease is frequently spoken of as "stag head," but this condition may be due to other causes. The progress of the disease depends upon the general health of the trees and the care to which they have been subjected. When the progress is slow cankers are frequently formed. In young plants the main shoot is frequently affected and the tree killed very quickly.

The fungus is a wound parasite, and is both parasitic and saprophytic. It is most severe on weak trees, and in low, poorly drained localities.

The diseased trees should be carefully pruned, and all wounds, from whatever cause, should be painted with tar or white lead. Burn or bury all prunings and all diseased fruits and husks. Cultivate and fertilize in such manner as will ensure healthy trees.

Scabby Pod.—This disease has been attributed to *Lasiodiplodia* sp., and may be due to *Lasiodiplodia theobromae.* It appears in the form of small, irregular, scabby, brownish black corky areas over the surface of the fruit. Microscopic examination reveals the presence of the mycelium just beneath the surface. Both the pods and the beans are small, and the beans of a very poor quality. This disease has been reported from Granada, Surinam, and Dominica, but is said to do very little damage.

Witches' Brooms.—The so-called witches' brooms are malformations which may be due to many causes. They are more or less common on both forest and cultivated trees in many parts of the world, and are known by the Dutch names of "Krullotemplaag," "Heksenbezems," and "Hexsennestens," by the German names of "Hexenbesen" and "Donnerbesen," by the French names of "Balais de Sorcières," and by the English names of "witches' brooms" and "bird nests." They may be caused by the insects *Eriophyes* (*Phytoptus*) or by any one of several species of fungi.

A very severe and destructive witches' broom has been reported from Surinam, British Guiana, Trinidad, and Demerara. It causes the formation of bunches of twigs which are very much enlarged and very knotty, and often show strongly marked longitudinal furrows at the base. The lateral branches are abundant, short, and thick, and grow vertically. The leaves are usually small, soft, and pliable. The flowers are numerous, in masses, frequently abnormal, and many of the pedicles give off branches which become vegetative in character and take the form of small witches' brooms. This entire structure dies quickly, the vitality and productiveness is reduced, and if the disease is severe the tree dies. The fruits also suffer from this disease, which attacks them when young, causing the diseased areas to become hard and swollen, and eventually to blacken. The diseased pods rarely mature, but fall when about half-grown.

This disease has been described by Ritz. Bos as due to the fungus *Exoascus theobromae*, and later by Van Hall and Drost as due to *Colletotrichum luxificum.* It is also thought that this disease may have been confused by planters with the *Phytophthora faberi* Maub. However, all authorities agree that the only practical method for the control of this disease is the cutting and burning of these brooms as soon as observed, and the painting of the wound with tar or some other protective substance.

Another witches' broom, which is said to be due to *Taphrina bussei*, Von Faber, attacks the young shoots and leaves in Kamerun.

Cankers.—Among the most important diseases of the cacao are the cankers which are usually caused by the species of the genus *Nectria.* These cankers cause the death of all parts of the plant beyond the point of attack.

Nectrias.—Fungi belonging to the genus *Nectria* are frequently mentioned as causing diseases on the branches, fruits, and trunks of the cacao, and several species have been described. However, in many cases the writer is unable to determine from the semi-popular accounts just which is referred to. The most injurious are those which attack the stems and branches. They are very widely distributed.

Nectria cinnabarina, (Tode) Fr., of Jamaica,[1] attacks

[1] This species is not mentioned by Stockdale, one of the recent writers on the diseases of the cacao in the West Indies.

the dead and dying branches and is also parasitic. It is sometimes called the coral-spot disease. The leaves droop, become yellow, die, and fall. The mycelium is primarily in the tracheary tissue. The bark becomes shrivelled, and eventually bright red warts about the size of millet seed are produced. They are bright coral red and very conspicuous, and covered with numerous conidia spores. In time they become brown, and the surface becomes roughened with projecting points. This, or more likely another species of *Nectria*, occurs in Trinidad, Grenada, and Dominica. It causes a gummy exudation from the bark, and the underlying tissues become discoloured and soft. It is strictly a wound parasite, and girdles the stems very quickly, causing their death beyond the diseased part. Still another *Nectria* has been reported from Jamaica as having yellow perithecia.

Nectria Bainii, Massee, of Trinidad, Martinique, and Ceylon,[1] causes semicircular dark blotches on the pods, which become soft and watery at these points. A little later they are covered with yellowish rust-coloured or orange-coloured mycelia, studded with minute red perithecia. The perithecia are preceded by a small snow-white *Fusarium*-like mould, which may be the conidial stage. In some localities the natives believe this disease due to sunburn. It has not been recorded as occurring on the stems.

Nectria theobromae, Massee, and *Calonectria flavida*, Massee, both occur as the cause of stem cankers in the West Indies, Trinidad, Dominica, Martinique, St. Lucia, St. Vincent, and Granada, and may work either alone or together. They can be detected at an early stage, but cannot be distinguished one from the other; the bark becomes dry and greyish brown. It is most easily seen in the dry season just after a rain, because it does not dry so quickly as the surrounding bark, for which reason it is sometimes called the bleeding

[1] The diseases reported from these two widely separated countries may not be due to the same cause, although the descriptions correspond quite well.

disease. When cut the tissues are found to be discoloured. The bark splits and allows a brownish red gummy fluid to ooze out. This gum dries and gives the dark rusty appearance. In Dominica the disease causes an abnormal number of flowers which never set fruit, and these flowers are produced continuously throughout the year. It is sometimes known as the "flowering disease." This peculiar flowering is the first symptom in Dominica. Similar flowering is said to occur in St. Lucia, but is not so common. The cankers may occur on either the branches or the main stem. The leaves are reduced in size and yellowish. The rate of spread of the patch varies, and it frequently girdles the branches and sometimes the trunk near the ground. In severe cases the wood becomes dark brown, but is said not to be affected with mycelium to any great depth.

It fruits most abundantly in the rainy season by white pustules, which push through the minute cracks, burst, and liberate the spores. In the perithecial stages it is very easy to separate the two organisms. The perithecia of *Calonectria flavida*, Massee, are yellow in colour, while the perithecia of *Nectria theobromae*, Massee, are red in colour.

The *Nectrias* are wound parasites and are much more common on the old than on the young trees. In fact, they are said not to attack trees younger than six years. They are worse in the shade than in the open. Their life history is not well understood.[1]

Stem cankers are quite common in Barbadoes, but the writer has been unable to find a satisfactory explanation of their cause. They are probably due to some of the *Nectrias*.

An undetermined species of *Nectria* in Ceylon attacks both bark and pods, causing the pods to blacken, become dry, and shrivel when about two or three inches long. Petch has recently said that the stem canker in this case is due to a different species of *Nectria* from the one on

[1] Recent investigations indicate that the primary cause of cankers on cacao and Para rubber is *Phytophthora faberi*, and that the *Nectrias* associated with these cankers are secondary fungi, chiefly saprophytic in nature.

the pods. He also states that the one on the stem agrees with *Nectria striatospora*, Zimm.

Nectria ditissima, Tull., which also occurs on the tea, has been reported on the cacao in Ceylon; Zimmerman has recorded *N. coffeicola* and *N. striatospora*, Zimm., on cacao stems, and *Calonectria cremea* on cacao pods in Java; *C. bahiensis*, Hempel, occur on the cacao stems in South America; *Chaetodiplodia* sp., occurs on twigs of cacao in Surinam; and *Fusarium album*, Sacc., which is ordinarily considered a saprophyte, may prove to be a wound parasite.

Van Hall and De Jonge have reported a canker disease from Surinam, due to a fungus, which they have described under the name of *Spicaria colorans*. It is said to be similar in many respects to the *Nectria* cankers which occur in Ceylon and Java.

Nectria camerunensis, Appel and Strunp, and *N. iungeri*, P. Henn., has been reported on the fruits of cacao in Kamerun.

The methods of treatment of the *Nectria* cankers have been the subject of considerable discussion, but it is very evident that the most satisfactory treatments are those which prevent the spread of the fungi. All dead trees should be cut and burned, and all dead and diseased parts of living trees should be cut and burned and the wounds painted with white lead or tar. All diseased pods should be burned or buried. The trees should also be pruned so as to admit free aeration and sunlight.

Pink Disease.—This disease is due to the fungus *Corticium lilaco-fuscum*, Berk. and Curt., which attacks the younger branches, covering them with a pinkish incrustation of hyphae. It spreads over the surface and penetrates the bark, causing it to crack and peel. A new bark is formed beneath the old bark. However, this new bark is tender and more susceptible to attacks from species of *Diplodia*, *Nectria*, and other fungi. The pink disease itself is not considered serious, but its greatest damage lies in that it facilitates the inroads of other and more dangerous organisms. It has been reported from Dominica and St. Lucia.

It is much more severe in damp, shady places than in the open, and under conditions of excessive moisture it sometimes attacks the larger branches. Proper drainage and the reduction of the shade will usually prove an efficient remedy. The diseased parts should be cut and burned, and the wound painted with tar or white lead. Where the trees demand a more radical treatment they should be washed with a preparation made as follows :—

$7\frac{1}{2}$ lbs. slacked lime.
2 lbs. sulphur.
10 gals. water.
Boil until of a red colour and allow to cool.

Bark Disease. (*Corticium javanicum*, Zimm.).—This fungus is the cause of a bark disease which frequently kills small branches, but is not severe in the large ones. It is very similar to the disease caused by *C. lilaco-fuscum*, Berk. and Curt., and causes its greatest damage by opening up roads for other fungi which cause more severe diseases. It should be treated in the same manner as the preceding disease. It has been reported as common in Java, Ceylon, and Southern India.

Another bark disease, which is due to *Eutypa erumpens*, Massee, attacks the cacao, nutmeg, some species of *Ficus*, and other trees in Trinidad, Barbadoes, and Grenada. It is probably a wound parasite. It causes irregular black patches of stroma with a dull rough surface, in which are sunken the perithecia. On cutting into the wood below these patches will be found irregular black streaks running more or less longitudinally, and scattered, small black patches. A very similar disease of the Para rubber occurs in the Malay States, and is caused by *E. caulivora*, Massee.

Thread and Horse-Hair Blight.—This disease is due to the sterile mycelial threads of either of two species of *Marasmius*: *M. equicrinus*, Mull, and *M. rotalis*.

These mycelial threads are variously coloured, and run over the branches and stems. They are closely appressed to the bark, and sometimes spread over the leaves, forming a delicate web-work. They penetrate the host and cause the death of the leaves and buds. These diseases have been reported on cacao from Trinidad, Dominica, Tobago, and British Guiana, and on tea and nutmeg in Ceylon. The writer has seen the same or a similar disease on other hosts in Cuba, but not on the cacao.[1] It is most severe in damp, shady places, and should be treated in the same manner as the pink disease.

Another blight, which is said to be due to an undetermined species of *Crepidotus*, has been reported from some localities. The writer has been unable to find any very satisfactory information concerning it, other than that the fully developed stage can be found on twigs which have fallen and commenced to decay.

Black Rot.—This disease is caused by the fungus *Phytophthora faberi*,[1] Maub, a species which is very closely related to the *P. infestans*, the cause of late blight of the potato in the north temperate zone. The pod darkens, beginning at the end, and then becomes covered with a white mycelium which carries the conidiophores and resembles a mould. It completely destroys both rind and seed. In its last stages the fruit may fall and rot, or may harden and hang on the tree for a long time. The oospores are produced abundantly in the decaying parts, and are released by the decay. It is much more severe in shady, damp places. This fungus is also common on the seedlings.

This disease occurs on the cacao in Trinidad, Philippines, Samoa, Kamerun, Java, St. Lucia, British Guiana, Surinam, Martinique, Barbadoes, and Ceylon, and probably has a very much wider range.

The soil should be well drained, and the shade

[1] A cacao blight has been reported from the Philippines, but the writer cannot say whether it is or is not the same.

[2] Rorer believes that this fungus is also the cause of a stem canker of the cacao.

reduced. The diseased fruits should be burned. When severe it would be well to spray with Bordeaux. The first spraying should be given when the pods just set, and repeated as often as circumstances demand.

Seedling Disease.—This disease has been reported by Massee, who found it on seeds and on seedlings grown from seeds from Jamaica. It is due to a fungus *Ramularia necator*, Massee, which appears on the cotyledons soon after germination, covering them with a dense white mould, and finally killing the young plants. Since it has not been studied in the tropics its relative importance is not known. It is also reported from Dominica.

Root Diseases.—These diseases are very abundant, and have been reported from many places. They usually spread underground from tree to tree, and the roots become infested with mycelium which invades their tissues. The diseased condition of the roots becomes manifest by the appearance of the upper parts of the tree. However, the symptoms vary with different organisms and under different conditions. Usually the leaves are small and yellowish. They wilt, the branches wither, and the trees finally die. In some cases death is very rapid, and in other cases very slow. The fungus may be present on the roots a long time before the tree shows any indication of disease. Organisms other than fungi may also cause root diseases (see page 67). Comparatively little attention has been given to the root diseases caused by fungi. However, the investigations thus far have proved them to be due to *Polyporus* sp., *Hymenochaeteae* sp. (Ceylon), *Sporotrichum* sp. (Java), *Macrophoma vistita*, Prill. and Del. (in Central America), *Fomes semitostus*, Berk. (Ceylon), and there are doubtless many others.

The difficulties in treating this class of diseases are many. The organisms which cause them also attack other species and varieties of trees, both cultivated and uncultivated. Very frequently an old log or stump serves as a source of contagion from which the fungus spreads to the surrounding trees.

The only satisfactory remedies known are to clean the land thoroughly of debris of all kinds which will in any way afford suitable food material for the organisms. Dig out and burn the diseased trees and treat the soil in that place with lime, mixing thoroughly, and stirring from time to time. Dig trenches from 18 to 24 inches deep around the healthy trees, and put in lime or a mixture of lime and sulphur.

Hymenochaete noxia, Berk., is an organism which is reported as killing the cacao in many places, and also the rubber trees in Apia. It has been reported from Samoa on cacao, castilloa, bread fruits, and other trees.

Epiphytes are very abundant on the cacao and other trees. Their injuries are due to the clogging or blocking of the lenticles, and thus preventing the proper physiological activities of the trees. They also interfere with the formation of the buds, flowers, and pods. They should be removed by hand. Washing the trees with a 6 per cent copper sulphate solution or rosin compound is also advantageous, especially for the removal and prevention of lichens. Species of mistletoe and dodder are also the source of some trouble, and should be removed in order to prevent their spreading and becoming more troublesome.

There are other fungus pests of more or less importance, among which may be mentioned *Clonostachys theobromae*, Del., on the fruits in Colombia; *Acrostalagnus vulmorinii*, a fruit mould which follows the attacks of beetles; *Phytophthora Faberi*, Maubl., of tropical America; *Exoascus bussei*, Von Faber; *Colletotrichum Cradwickii*, Bancroft, from Jamaica; *C. theobromae*, Appel and Strunp, from America; *C. brachytrichum*, Del., from Trinidad; *C. theobromae*, Del., from the West Indies; *C. incarnatum*, Zimm.; *Pestalozzia* sp. A *Capnodium* has also been reported as troublesome in St. Lucia and Grenada. This pest, like others of this genus, is not parasitic on the plant, but lives in the excrement of scale insects which are common on the trees, and interferes with the normal physiological functions of the plant.

RUBBER

Cankers.—Probably the most important diseases of the rubber trees are the cankers, most of which are due to the various species of fungi which belong to the genus *Nectria.* They attack the trunk and branches, and if not controlled will kill all parts of the plant beyond the point of attack (see page 185).

Nectria.—One of the most common diseases of the trunks of the rubber trees is a *Nectria*, which is probably *N. diversispora*, Petch. It attacks the Para rubber trees of the Straits, Ceylon, and the East Indies, causing them to become very much roughened and swollen places to be formed on the branches and trunks. On peeling the bark the tissues below are found to be brownish or claret in colour. The branches lie beyond the point of injury, and the vitality of the tree is greatly reduced. Although the disease has no connection with the roots it is usually much more severe in low, poorly-drained soils than in high, well-drained land. The fruiting bodies of the fungus are pink or red in colour. They, together with the diseased parts of the tree, should be cut and burned. It has been recommended that close planting be avoided, and that *Ficus elastica* be used as wind-breaks to prevent the distribution of the disease.

N. diversispora also occurs as a saprophyte on dead fruits.

Nectria funtumia, Massee, is the cause of a canker disease of the rubber tree (*Funtumia elastica*) of Uganda. It attacks the trunk from four to six feet above ground, causing the bark to become thickened, cracked, and ragged. It has very much the appearance of the large wounds caused by the "slime flux." It also very much resembles the *Nectria* canker of the cacao in Ceylon, and is very closely allied to *N. ditissima*, Tul. In time it may even girdle the tree. It is not considered very serious. The conidial stage is a *Fusarium*.

N. coffeicola and *N. gigantospora* have been reported as attacking the Para rubber in Java.

A bark disease has been reported from the Straits and Federated Malay States (Perak), which starts at the tip and travels down, and which kills the trees in a very short time. It is evidently due to an Ascomycete, and is apparently allied to *Cucurbitaria*.

Corticium javanicum,[1] Zimm., is the cause of a serious bark disease of the branches and trunk of *Hevea Ficus* and *Castilloa*, tea and coffee in the Straits Settlements, Ceylon, Java, and Malay. It attacks the trees of all ages, but usually does not kill those above two and a half years of age. It appears as a small rosy, nearly whitish spot on the bark, and gradually extends in all directions until it girdles the affected part. As it enlarges it thickens and becomes a more vivid rose tint. The bark finally cracks and is easily crushed. It is contagious, and the diseased parts should be cut and burned. The diseased parts should not be carried from place to place, but should be burned as soon as possible. Spraying young trees with Bordeaux mixture has proved very successful.

Corticium Zimmermanii, Sacc. and Syd., is the common cause of a bark disease of the Para rubber throughout the eastern tropics. It is very similar to *C. javanicum*, Zimm., and in fact may be the same. It also attacks the orange, cacao, cinnamon, pepper, mango, ramie, tea, cinchona, and other plants. *C. calceum* is a bark disease which has been reported from the Malay Peninsula.

Fusicladium sp. is the cause of a black canker on *Hevea* in the Straits. It gains entrance to the trees through the cut ends of branches and other wounds, causes the leaves to become yellow and die, and sometimes kills

[1] This fungus has also been reported on the Manihot.

part or all of the tree. The bark cracks and peels, exposing the fungus as a blackish fur on the surface of the wood. The mycelium is brown in colour, branching, and, after killing the bark, penetrates the young wood, which soon becomes dark. It is not often serious, but it sometimes kills the tree, and frequently reduces the flow of latex. It can be controlled by cutting and burning the diseased parts, painting the wounds, and if very severe by spraying with Bordeaux mixture.

Stem Disease.—A stem disease of the Para rubber, due to *Diplodia rapax*, has been reported from the Federated Malay States. It attacks the younger shoots, causing them to turn black and die. It gradually spreads downward until the trunk becomes affected and dies. After a time many raised spots appear, and the bark splits, thus exposing the black perithecia embedded in a stroma.

Another bark disease which is caused by *Eutypa caulivora*, Massee, occurs on the Para rubber in the Malay States. It is very similar to the bark disease of the cacao and nutmeg which is caused by *E. erumpens*, Massee (see page 187).

Dieback.—This is a disease of the Para rubber which has been reported from Ceylon and the Federated Malay States, and probably occurs in other places. It is said to be due to *Thyridaria tarda*,[1] which also attacks the cacao. It causes a dying back of the young shoots which may eventually reach the trunk and roots and cause the death of the tree. Although the fungus is a wound parasite, its development is facilitated by the presence of dead wood on which it grows and produces its perfect stage. Dead stubs which are left are the result of poor pruning and topping, and the dead wood about old wounds is exceptionally favourable for its development. The diseased parts should be pruned out and burned, and the wounds should be painted with tar, white lead, or other antiseptic substance.

[1] Petch attributed the early stages of this disease to *Gloeosporium alborubrum*, and the later stages to *Botryodiplodia elasticae*, which he believed to be identical with the fungus causing the dieback of the cacao.

Asterina tenuissima, Petch, is a fungus which occurs on the fruits and stems of *Hevea* in the Straits Settlements, causing a blackening discoloration and later a great number of minute black points. It is superficial and does not do much damage.

Fruit Disease.—A species of *Phytophthora*[1] in the Straits Settlements attacks the fruits of the Para rubber, causing them to turn black. This disease and the organism which causes it are very similar to the black rot disease of the cacao, and should be treated in the same way (see page 188).

Seedling Disease.—*Pestalozzia guepini*, Desm., is the cause of a leaf disease known as the grey blight. It occurs on the leaves of mature trees of *Hevea*, but is of no importance. However, it sometimes attacks the stems of the seedlings and becomes very destructive. It has been reported from Java, Ceylon, and probably has a very much wider distribution in the eastern tropics.

Pestalozzia palmarum, Cooke, which is also a leaf parasite on the coco-nut, tea, and gutta percha, attacks the Para rubber in Java, Ceylon, and other places.

Helminthosporium hevea is a leaf-spot disease which attacks the large *Hevea* seedlings in the nursery in Ceylon and the Straits. It occurs as a small circular, semi-transparent spot bordered by a purple brown line.

A very severe seedling disease has also been reported from Borneo, but without data as to its character.

Other leaf diseases are *Phyllachora Huberi*, P. Henn., *Dothidella Ulei*, P. Henn., *Aposphaeria Ulei*, P. Henn., *Ophibolus hevea*, P. Henn., and *Parodiella melioloides*, P. Henn, on the Para rubber in Brazil, *Diplopeltis Zimmermanii*, P. Henn., *Gloeosporium brunneum*, *Colletotrichum hevea*, Zimm., *C. elasticae*, Kood and Zehn., *C. ficus*, Kood and Zehn, *Phyllosticta ramicola*, *P. hevea*, in various parts of the East Indies, but are thus far of little or no importance. However, *Gloeosporium alborubrum*, Petch, on Para rubber in the

[1] *P. faberi.*

East Indies is frequently followed by *Botryodiplodia elasticae* which may become very destructive. *Altenaria castilloae*, Zimm., and *Capnodium javanicum*, Zimm., have both been reported from the Dutch East Indies, but the latter is doubtless saprophytic on the secretions of insects.

Root Diseases.—*Fomes semitostus*, Berk., is a fungus which attacks *Hevea braziliensis* and other trees, causing a root disease which has proved very destructive, in some cases destroying as much as 40 per cent of the trees of the Malay States, Ceylon, and Straits Settlements. The roots of the dead trees become covered with white or straw-coloured masses of mycelium which also penetrate the soil and may pass from tree to tree. If the dead tree or stump be protected by a vine or other dense plant growth, the fructifications will be produced in the form of hoof-shaped or bracket fungi. These fruiting bodies are frequently four to six inches across. The upper surface is a dirty yellow or buff colour, which may be orange or maroon in the older parts. It is covered with a delicate map and marked with concentric, shallow grooves. The lower surface is orange-coloured when young, shading into brown as it grows older. It is filled with numerous very small pits which can be distinguished only by aid of a hand lens. Within these pores the spores are produced. Although parasitic the fungus will persist on the dead trees as a saprophyte.

The only satisfactory remedy that can be recommended is the complete destruction of the diseased trees by digging and burning. However, it is possible that trees may be protected to some extent by digging trenches about two feet in depth around the healthy trees, which are close to infected areas, and putting a considerable quantity of lime in the trenches. This precaution may serve to prevent infection through the soil, but would not interfere with many insects and animals which may carry the organism from the diseased or dead trees to the healthy ones.

A *white root* fungus has been reported as attacking the roots of the rubber trees of Java and Sumatra. It occurs on trees of all ages, but especially those of from one to two years. The diseased trees suddenly become brown at the top, the leaves become yellow and fall, and the tree dies in from ten to fifteen days after the appearance of the first symptoms of disease. Examination of the roots of the dead trees shows them to be covered with white, leathery, elastic, branching mycelium, and in all probability the tap root was the first to be attacked. The disease is not ordinarily very serious, and the fungus is probably a species of *Irpex*. *Irpex flavus*, Klotsch, is known to be a root parasite on Para rubber in the Straits Settlements. It has also been reported from Java, Ceylon, Queensland, and North America. In Malacca it is said to attack the clove trees, and in the East it has been reported on coffee.

An undetermined species of *Vermicularia* has been found to be the cause of a root decay of the Para seedlings in the Straits Settlements.

Another undetermined fungus, which has been referred to as a *white fungus*, causes a disease of the roots of the rubber in the Straits Settlements. It occurs on plants of all ages, but is most severe on those of two years or less, and is first recognised by a browning of the leaves at the top of the young trees. These brown leaves finally fall, and the flow of latex is greatly reduced. Examination of the roots shows the abundance of the white fibrous fungus.

Rosellinia radiciperda, Massee, is a fungus which attacks the roots of *Ficus dubia* and also many other plants. It appears on the roots as a black, sooty substance and gradually works up the trunk. Like many other root fungi it first attracts attention by causing a dropping of the leaves.

The fruiting bodies are round, globose, black pustules which are densely covered with small warts. The entire destruction of the diseased plants by burning is the only satisfactory remedy.

Ficus nitida is a fine evergreen and ornamental tree of the tropics which is frequently referred to as the laurel. These trees have suffered greatly in the Barbadoes and Cuba, from some unknown cause. The fruiting bodies of the fungus *Eutypa erumpens*, Massee, occur under and push off the bark of the dead and dying trees, but the observers are by no means sure that it is the cause of the trouble. This same fungus has been reported on the nutmegs and cacao in Trinidad and on other plants in various parts of the West Indies.

Hymenochaete noxia,[1] Henn., has been reported on rubber from Malay and Ceylon, and on cacao in Ceylon and Apia. It causes an encrustation on the roots, especially the tap root, and on the base of the stem. The fructifications always occur on the stems or dead stumps and may persist for a long time. The fungus spreads primarily from the roots of one plant to the roots of a neighbouring plant. Dead trees and stumps should be burned.

Poria vincta, B. & Br., is another fungus which attacks the roots of the rubber in Ceylon, but does not do much damage. A species of *Helicobasidium*, which is probably *H. mompa*, occurs in Selangor, and is said to be a serious pest; and *Sphaerostilbe repens* has been reported as the cause of a root disease in Ceylon.

In contending with the fungi which cause the root disease of rubber and other plants, we must adhere to clean cultivation, *i.e.* the removal of dead logs and stumps, and the selection so far as possible of vigorous varieties. It has also been recommended that the Para rubber should not be set on worn-out coffee lands, and that the plantings should be separated into small lots by barriers of *Ficus elastica*.

COCO-NUT AND OTHER PALMS

Bud Rot.—This is the most serious coco-nut disease of the West Indies, from which it was first reported.

[1] It also attacks tea, dadap, Castilloa, Caravonica, cotton, camphor, and many other plants.

It is so severe that in many places it has practically destroyed the industry of coco-nut growing. It was first observed in Cuba in 1870, and a Commission was appointed to make a study of it in 1880. In 1875–6 it was reported from Demerara, in 1891 from Jamaica, and in 1893 from Honduras. It has since been reported from Trinidad and British Guiana, and in 1896 Petch reported a disease from Ceylon, India, and East Africa which is very similar, and may prove to be the same.

The disease makes its first appearance in the bearing trees, the young trees being comparatively free and healthy until the plantation is well infected. The young and, finally, the half-grown nuts drop, but the ripe nuts may hang on the tree until it is dead. As the disease advances the flowers blacken and die soon after breaking from the sheath, and often before the sheath breaks open. In case the flower-cluster is well advanced before it is attacked, the disease does not seem able to follow the hardened tissues to the base; but in case the cluster is young it may penetrate to the base, and no doubt does penetrate the bud of many trees in that manner.

The leaves begin to yellow irregularly, *i.e.* the young leaves may be yellowed in advance of the older ones. They eventually break (Fig. 70), and this may be considered a good indication of the presence of the disease. As the disease advances, the young trees as well as those bearing fruit become affected. However, a yellowing of the leaves is not always an indication of bud rot, since the yellowing may be due to any one of several causes, such as drought, excess of water, attacks of insects.

The third and last stage is the rotting of the bud, a condition which is frequently the first to be noted by the grower. This stage has been described by Horne as follows:—

The first stage of this is the appearance of watery, decayed spots on the surface of the unopened leaves. These spots must extend rather rapidly; but if the growth of the leaf carries them out into the air more rapidly than they extend downward, they

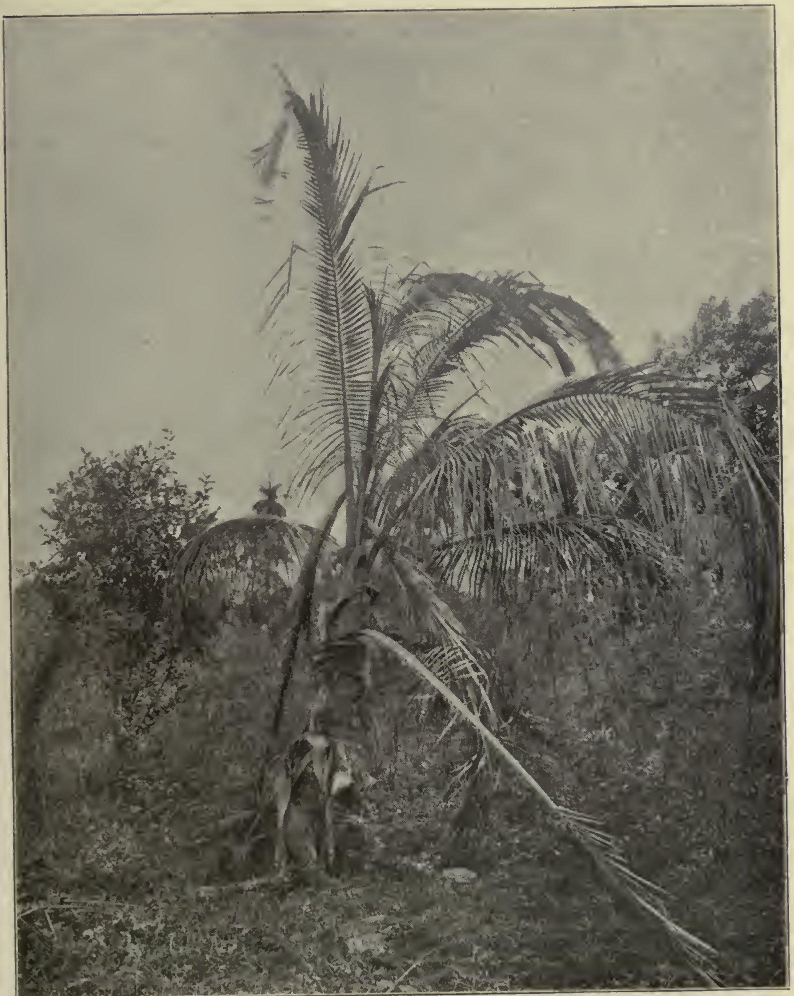

FIG. 70.—Coco-nut trees affected with bud rot.
(After Cook and Horne, Bul. 15, *Estación Central Agronomica de Cuba.*)

dry and do not spread farther. In this case nothing is noted except on close examination, when a number of the natural leaflets are seen to be dead when the leaf is expanded. If the leaf attacked is a little younger, or the rot works a little more vigorously, the midrib of the leaf is rotted, and the wind breaks the leaf, so that the end falls over and hangs down from the centre of the top.

If a very young leaf, with only the point coming out into the air, is affected, it rots rapidly, and, from the base of the tree, nothing is seen to be very wrong until the bud is examined.

Once well started, the rot moves down along the surface of the undeveloped leaves, rapidly penetrating the tender tissues and destroying them completely. The foulness, and probably the rapidity of the rot, increases as it descends. The whole central column is converted into a soft, stinking mass. When the terminal bud is reached it rots, and the tender upper end of the trunk also. About 3 dcm. (12 inches) below the apex of the trunk the tissues begin to harden perceptibly, and as soon as the rot comes in contact with the firmer tissues it is checked. By the time the terminal bud is decayed the tree is evidently sick, and usually shows an advanced stage of the disease. Such a tree, when cut open longitudinally, shows a central hollow, partly filled with soft, rotten remains of the youngest leaves, and a rounded cavity, nearly the breadth of the trunk, where the terminal bud was. Nothing remains of the bud but an exceedingly offensive, soft, rotten mass.

Below this the rot extends, converting the top of the trunk into a shell filled with rotten fibres, for a space of 4 dcm. (16 inches) or more, while the lower leaves are falling off, and the centre of the top, which is bound together by sheathing materials, falls from the top of the trunk.

From the time the first signs of the disease appear, within one or two months the tree is usually in the advanced stages. Usually three or four months more elapse before the stump is left bare. After the top falls off, the upper end of the trunk decays very completely for the length of about a metre, leaving only rotten fibres within and a shell on the outside. After this the trunk decays gradually and may stand for a number of years.

The disease, so far as our observations have been able to discover, consists of this rot, which develops on the moist, covered surfaces of the younger parts, penetrating and completely destroying the tender tissues, but always checked on reaching those which have commenced to harden or mature. Drying of an affected part also seems immediately to check the rot.

So far as our observations go, there is in nature no recovery. Apparently all genuine cases of bud rot prove fatal.

A number of explanations have been offered to account for the disease. Dr. Carlos de la Torre and many other writers believe that it is due to scale insects; Mr. Wm. Fawcett expressed the opinion that it was due to an organised ferment; Mr. August Busch believed it was due to *Pestalozzia palmarum*; while Prof. F. S. Earle, Prof. Wm. T. Horne, Dr. Erwin F. Smith, and the writer are all of the opinion that it is of bacterial origin.[1]

Associated with the disease are many fungi, such as *Pestalozzia*, *Diplodia*, *Aspergillus*, *Penicillium*, *Rhizoctonia*, and others, but experimental work has shown that they do not cause the disease.

No satisfactory remedies have been devised, but the following suggestions have been offered, and, in fact, are being followed in some parts of the West Indies. (1) Cutting and burning the tops of all affected trees; (2) burning out the loose fibrous materials from the tops of all slightly affected trees; (3) spraying the slightly affected trees with Bordeaux mixture; (4) the establishment of wind-breaks; and (5) the selection of seeds from healthy trees. However, in order to meet with any degree of success, it is necessary to follow the disease very closely and prevent its spread as much as possible. It is far better to destroy an affected tree than to allow the disease to spread to the neighbouring healthy trees.

Leaf Disease.—This disease is said to be due to the fungus, *Pestalozzia palmarum*[2] (Cooke), and is more or less common on the coco-nuts throughout the East Indies, Ceylon, Travancore, and in Trinidad and Cuba. It is also said to occur on tea and other plants. It appears as little, transparent, whitish spots near the tips of the young leaves. These spots gradually increase in size and frequently run together, thus forming

[1] The latest studies upon this subject by John R. Johnson ("The History and Cause of the Coco-nut Bud-rot," *U.S. Dept. of Agric.*, *Bureau of Plant Industry*, *Bulletin* No. 228) seems to prove that this disease is due to *Bacillus coli* (Escherich, Migula).

[2] *Diplodia epicocos* is frequently found on the leaves in connection with the *P. palmarum*.

irregular patches, which are at first yellowish and then whitish in the centre, with a brownish margin. The tissues become dry, the leaves ragged, and die prematurely. The spores are formed on the upper surface. The disease is much more severe in some places than in others. Although it is not nearly so destructive as the bud rot, it no doubt greatly reduces the vitality of the trees.

Its occurrence in the West Indies has been questioned. However, there is no doubt that a species of *Pestalozzia* does occur on the coco-nut in the West Indies, and other American tropics, and it is very probably a variety of this species. However, in the West Indies, the spores are said to form on the under surface of the petioles. Stockdale has reported a *Pestalozzia* on the coco-nuts in Mahaicony (British Guiana) which causes yellowish spots on the leaflets near the tips, and later causes the entire leaves to turn yellow, then brown, and finally die. The dead parts break and hang vertically, and the spots bear spores on the upper surface.

P. palmarum appears to be much more severe in the East Indies than this same or similar disease in the West Indies. It is especially severe on young palms, and the most destructive outbreaks have been reported from Travancore.

The diseased parts should be cut and burned, and the trees then sprayed with Bordeaux mixture.

Godaveri Disease.—This disease is caused by the fungus *Pythium palmivorum*, Butler. It was first reported from the island of Godaveri in 1909. It attacks the buds of both the coco-nut and Palmyra palms[1] and causes heavy losses. It enters the bud through the leaf sheath; at first the leaf turns white, usually beginning at some outer point and working inward. Irregular, sunken spots, with raised edges, are formed on the sheaths of the diseased trees. These spots are white at first, but become brown. They

[1] It also attacks *Areca catechu*.

originate on the outer surface, and gradually work their way through to the heart. On the surface they become dry and frequently covered with mycelium. Finally, the central shoot turns white, the cabbage becomes putrid, and the crown drops off. The spores are formed on the young blades. This disease threatens the extinction of the Palmyra, coco-nut, and betel-nut palms of many parts of Madras. All diseased trees should be cut and burned as soon as the disease is detected, in order that its spread may be prevented.

A similar disease has been reported from Ceylon, India, and East Africa, but we cannot say whether it is or is not the same.

Smut.—This disease is due to the fungus *Graphiola phoenicis*, Poit, and occurs on the leaves of *Phoenix dactylifera*, *Chamaerops humilis*, and probably on other palms, but is said to be of little or no consequence, except in conservatories. It causes small dark-coloured spots which project on both surfaces of the leaves.

Koleroga.—This is a disease of the betel nut palm (*Areca catechu*) which occurs in parts of India. It is due to *Phytophthora omnivora*, var. *Arecae*, Coleman, which causes the young nuts and flowers to fall without setting fruit, and the stalks to blacken. It spreads along the flowering shoot, causing the nuts to fall, passes into the leaf-sheath and finally into the centre of the bud, which it destroys. The disease first causes areas on the nut to appear a darker green and water soaked. A little later it becomes covered with a whitish mass of fungus which can be easily scraped off. This stage is soon followed by falling of the nut. The disease is most severe in wet seasons. The spores are carried from one wet season to the next in the old diseased parts or possibly in the soil. It can be controlled by removing and burning the old infected parts and by spraying with Bordeaux mixture. The boiled resin and soda mixture should be added to the Bordeaux to improve its adhesive qualities.

Mr. E. J. Butler also reports a disease from the

Travancore[1] which attacks the coco-nut palm (*Cocos nucifera*), the talipot (*Corypha umbraculifera*), and the sago palm (*Caryota urens*). This disease works very slowly, causing the leaves to droop and lose colour. The tips of the leaflets turn yellow and become dry, and finally the entire leaf does the same. They are then easily torn off. As the disease progresses the leaves become smaller and fewer. The kernels are frequently shrivelled and deficient in oil. Finally, the cabbage rots and the tree is dead. This disease was at one time supposed to be due to *Thielaviopsis ethacetica*, Went, which is the cause of the so-called "pine-apple" disease of the sugar-cane; but Butler has demonstrated that although this fungus is frequently found upon many species of palms it is not the cause of the disease.

Examination of the roots shows that they have been invaded by the mycelium of a fungus which kills them and causes the roots to turn brown, and then to become black and shrunken. Mr. Butler was unable to find trace of the fungus in the trunk. The fungus on the root proved to be a *Botryodiplodia* sp., but Mr. Butler could not be positive that it was the cause of the disease. The disease is no doubt infectious, and if the fungus is the cause, it probably spreads through the soil.

It is possible to control it to some extent by destroying the debris, adding lime to the soil and allowing it to rest for a time where possible. Select healthy trees which are as near immune as possible, and fertilize freely.

Mr. F. A. Stockdale has described a similar disease for Trinidad, which also occurs in British Guiana, and possibly Jamaica, but in this case he found the spores on the petiole. It is very doubtful if it is the same as the disease described by Butler. However, the disease is due to a species of *Botryodiplodia*. It works very slowly, causing the leaves to wilt, turn yellow at the tips, become dry, and hang down for some time before falling. Sometimes these hanging leaves entirely enclose the trunk.

[1] See *Agri. Research Institute* (*Pusa*), *Bul.* 9, March 1909.

The petioles frequently break, leaving the sheaths. The nuts are shed frequently before the yellowing of the leaves. The fungus can be found in both roots and petioles, but is seldom found in the trunk. It comes to fruit on the petioles. The mycelium pierces the cortical cells of the roots and causes them to become shrunken. The point of attack has not been definitely determined, but the fungus clogs the tracheary tissues, and interferes with the passage of water. It kills the trees in from three to four months. The tops of the trees should be treated in the same manner as for bud rot, and the soil should be well drained.

A similar disease, due to *Botryodiplodia* sp., which attacks the roots and cuts off the water-supply, causing the trees to die of drought and starvation, has been reported from Borneo by H. N. Ridley. It attacks the coco-nut, betel, and caryota palms.

Stem-Bleeding Disease.—This disease has been reported as serious in Ceylon, and is said to be due to *Thielaviopsis ethacetica*, Went, which is the cause of a disease of the sugar-cane (see page 84). The disease causes the bark to crack and a viscid sap is exuded, which becomes dark and then black. On young trees the patch is small, and not an index to the amount of internal injury; in trees from ten to forty years, the trunks frequently become hollow, but in trees of more than forty years it is of little consequence.

The **wasting disease** of the coco-nut is a rather indefinite disease which has been reported from Jamaica. The leaves droop and fall prematurely, the nuts fall slowly, and finally the tree dies. The cause is unknown.

The **coco-nut trunk rot** is another disease which has been reported from Jamaica and Cuba. Fungi of some kind appear to enter the tree through wounds and cause the interior to rot. The top may live for some time with the hollow trunk, but the tree eventually dies.

E. B. Copeland[1] describes a very severe bud rot for

[1] *Phil. Agri. Rev.* 1. No. 5 (1908), pp. 210-220.

the Philippines, which according to his description is very similar to the supposed bud rot of Cuba and Jamaica, but offers no explanation as to the cause. A similar bud rot has also been reported from Portuguese East Africa.

Root Rot of Betel-nut Palm.—This disease has been reported from India, where it occurs on the betel-nut palm (*Areca catechu*). The disease is first detected by a dropping of the nuts, followed by a change in the general appearance of the apical bud, a withering of the leaves, beginning with those on the outside, and, finally, destruction of the entire head. The cause of this disease is a fungus which works on the roots, and although the species has not been definitely determined it is supposed to be *Fomes lucidus*, Fries. The remedies suggested are the digging of a trench outside the root area to prevent the spread of the fungus through the soil, and the complete destruction of the diseased tree by burning. The ground should not be replanted with another tree of this kind for at least one year. *F. lucidus* is also said to attack the coco-nut palms in Ceylon.

Root diseases have been reported from Trinidad, British Guiana, Jamaica, and Travancore, but the data concerning them is not sufficient to warrant definite statements at this time.

CHAPTER VII

POTATOES

Late Blight and Rot.—This disease is responsible for greater losses in potato growing than any other disease, the annual loss in the United States being estimated as $36,000,000. It is more strictly a northern disease, which is supposed to have originated in South America. It has been reported from Ecuador, Italy, Florida, India, and New Zealand, all of which are in or near the tropics. There is no reason why it should not become serious within the tropics, especially in the more elevated places at any time. It is this possibility of its occurrence that leads the author to give this discussion.

This disease is most destructive in damp rather cold weather. The presence of the disease is indicated by a tendency to wilt quickly, followed by the occurrence of dark spots, which usually start near the edge or tip of the leaf and gradually spread over its entire surface. If the weather is damp the spots are purplish, water-soaked in appearance, and the disease spreads rapidly. If the weather is dry the spots are brown and the disease spreads slowly. Under favourable conditions the disease spreads so rapidly that a promising crop will be entirely destroyed within a very few days. When the disease is active it can be readily recognised by a characteristic vile odour. This disease also attacks the tubers, causing the dry rot, which is very destructive in storage. Not only does the dry rot cause heavy losses, but it makes favourable conditions for infection by the wet-rot bacterium. This disease is caused by the fungus known as *Phytophthora infestans*, De Bary. The slender, filamentous, unicellular mycelium spreads throughout the host plant, finally coming out through the stomata on the under side of the leaf, where it can be seen, by the use of a hand lens, as a delicate white mould. Examination shows this mould to be a branched hypha with terminal conidia. These spores almost immediately give rise to about eight zoospores each, which swim for a short time in the moisture on the surface of the leaf, come to rest, germinate, and penetrate the host plant. They may be carried from plant to plant by the wind, by insects, by the labourers, and farm implements, or they may fall upon the ground, and cause an infection of the tubers. No oospore or resting spore has been discovered for this species, but it is doubtless carried from season to season by tubers. This disease is also known to attack the tomatoes, but is not often destructive (Fig. 25).[1]

Fortunately it can be controlled: first, by the use of clean, healthy seed, and second, by frequently spraying with Bordeaux mixture, which prevents the spread and germination of the spores. The first application of Bordeaux should be made when the plants are 4-6 inches in height. Other applications should be made in accordance with the conditions of the weather and spread of the disease. The progressive grower will also endeavour to secure varieties which are partially resistant to the disease.

Early Blight or Leaf Spot.—Although this leaf spot is not so destructive as the late blight it has a much wider distribution, and the losses are sometimes said to amount to as much as 50 per cent of the crop.

In temperate climates it occurs earlier in the season than the late blight. It produces brown spots which are more or less circular, and can be readily distinguished from the late blight by the faint concentric circles which give a characteristic target-board appearance to each spot. The spots frequently unite, forming irregular blotches,

[1] Since writing the above, the oospore has been discovered by Dr. Geo. P. Clinton.

and after a few days the leaves become yellowish, show a tendency to curl inward, and die. Furthermore, this disease is not accompanied by the vile odour which is so characteristic of the late blight.

The disease is due to the fungus *Macrosporium solani*,[1] E. & M., which is decidedly different from the *Phytophthora infestans*. The mycelium is also filamentous, and after working in the tissues of the host comes to the surface through the stomata and gives rise to numerous, multicellular club-shaped spores. These spores germinate, and the new mycelium readily penetrates the tissues of the host.

This disease is equally injurious to the tomatoes, and attacks other Solanaceous plants. It can be readily controlled by the use of Bordeaux mixture in the same manner as recommended for late blight.

Tip Burn, Leaf Burn, or Scald.—These are climatic diseases which are frequently confused with the blight diseases. They usually begin at the tips and margins of the leaves and work inward, but do not show the spots which are so characteristic of the blight.

Rhizoctonia Blight.—A great many plants suffer from a soil fungus known as *Rhizoctonia*. Recent investigations have led the workers to classify this fungus of the potato, and possibly of many other plants, as *Corticium vagum*, B. & C., var. *solani*, Burt. The disease is very widespread, and although the writer is unable to find any record of its occurrence in the tropics, diseases of this class are so common in tropical countries that there is little or no reason to doubt its presence. Furthermore, it has been reported from the semi-tropical countries of both hemispheres, and a very similar disease has been reported as destructive in Porto Rico. The fungus attacks the roots, tubers, and other underground parts of the stems, spreading over the surface and penetrating the pith. The young stems rot as soon as formed, many of them die, and others are enfeebled. Frequently the tops of those which live are aborted and

[1] Syn. *Alternaria solani*, E. & M.

twisted, sometimes becoming rosette in character. Small hard knots of the mycelia, known as *sclerotia*, are frequently formed on the surface of the tubers. The disease is not especially severe, and can be controlled by the method recommended for scab.

Bacterial Blight.—This is a very widely distributed disease, which also attacks the potato and the egg plant. It is very destructive in warm climates. It causes the wilting of a part or the whole of the plant, which soon dries and drops its foliage. It is due to *Bacillus solanacearum*, E. F. Smith, minute organisms which live in the fibro-vascular bundles of the plant. A section across the stem shows these bundles to be very much discoloured. The disease also attacks the tubers, causing the brown or black rot, which is easily distinguished in all the fibrous parts. It is readily carried by many kinds of insects, especially leaf-cutters, which should be destroyed so far as possible. Nothing but clean, healthy seed should be planted, and if the disease is not abundant the unhealthy plants should be destroyed.

Black Leg or Potato Stem Rot.—This disease is due to *Bacillus phytophthorus*, Appel, and has proved very destructive in Western Australia. The leaves wilt, turn yellow, and gradually shrivel from below upwards. The stem gradually becomes black and rotten, and the disease penetrates to the new tubers. Since the organism will attack many root crops, and will persist in the soil for some time, it is rather difficult to control. Old diseased plants should be burned; tuber and root crops should not be cultivated on infested land for at least two years after the disease is discovered; lime and nitrogenous manures should not be used.

A bacterial disease which is very similar and may prove the same is very common in the eastern part of North America, where it is also known as black leg. The diseased plants are light green, sometimes yellowish and dwarfed. The branches and leaves grow upward, forming a more or less compact top. At or below the surface of the ground the stems show a black discoloration which frequently runs upward for several inches. Drying kills the organism, but the corrosive sublimate treatment as used for scab is recommended.

Wet Rot.—This is also a bacterial disease, which occurs in Western Australia and causes considerable trouble in warm, damp seasons and also in storage. Dark patches appear beneath the skin of the tubers, and the entire interior becomes brown and slimy. All diseased plants and tubers should be destroyed. If it is desirable to use the tubers for feed for live stock they should first be boiled, or the spores will be returned to the soil and re-infect the new crops. Use clean seed and rotate the crops.

Scab.—This disease is due to the fungus *Oospora scabies*, Thax., and is widely distributed throughout most, if not all, of the potato-growing countries of the world. It is very abundant in the West Indies, Europe, Africa, New Zealand, and the United States. The surface becomes more or less roughened and scabby, and its value is greatly reduced. The scabby condition may be confined to the surface, or it may extend throughout the greater part of the tuber. The fungus penetrates the tuber, causing an irritation which results in the scabby growth just referred to. Unfortunately the organism will live in the soil for several years (five or seven), and will also attack other plants, such as beets, turnips, cabbages, carrots, etc. Alkaline soils and fertilizers are said to be most favourable for its development.

Crops which are subject to this disease should not be put in soil known to be infected, but some other crop should be used until the disease has had time to die out. Use clean tubers for seed, and, as a precaution, treat them with either corrosive sublimate or formalin. The corrosive sublimate (bichloride of mercury) should be dissolved at the rate of two ounces in fifteen gallons of water. Put the potatoes into a sack or crate and suspend in the solution for one hour and thirty minutes. Spread and allow to dry. CAUTION:—*Corrosive sublimate is poisonous, and must be kept* *out of reach of children and away from animals. Because of its action on metals it must be mixed in a wooden vessel. This vessel, and in fact everything with which the solution comes in contact, must be thoroughly cleaned or destroyed.* The formalin should be used at the rate of a half-pound (a half-pint) in fifteen gallons of water. The tubers should be soaked as above for two hours, then spread out and allowed to dry. This treatment has some advantages, in that it can be mixed in any kind of a vessel and is not poisonous to handle. However, it is quite irritating to the nose and to the skin.

Black Scab.—This disease is known in Australia, and is due to the fungus *Oedomyces leproides*, Trub. The young shoots become brown and wrinkled; the tubers wrinkled and warty. The organism lives in the soil, and is thought to gain entrance to the tubers through the eyes. It also attacks the beets and many other root crops. The crops should be rotated, and only clean potatoes used for seed.

Fusarium Wilt (*Fusarium oxysporum*, Schlecht).—This disease is also very widespread, but appears to be very much more severe in some places than others. It may appear upon the plants at any age, but the earlier it appears the more severe it will be. The diseased leaves are a much lighter green in colour than the normal leaves, and eventually the plant withers and falls. Examination of the roots shows that many are dead and covered with a white or pinkish mould. Sections of the stem show brownish discoloration in the fibro-vascular bundles, and sections of tubers show discolorations just below the surface.

This disease also appears in the stored potatoes, causing what is known as dry rot, in which the tubers shrivel, beginning at the stem end; the inside becomes brown, and the tuber light in weight. This dry rot is frequently accompanied by a secondary soft rot which is due to bacteria. Use clean healthy tubers, and rotate the crops.

Leak.—This is another storage disease, and is due to *Rhizopus nigricans*, Ehrbg. It sometimes causes considerable loss. The organism cannot enter the plant except through wounds. It lives in the soil and attacks white potatoes, sweet potatoes, apples, and other plants.

The **dodder** or love vine (*Cuscuta epithymum*) has been reported as growing on the potato in Victoria, Australia. It does not do a great amount of damage.

Nematodes.—These pests, which are so widely distributed over the world and attack so many species and varieties of plants, are also found on the potatoes. They cause the formation of small pimples, each surrounded by a slight depression. The tip of this pimple is frequently broken, and the tissues below are discoloured for a short distance. While the injury itself may be slight, it gives a most favourable condition for infection with other organisms. Diseased potatoes should not be used, and such rotation of crops should be practised as will renovate the soil of these pests.

TOMATOES

Tomatoes in the tropics are subject to many diseases, which are caused by the same organisms as the diseases in the temperate zones.

Black Rot, Blossom End Rot, Point Rot.—This is a fruit disease which originates as a small dark green, watery, irregular spot, usually at the tip or blossom end. The spot enlarges, and since the growth is stopped at that point, the spot soon appears to be sunken. After a few days the spot may appear dry and somewhat shrivelled. The disease is very destructive, frequently destroying a large percentage of the crop. It is well known throughout the United States and in Cuba.

The cause of this disease is disputed. It has been attributed to *Alternaria fasciculata*, (C. & E.) J. & G.,[1] but the more recent studies of Smith of Massachusetts, on what is probably the same disease, indicates that the

[1] Synonyms, *Macrosporium tomato*, Cooke; *Macrosporium solani*.

real cause is *Fusarium solani*, Mart., and that the *Alternaria* is secondary and saprophytic. However, some workers believe that the true cause is *Bacillus* sp. It is possible that what appears to be the same disease may be due to different organisms in different localities, but that the secondary fungi are the same throughout very wide ranges. This disease is most severe after periods of drought and may be due to climatic conditions.

It is very doubtful if the disease can attack the fruit except through wounds. Over-fertilization, especially with nitrate of soda, makes the fruit more susceptible to the disease. The use of Bordeaux is not especially successful. The growers should endeavour to select seed from immune plants.

FIG. 71.—Tomato affected with anthracnose, *Colletotrichum phomoides*.

Anthracnose.—This disease (Figs. 71, 72), which is frequently spoken of as the ripe rot, is caused by *Colletotrichum phomoides*, (Sacc.) Chester. It attacks the fruit when nearly ripe, causing discoloured, sunken spots. It spreads rapidly in damp, warm weather, causing decay of the fruits and resulting in heavy losses. The only practical remedy is hand-picking and destruction of the diseased fruits, thus preventing the formation of spores and the spread of the disease.

Brown Rot of Green Fruit.—This disease has been reported from Cuba. It originates as a spot on the green fruit and causes a rot before ripening. It appears to be due to a *Rhizoctonia*, and is most destructive in wet weather. Careful draining, a thorough cleaning and burning of the rubbish in the field, and rotation of crop would no doubt prove helpful.

Cracking of the Fruits.—This is a physiological disease (Fig. 73) which is due to a variation in the water supply. A period of drought followed by a period of considerable rainfall causes the inner part or pulp to grow more rapidly than the peel, and necessarily causes the latter to be ruptured. The only remedy lies in a thorough cultivation or mulching.

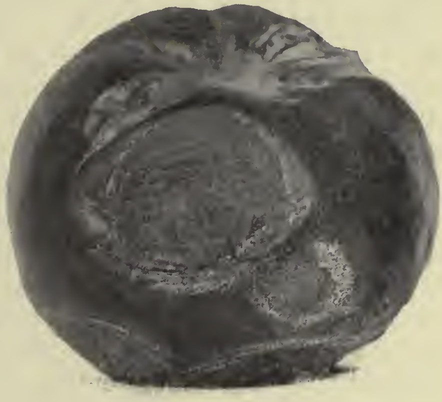

Fig. 72.—Tomato affected with anthracnose, *Colletotrichum phomoides*.

Dropping of the Flower Buds. — This disease interferes with the setting and formation of the fruit. It frequently causes much greater losses than the diseases which are due to specific organisms. It may be due to any one of several causes, such as—(1) Unfavourable climatic conditions, lasting from a few to several days, which interfere with the blooming and pollination. If from this cause there is no remedy. (2) It may be due to excessive use of nitrogenous fertilizers, which may cause the plants to grow too rapidly, producing vegetative structures rather than fruit. This may be readily checked by cutting out the terminal buds. (3) It may be due to the attacks of certain insects.

Fig. 73.—Tomato showing fruit cracks.

Fusarium Wilt or Sleepy Disease. — This very widely distributed disease is caused by *Fusarium lycopersici*, Sacc., an organism which is very closely related to the species which cause similar diseases on the cotton, melon, and cow-pea. It is especially characteristic of warm climates, lives in the soil, and probably gains entrance to its host through wounds on the roots. The diseased plants undergo a gradual wilting and dying. The fibro-vascular bundles are discoloured and filled with the white mycelium of the fungus. As the disease progresses the part of the stem just above the ground becomes covered with the mycelium and the conidia.

Fortunately this fungus does not maintain itself in a soil which is free from the host plants as long as some related species of this genus. Therefore, it is possible to combat it advantageously by short rotation of crops. Care should be taken to use seed from healthy plants. Spraying is of little or no value. This disease is also said to attack potatoes, egg-plants, etc.

Bacterial Wilt.—This is another wilt disease, but is due to an entirely different organism. It is caused by *Bacillus solanacearum*, Erwin F. Smith. It has been reported from Western Australia and Straits and Federated Malay States, and is quite common in the Southern United States and in the West Indies. The general appearance of the diseased plants is very similar to the plants which are suffering from *Fusarium lycopersici*. The leaves wilt and the stem shrivels, changing to yellowish green, brown, and black, and sometimes there is a gummy deposit on the surface of the stems. A cross-section of the stem shows a discoloration of the fibro-vascular bundles, and a microscopic examination reveals the organisms which cause the disease. These organisms also live in the parenchyma and in the bark, and are transmitted from plant to plant by means of insects.

The diseased plants should be pulled out and destroyed. Spraying with Bordeaux mixture or other fungicides is of no value; but if a treatment to destroy the insects can be given, it will be advantageous.

Tomato Wilt.—Another wilt disease which resembles the one caused by *Bacillus solanacearum* is very serious in Porto Rico. It works through the fibro-vascular bundle of the plant, and cannot be counteracted by the use of Bordeaux.

Sclerotium Wilt.—This disease is first apparent by a wilting of the tips of the plants. A careful examination of these diseased plants shows *Sclerotium Rolfsii*, Sacc., a fungus just below the surface of the ground. This fungus finally forms a number of small bodies (sclerotia), about the size of mustard seed, by which it is carried over from year to year. When young, these bodies are white, but when mature they vary from black to red. This fungus also attacks many other plants, such as potatoes, egg-plants, beans, cow-peas, summer squashes, cabbages, beets, melons, and many ornamental plants. The plants can be protected over small areas by spraying the soil around the plants with ammoniacal copper carbonate solution. Over large areas it will be necessary to rotate the crops, avoiding where possible the use of manure and decaying vegetable matter for fertilizers.

Leaf Mould.—This disease is caused by the fungus known as *Cladosporium fulvum*, Cooke. It has been reported from Western Australia and Southern United States, and from Cuba. It spreads rapidly, forming rusty, brown patches on the under side of the leaves. The leaves become yellow, wilt, and shrivel. Poor drainage and moisture are favourable to the rapid development and spread of the disease. The plants should be trellised, and sprayed with Bordeaux.

Early Blight, Target Board Blight.—This disease is due to the *Macrosporium solani*, E. & M., which has already been discussed in connection with the diseases of potatoes. Prevention is much better than a cure for this pest. The young plants should be sprayed with Bordeaux mixture while yet in the seed-bed; and if the conditions are such that it can be done with profit, the treatment may be continued in the field (page 208).

Late Blight or Winter Blight.—This disease is due to *Phytophthora infestans*, De Bary, and has been discussed in connection with the diseases of potatoes. Although it has been frequently reported as a disease of the tomatoes, it was not considered destructive until it proved to be a very serious pest in Southern California. It is not serious, except in very wet, rather cool weather; and in case it should be introduced there is every reason to expect it to prove serious in the more elevated parts of the tropics. It attacks the green and ripe fruits

FIG. 74.—Tomato leaves affected with blight, *Septoria lycopersici.*

and the stems, causing spots which ruin the fruits for markets, and under suitable weather conditions destroying the entire crop. It can be controlled by spraying with Bordeaux immediately after each rain (page 207).

Leaf Spot or Leaf Blight.—This disease (Fig. 74) is sometimes confused with the early blight, but is quite different in both its general appearance and the character of the fungus which causes it. The spots are much smaller than in the early blight, and the lower leaves are the first to be attacked. As the disease progresses the leaves curl, die, and fall. The vitality of the plant is reduced, and the crop is injured proportionately. It is common in the tropical and temperate regions of America.

The disease is caused by *Septoria lycopersici*, Speg., a fungus which lives from season to season on the old and dead leaves. Therefore, all debris from the tomato field should be destroyed. Spraying with Bordeaux during the early part of the season is successful in combating the pest, and should be used wherever practical.

Rosette.—This disease, which has already been discussed in connection with the potatoes, causing a dwarfing of the plant, curling of the leaves, and other abnormalities, has been reported from many parts of the world. In some places it is known to result from the attack of the root fungus, *Corticium vagum*, (B. & C.), var. *solani*, Burt (*Rhizoctonia*), but it is by no means certain that this is the only cause. It can be controlled by the rotation of crops and free use of lime.

Leaf Curl.—This is not due to an organism, but to any one of several causes. It may be due to too much moisture in the soil, or to the excessive pruning of the plants. Plants affected with this disease are less productive than healthy plants.

Mosaic Disease.—This is similar to the mosaic disease of the tobacco. The leaves are more or less distorted, and frequently reduced in size, and variegated into light and dark green areas. The disease is said to be due to malnutrition. (See the disease of tobacco, page 152.)

Hollow Stem.—In this disease the plants appear to be normal until of considerable size, when they show a tendency to fall over. An examination shows the stems to be hollow. It is due to too much nitrogenous fertilizers.

Nematodes.—These little pests are sometimes the cause of very heavy losses. They have been discussed in other relations, so that it is not necessary to give them further consideration.

White Mould or Phytoptosis.—This disease (Fig. 75) is due to a small insect, or more strictly speaking a mite, *Eriophyes* (*Phytoptus*) *calacladophora*, Nal., but is frequently mistaken for a fungus disease, and for that reason is mentioned here. These small mites attack the stems and leaves, causing an irritation which results in

FIG. 75.—Tomato affected with Phytoptosis.

the formation of an enormous number of plant hairs. This abnormal growth of plant hairs gives the plant a fuzzy appearance, and is frequently mistaken for a fungus growth. This pest can be controlled by the use of the sulphur caustic soda mixture. Mix in a wooden vessel 30 pounds of flowers of sulphur with enough water (about 3 gallons) to form a paste; add 20 pounds of 98 per cent caustic soda (or 28 pounds of 70 per cent), and mix thoroughly. The mixture becomes very hot, turns brown, and forms a liquid; add enough water to make 20 gallons, and stir thoroughly. Pour off the liquid part and put in tight keg for stock solution. Four quarts of this solution in 50 gallons of water applied with a spray pump will prove efficient.

Damping Off.—This is a very common seed-bed disease of tomato and many other plants, and is due to the same causes. Where the plants are grown in large quantities the beds should be treated as recommended for tobacco (see page 29). Where grown in small quantities, use fresh clean soil and make the beds so that the watering, drainage, and ventilation can be controlled.

EGG-PLANT

The egg-plant is subject to many of the diseases which attack the tomatoes, potatoes, and other solanaceous plants. Among the most important of these are the bacterial wilt (*Bacillus solanacearum*, E. F. Smith), fusarium wilt (*Fusarium lycopersici*, Sacc.), sclerotium wilt (*Sclerotia* sp.).

In addition to these, the most important diseases are the seedling stem blight and the leaf spot.

Stem Blight or "Damping Off."—This disease is not caused by the organism which causes the "damping off" of so many plants, but by a fungus known as *Phoma solani*, Hals. So far as the writer knows, it has not been reported from the tropics, but with the increased production of winter vegetables for northern markets it may occur at any time. It is primarily a seed-bed disease, which attacks the young plants near the ground, causing them to break and decay. If only slightly affected, the plant makes a slow and feeble growth. The fungus is very small, but examination of the diseased part of the stem shows small black specks within which are produced the enormous number of spores. When mature and when brought in contact with water, these spores pour out and are carried to other plants. The treatment recommended for "damping off" would no doubt prove a valuable remedy for this disease.

Leaf Spot.—This disease (Fig. 76) attacks the foliage of plants of all ages, and also the fruits. It produces characteristic leaf spots, in the centre of which are a great number of small black specks. When the foliage is badly diseased the vitality and fruitfulness of the

FIG. 76.—Egg-plant leaves affected with leaf spot, *Phyllosticta hortorum*.

plant is reduced. When the fruits become diseased their market value is practically destroyed. This disease, which is caused by *Phyllosticta hortorum*, has been reported from Cuba, and no doubt has a very much wider distribution throughout the American tropics. It is especially severe in wet weather, and is very common on the fruits, causing them to decay. It is especially severe on fruits which have suffered from mechanical injuries or from sun scalds. This disease can be controlled by the use of Bordeaux mixture.

Stem Rot.—A stem rot due to *Nectria ipomoeae*, Hals., which is supposed to be the same as the species on the sweet potato, has been reported from New Jersey, U.S.A. The abundance of sweet potatoes in the tropics, and the number of species of nectria found there, would naturally lead us to expect to find disease.

Shedding of Fruits.—The shedding of fruits may be due to any one of several causes, but excessive wet weather is a very common cause in the American tropics.

Other Diseases.—Other diseases which are known to

FIG. 77.—Peppers affected with anthracnose, *Gloesporium piperatum.*

attack the egg-plant, but which have not been reported from the tropical countries, are the well-known "damping off" fungus *Pythium De Baryanum*, which does occur in the tropics, the fruit mould caused by *Botrytis fascicularis*, (Corda) Sacc., and fruit rot caused by *Penicillium* sp.

PEPPER

Black Mould.—This is caused by *Macrosporium* sp., and is very destructive. It attacks the blossom end of the fruit, causing an unsightly spot and destroying the tissues. (Fig. 78.)

Anthracnose.—This disease is due to *Gloeosporium piperatum*, E. & E., which causes soft, sunken cankers (Fig. 77) on both ripe and green fruits.

Another anthracnose is due to *Colletotrichum nigrum*, E. & Hals., which makes similar spots, but can be distinguished by very minute dark spines in the spore patches.

Blight or Wilt.—This disease causes an alternate

FIG. 78.—Peppers affected with rot, *Macrosporium* sp.

wilting of the young parts of the plant during the day and revival during the night, but the wilting increases on each successive day. By the fourth day the plant is usually beyond recovery, undergoes a change of colour, drying and dropping of foliage, and finally dies. In the early stages of the disease the roots are apparently healthy, but there can usually be found on the stem, just below the surface of the ground or on one of the larger roots, a discoloured, shrunken spot. With the progress of the disease this spot increases in size, and is followed by a rapid decay. The disease starts with the formation of the fruit pods and spreads rapidly through the soil. It is due to a fungus, *Sclerotium Rolfsii*, Sacc., which produces an enormous amount of mycelium by which it is spread, and dense *sclerotia* by which it is carried from season to season; but does not, so far as we know, produce spores.

The disease is well known throughout the southern part of the United States, where it is also said to attack tomato, egg-plant, white potato, sweet potato, beet,

FIG. 79.—Bean seedlings affected with anthracnose, *Colletotrichum lindemuthianum.* (Photo by C. W. Edgerton.)

peanut, bean, cow-pea, cabbage, squash, water-melon, rhubarb, fig, cotton, violet, hydrangea, daphne, chrysanthemum, morning glory, sugar-cane, and many other plants. Either the same or a very similar disease has been reported as causing the "red mucus" (Roten Rotz) disease of sugar-cane in Java by Dr. J. H. Wakker. The disease can be held in check by spraying the soil around each plant with about one pint of ammoniacal copper carbonate solution or *eau céleste.* The first application should be made when the disease first appears, and repeated about once every two or three weeks. Bordeaux mixture is not successful in combating this disease.

Bacterial Wilt.—The bacterial wilt (*Bacillus solanacearum*, Smith), which is so destructive on potatoes, tomatoes, and egg-plants, also attacks the peppers (pp. 210, 216).

Fusarium Wilt.—This disease is very similar to, and probably the same as the disease of the same name which attacks the tomatoes (page 212).

Leaf Spot.—This disease, which is due to *Cercospora* sp., is very common on the pepper throughout tropical and subtropical America. Although it reduces the vitality of the plants, it is not destructive.

Leaf Spot.—The pepper is also subject to the attack of an undetermined species of *Phyllosticta*, which causes small circular greyish spots, with pycnidia in the centre.

BEAN

Anthracnose.—This disease (Figs. 80, 81) is due to the fungus *Colletotrichum lindemuthianum*, Sacc. & Magnus, and is widely distributed throughout the bean-growing districts of the world. It attacks plants of all ages and all parts above the ground, and is carried in the seed. It can be detected on the young plants, by the discoloured, sunken spots or cankers on both stems and leaves. If the attack is severe, many of the plants die. If the plant escapes death and grows, the stems and leaves are more or less covered with spots and cankers. Those on the leaves frequently break into holes, giving an ugly, ragged appearance to the plant. On the pods it causes canker-like spots, which are usually circular or slightly irregular in outline, and frequently have reddish margins. Within these spots great numbers of spores are produced, and are readily distributed by the rain and dew.

Since the disease penetrates the pods and into the seeds themselves, the planter should use care in the selection of the seed. Diseased seedlings should be destroyed, and the crop should not be cultivated while the plants are wet, as such cultivation facilitates the distribution of the spores. Bordeaux mixture can be used to advantage on small areas, and wherever else it is practicable and profitable. After the crop is harvested, the rubbish should be collected and burned. Where the disease is especially severe, rotation of crops will prove advantageous.

FIG. 80.—Beans affected with anthracnose, *Colletotrichum lindemuthianum*. (Photo by C. W. Edgerton.)

Bacterial Blight. — This disease, which is due to *Pseudomonas phaseoli*, Smith, is well known in the United States, and has no doubt found its way to the American tropics at least. It attacks leaves, stems, and pods. On the leaves it produces brown spots, which spread and frequently destroy the leaf. In dry weather this diseased tissue is brittle, but in wet weather it has the appearance of being water-soaked. It causes the young pods to shrivel and die, but on the larger pods it produces watery spots, which finally become discoloured but not sunken.

The organisms are carried from season to season in the seed and in the soil. When a field is once infected the organism gains entrance to healthy plants through wounds. The only consistent method of control which can be recommended at this time is the careful selection of seed and the rotation of crops.

Downy Mildew.—This disease is due to *Phytophthora phaseoli*, Thax., and thus far has been reported only

FIG. 81.—Beans affected with anthracnose, *Colletotrichum lindemuthianum*. (Photo by C. W. Edgerton.)

from Northern United States and Russia. Whether it will prove to be a strictly northern parasite or will follow the lead of its close relative, *Phytophthora infestans*, De Bary, of the potato (page 208), and work into the warmer climates remains to be seen. This possibility makes it worthy of brief mention at this time. It is most abundant on the pods, but will attack any part of the plant above ground. On the pods it causes prominent patches, containing abundant conidiophores, and finally causes a wilting and dying of the diseased part. It also reproduces by oospores. It can be controlled by careful selection of seed and rotation of crops. Bordeaux mixture can be used advantageously on small plantings.

Powdery Mildews. — These diseases are quite abundant in the tropical and subtropical countries. They produce the characteristic whitish growth on the leaves which causes them to fall prematurely. Usually only the conidial stage occurs in tropical countries. As a rule these diseases are not severe, but they sometimes cause considerable loss. They can be readily controlled by the use of Bordeaux.

Rust.—This is a true rust disease, caused by *Uromyces appendiculatus*, (Pers.) Lev. It is well known and widely distributed throughout the bean-growing districts of the world. The mycelial threads penetrate the tissues of the host, finally coming to the under surface of the leaf and forming the characteristic blisters containing the spores. There are two kinds of spores, the brown uredospores and the black teleutospores, which are formed later. In most cases this disease is not of much importance, but late in the season it may cause an excessive dropping of foliage, resulting in the early maturity of the pods and shortening of the crop. It can be controlled to some extent by careful selection of seed from healthy plants only, by the destruction of the rubbish of the field, and by the use of Bordeaux on small areas. This disease also attacks the cow-pea, and other related plants.

Leaf Spots.—Beans also suffer more or less from *Cercospora* and other leaf-spot fungi, but as a rule they do not prove serious.

Rhizoctonia Rot.—This disease, which is so common in tropical countries, attacks the beans. It is most severe in warm, wet weather. It may cause a "damping off" of the seedlings, and it may attack the stems and pods of the older plants. On the stems it produces a dry-rot canker which extends to the pith, and which may eventually cause the death of the plant. In infected areas the pods which come in contact with the soil or with decaying vegetable matter undergo a rot which penetrates their entire thickness.

Spraying cannot be used successfully in combating this disease. However, by careful selecting of seed, cleaning the old fields, and burning the rubbish, and rotation of crops, the disease can be held in check.

Cercosporium urticola has been reported as one of the causes of root rot of the beans in Porto Rico.

PEA

Powdery Mildew.—The powdery mildews are among the most destructive pests of both garden and field. They are widely distributed throughout the world, and under favourable conditions are likely to occur wherever these crops are grown. The stems, leaves, and pods are covered with a more or less dense white mycelium, which produces an abundance of conidia, by which the disease is spread. It can be controlled by the use of Bordeaux mixture.

Blight.—This disease, caused by *Ascochyta pisi*, Lib., is well known from some parts of the world, but so far as the writer knows has not been reported from the tropics. It often attacks the stems of the young plants near the ground, causing more or less circular spots; and on the pods it causes spots which resemble the spots on the bean which are caused by the anthracnose. The disease is carried from season to season in the seed. It can be controlled by spraying with Bordeaux, careful seed selection, burning of debris from the old fields, and crop rotation.

Other Diseases.—Other diseases which are known to attack the peas are the rust, which is caused by *Uromyces pisi*, (Pers.) De Bary, the root rot which is caused by *Thielavia basicola*, (B. & C.) Zopf., and the root and stem rot which is caused by *Corticium* *vagum*, B. & C., var. *solani*, Burt. At least one of these is known to occur on other plants in the tropics, and may be reported at any time.

Root Rot.—A variety of *Necosmospora vasinfecta*, Smith, attacks the cow-pea in tropical and semi-tropical America. Its behaviour is practically the same as the related variety on cotton (page 108), melons, and okra.

PEANUT

Very little has been written concerning the diseases of this very important crop.

Rust.—A disease due to the rust fungus *Uredo arachidis*, Lagh., has been reported from St. Vincent, Dominica, Montserrat, St. Kitts, Cuba, and the Carolinas. It causes minute brown or yellow pustules on the under surface of the leaves, and to some extent on the petioles. As a rule it does not appear until the plants are almost mature, and is frequently confined to the older leaves. The fungus is known only in the uredo stage.

This disease is generally considered of very little importance, although there have been some rather severe outbreaks which injured the foliage and interfered with the maturing of the nuts. Wherever this disease is threatening, it would be well to clean the field thoroughly and burn the old vines. Small plantings can be protected in a great measure by the use of Bordeaux mixture, but it is doubtful if this would be practical on large plantings.

Leaf Spot.—The most important leaf-spot disease is due to *Cercospora personata*, Ellis,[1] which causes rather large, black, circular spots on the leaves, and is also said to attack the very young fruits and to interfere with their development. It has been reported as very injurious in the United States, Porto Rico, and Dominica.

Septogloeum arachidis, Racid, is a fungus which

[1] *Cladosporium personatum*, Berk. & Curt.

attacks the foliage, causing numerous circular, black, velvety, slightly-raised spots, mostly on the lower surface of the leaves, with correspondingly slight depressions on the opposite surfaces. This disease is more or less common in the Eastern Hemisphere, and the same or a similar disease has been reported from Dominica.

Root Disease.—This disease has been reported from Barbadoes, Grenada, Dominica, St. Kitts, and Nevis, but the data is so meagre that it is impossible to say whether it is the same in all places. The diseased plants lose colour, and shrink in some places. The loss from this cause alone has been very great. The fungus causes a cobweb growth of mycelium over the roots, resulting in their death. It then spreads to the collar and the stems. Thus far, no fruiting stage of the fungus has been discovered, but after a time many small brown spherical sclerotia about one mm. in diameter are formed, and serve to perpetuate the pest. This fungus has been reported on the aroids, antirrhinums, and some composites of Barbadoes, on egg-plants, tomatoes, and seedling limes in Dominica, and alfalfa in Antigua. The diseased plants should be pulled and burned, the land limed rather freely, and put in some crop not subject to the disease for some time. The seeds can be sterilized by soaking them in a solution of corrosive sublimate (one part to 1000 parts of water) for five minutes.

CABBAGE AND RELATED PLANTS

Club Root.—This disease is due to *Plasmodiophora brassicae*, Wor., and is widely spread throughout both tropical and temperate regions. It is known under a great many common names; in Germany it is "Kohlhernie," in France it is "maladie digitoire," in Belgium it is "Vingergiekt," in Russia it is "koponstnaga kila," in Great Britain it is "Aubury," "Hamburg," and "finger and toe," and in America it is "club foot," "club root," and "clump foot." The organism gains entrance through the roots, causing them to become more or less enlarged and knotty, and then to undergo a decay. This enlargement frequently begins in the seed beds. The organism is very low in the scale of plant life and attacks a great many other cruciferous plants, in many cases becoming very destructive. The malformations of the roots frequently cause the disease to be confused with the nematode root knot, but an examination with the microscope will readily detect the true cause. It can be controlled to some extent by the selection of healthy plants, burning the diseased plants and rubbish, heavy applications of lime, and the rotation of crops.

Cabbage Rot.—This disease is due to *Pseudomonas campestris*, (Pam.) Smith, and is also widely distributed throughout both tropical and temperate zones. It causes a dwarfing of the plants and a one-sided growth of the heads, or even prevents the formation of a head. It frequently causes the death of the entire plant. Occasionally the heads rot and drop off. The organism, which is a bacterium, enters the plant through the small water pores along the margin of the leaf. The organisms are very abundant, and travel rapidly downward along the fibro-vascular bundles to the stem, and thence outward through the other leaves of the plant. The diseased leaves get yellow, the veins become black, and finally the entire structure dies and falls off. This organism also attacks the turnip, and many other cruciferous plants. No successful treatment is known, but the treatment given for club root would no doubt be helpful in controlling the pest.

Other Diseases.—The cabbage and related plants suffer from a number of other diseases, such as *Rhizoctonia* stem rot, downy mildew caused by *Peronospora parasitica*, (Pers.) De Bary, white rust caused by *Cystopus candidus*, (Pers.) Lev., a soft rot caused by *Bacillus carotovorus*, Jones, and a rot caused by *Sclerotinia libertiana*, Fckl. Our information concerning the occurrence of these diseases in tropical countries and their character is such that we have every reason to expect them at any time.

ONION

Bermuda Onion Disease.—This disease is due to *Peronospora Schleideni*, De Bary. The first appearance of the disease is the formation of a silvery-white powder on the upper surface of the leaves about three or four inches from the base. The disease spreads rapidly and the powder turns a greyish black. Finally the tips turn downward, become dry and withered, and the growth is arrested. It does not attack the bulb, and there is no rot. The air passages of the plants become choked. The fungus reproduces and spreads in the usual manner (see page 39). It is especially abundant in warm damp weather. The remedies are the use of good fertilizers, burning of rubbish, and spraying with Bordeaux.

Macrosporium parasiticum is a fungus which sometimes follows the attacks of *P. Schleideni*, but does not attack healthy plants.

Bacterial Rot of onions in Barbadoes attacks one or more of the inner scales and causes considerable loss. The onions should be kept as dry as possible both while growing and afterwards. Avoid the use of barnyard manure.

There are other diseases of the onion, especially rots, which have received little or no attention.

BEET

Leaf Blight.—This disease (Fig. 82) is widely distributed and no doubt occurs wherever beets are grown. The disease is due to *Cercospora beticola*, Sacc., which causes numerous spots with ashen-grey centres. The leaf becomes dry and black, the disease working from the tip to the base. Bordeaux is an efficient remedy wherever it can be used with profit.

Other Diseases. — The beets are also subject to the attacks of the root disease due to *Rhizoctonia medicagnis*, DC., and *Corticium vagum*, B. & C., var. *solani*, Burt; to the heart rot caused by *Phoma betae*, Frank; to a rust caused by *Uromyces betae*, (Pers.) Kühn; to the scab caused by *Oospora scabies*, Thaxter, which also attacks potatoes; to a downy mildew which is caused by *Peronorpora schachtii*, Fckl., and to the nematode root galls. The scab and the nematode root galls are known to occur in the tropics, and the nature of the others is such that we may expect them at any time.

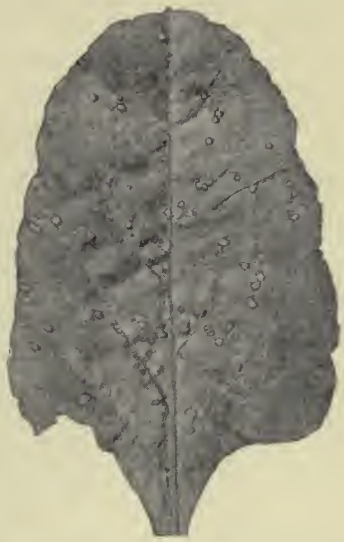

Fig. 82.—Beet leaf affected with leaf spot. *Cercospora betae.*

LETTUCE

Lettuce is known in the temperate regions to suffer from the "damping-off" fungi, such as *Corticium vagum*, B. & C., var. *solani*, Burt; the downy mildew caused by *Bremia lactucae*, Reg.; and the drop which is caused by *Sclerotinia libertiana*, Fckl., and *S. Fuckeliana*, De Bary.

CELERY

"**Damping Off.**"—This is due to the same organism that attacks the potato and various other plants (see page 29). It is very destructive in the seed beds and may prove very destructive in the fields if the conditions are favourable for its development. In the seed beds it should be controlled in the same manner as has been recommended for tobacco, etc. (page 149).

Early Leaf Blight.—This disease is due to *Cercospora apii*, Fr., and is widely distributed throughout the celery-growing districts in the world. It first causes a spotting of the leaves, which later become yellow and dry. The conidia are produced in abundance and the disease spreads rapidly. It can be controlled by the use of Bordeaux.

Late Blight.—This disease is well known in Europe and in the United States, but the writer has not found a record of its occurrence in the tropics. In the countries where known it is most abundant in the fall, and since it occurs in the cooler part of the season it may not occur in the tropics. However, the possibility of its occurrence in the tropics leads the author to give it mention at this time. It is caused by *Septoria petroselini*, Desm., var. *apii*, Br. Cav., and appears as irregular rusty brown spots which spread over the entire surface of the leaf. It can be controlled by the use of Bordeaux mixture.

OKRA

Fusarium Wilt.—The okra suffers from a wilt disease, which is said to be due to the *Necosmospora vasinfecta*, (Atk.) E. F. Smith, which attacks the cotton (see page 108). It should be held in check to some extent by destroying diseased plants, by selecting immune varieties, and by proper rotation of crops.

Leaf Spot.—A leaf-spot disease due to *Cercospora hibisci*, Tracey & Earle, has been reported from the southern part of the United States, and from Cuba. It causes the leaves to turn yellow and fall, weakens the plant and reduces the quantity of the pods. It can be controlled by the use of Bordeaux mixture wherever that treatment is practical.

SWEET POTATO

The sweet potatoes are grown extensively in both tropical and temperate zones. The diseases occurring in the United States have been the subject of extensive studies, but our information concerning the diseases

FIG. 83.—Sweet potato affected with black rot, *Sphaeronema fimbriatum*. (Photo by J. J. Taubenhaus.)

occurring in the tropics is decidedly meagre. Very little can be given at this time except a discussion of those diseases which probably occur in the tropics, especially the American tropics.

Black Rot.—This disease is due to *Sphaeronaema fimbriatum*, (Ell. & Hal.) Sacc. (Fig. 83), and occurs in the seed bed, causing a discoloration on roots and stems of the seedlings which is known as black shank. On the full-grown roots it causes decay spots of various sizes, which upon removal of the skin appear green in colour. Care should be taken to select clean seed roots and clean plants, and rotation of crops should be followed.

Dry Rot.—This disease is due to *Phoma batatae*, Ell. & Hals. It occurs on the underground portion of the plant, causing the upper end of the root to become wrinkled and covered with small pimples or fruit bodies. The disease works downward, converting the interior into a dry powdery mass, with but little change in colour. The only remedy known at present is to collect and burn the diseased roots.

Soft Rot.—This disease is due to that widely distributed organism known as *Rhizopus nigricans*, Ehr. (Figs. 11 and 12). It attacks the roots and does its greatest damage in storage. It causes the root to become shrivelled and the interior to become black with the enormous quantity of spores. It is accompanied by a very disagreeable odour. All diseased roots should be destroyed.

Other Diseases.—Other diseases which have been reported as more or less severe on sweet potatoes, especially in temperate zones, are *Rhizoctonia* root rot, the root rot caused by *Ozonium omnivorum*, Shear.; stem rot caused by *Nectria ipomoeae*, Hals.; the soil rot caused by *Acrocystis batatas*, and the scurf which is caused by *Monilochaetes infuscans*. Also *Lasiodiplodia tubericola*, E. & E., which was found in Louisiana on potatoes imported from Java and also from Florida; *Coleosporium ipomoeae*, which causes reddish brown spots on the leaves; an undetermined species of *Marasmius*, which has been reported by Stockdale; an undetermined species of *Penicillium*, which causes a dry, chalky coloured rot which is usually not detected until the root is cut; *Phyllosticta bataticola*, E. & M., which causes a leaf spot; *Albugo ipomoeae-panduranae*, (Schwein) Swingle, or white rust, which also attacks the leaves.

YAM

Leaf Spot.—A leaf spot due to *Gloeosporium pestis*, Massee, attacks the yams in Fiji, causing numerous black spots on the upper surface of the leaves. It is very severe, and the cause of considerable injury, especially in wet seasons.

TARO, MALANGA, ETC.[1]

These plants appear to be comparatively free from diseases. Barrett[2] says that "all parts of the yautia excepting the parenchyma of the leaf are filled with a thick juice, which protects the plant against the attacks of insects, fungi, and bacteria. A tuber cut nearly in two transversely was recently received from Central Guatemala, without a trace of decay having spread from the wound, the cells at a distance of 1 millimetre from the cut surface being perfectly healthy upon arrival. The juice undoubtedly has great germicidal power."

The most important diseases are as follows:—

Rot.—This disease has been reported as severe on the lowland or irrigated taro of Hawaii. T. F. Sedgwick says that "the disease appears to be of two forms, one of which is due to soil conditions and lack of drainage. The other is of a fungus or bacterial nature, and is due in part at least to the planting of diseased bulbs." The disease usually starts when the plants are about two months old, and is most likely to attack plants which are weak from other causes. It starts at the lower end and works upward, causing the root to become hollow or to rot. The upper part of the plant appears stunted, the leaves curled, yellowish, and spotted, and a cross-section shows a blackening of the fibro-vascular bundles. If the disease attacks the plants when very

[1] This plant (*Colacaisa esculenta*, Schott) is also known as cocoes, tayas, yautia, tanias, tanniers, and eddoes.

[2] Barrett, O. W., *Porto Rico, Agri. Exp., Station, Bul.* 6 (1905).

young the root becomes spherical or oval instead of conical, matures early and rots soon after harvesting. It is very frequently localized in a field and is spread by setting diseased plants, transfer of dirt from place to place, poor irrigation and poor drainage. It can be controlled by proper attention to the above points and by rotation of crops.

Downy Mildew.—This disease has been reported from Jamaica. It attacks the young tubers or heads, and originates and spreads first through the fibro-vascular bundles, and then to the surrounding parenchyma. The fibro-vascular bundles are at first bright yellow, eventually becoming brown or blackish. However, the diseased parts remain dry instead of becoming putrid, as in the case of some other plants when suffering from similar diseases.

The disease is due to *Peronospora trichotoma*, Massee, which reproduces by means of both conidia and resting spores. It apparently gains entrance to the host through wounds only, and if the healthy new plants are allowed to dry some time before planting, it will no doubt prove a great protection against this disease. Fields in which the disease is prevalent should not be reset with this crop for two or three years.

Phytophthora colocassiae, Rac., is the cause of a leaf and corn disease of the colocassia in India and Java.

Leaf Spots.—The yautia of Porto Rico is affected with two leaf fungi, *Pericoria pysnospora* and *Gloeosporium* sp.

It also suffers from a supposed bacterial disease commonly known as "el mal," which attacks the base of the rhizomes, clogs the fibro-vascular bundles, and causes a gradual discoloration and decay, extending over a period of six months before the plants are completely destroyed. All the upper parts of the plants may become attacked, but the tubers rarely suffer, and will germinate, sending up perfectly healthy plants.

The yautia also suffers from some other diseases, which are of little consequence.

CASSAVA

The cassava of Jamaica suffers from a root rot which is due to a fungus. The disease is most common on plantations in new log clearings. On these clearings there is a fungus which is quite common on the old logs and stumps of the logwood, which has been supposed to be the same as the one on the cassava, but the connection has not been satisfactorily traced.

CUCUMBERS AND MELONS, ETC.

Very little is known of the diseases of these plants in tropical countries, but many of the diseases reported in the temperate zones doubtless occur in the tropics.

Downy Mildew.—This is a disease of the cucurbitaceous plants which is known in the United States and Cuba, and is the chief cause of poor cucumber crops in some localities.

It is due to the fungus *Plasmopora cubensis*, (B. & C.) Humphrey, which causes the leaves of the diseased plants to show yellow spots with indefinite outlines. In a short time the whole leaf becomes shrivelled and dies. The disease starts with the oldest leaves and works towards the tip of the vine. It can be controlled by spraying with Bordeaux mixture.

Water-melon Wilt.—This disease is caused by a variety of *Necosmospora vasinfecta*, E. F. Smith, which is very closely related to the variety which attacks the cotton (page 108). The character of the fungus and the disease is very similar to what has been described for cotton, and the remedy is practically the same.

Other Diseases.—The "damping-off" fungi *Pythium De Baryanum*, Hesse, and *Corticium vagum*, var. *solani*, Burt, attack the cucurbitaceous plants. These fungi are known to occur in the tropics, but have not been reported on these plants. Other diseases of these plants which may be reported from the tropics at any time are the anthracnose caused by *Colletotrichum* *lagenarium*, (Pass) Ell. & Hals.; the blight or wilt caused by *Bacillus tracheiphilus*, Smith.

PASSION VINE

Woody Fruit.—This disease has been described by Cobb as follows:—

The portions of the surface which crack—generally the lower parts, as the fruit hangs on the vine—turn to a dirty white or very light russet colour, and the surface cracks off in thin layers, leaving a rougher and more russet surface; that is to say, a dry corrosion takes place. Before the dirty-white area cracks away its margin is sometimes separated from the green and intact parts of the fruit by a green area, where the cells seem to have collapsed without losing their green colour. If a fruit showing the foregoing appearances is plucked, it will, after forty-eight hours, begin to "crinkle" on the green parts, but will remain unchanged in the woody parts—remain quite hard, dry and woody.

Macrosporium Rot.—This disease of the ripe or half-ripe fruits has been described by Cobb as follows:—

Spots which at first are greenish on the purple background of the fruit, later turn brownish or buff, and show a somewhat concentric arrangement of slightly varying colours. Ultimately the skin or shell of the fruit becomes very thin and brittle at the diseased spot, and caves of its own accord as the result of some slight accident.

Either this or another species of *Macrosporium* is said to be the cause of a leaf-spot disease. There is also a *Gloeosporium* rot of the leaves, and a shot-hole disease of the leaves.

VANILLA

Although a number of fungi have been reported on the vanilla, the information concerning their importance is very meagre. The most destructive, so far as known at the present time, is *Calospora vanillae*, Massee, which has three stages, the *Hainsea*,[1] *Cytospora*, and

[1] This stage is also said to be a synonym of *Gloeosporium vanillae*, Cke. & Mass., which has been reported on the orchids *Onicidium* and *Dendrobium*.

Calospora stages. The *Hainsea* stage occurs on both the living stems and leaves, the mycelium spreading through the tissues and eventually killing the entire plant. The *Cytospora* and *Calospora* stages are developed later on the dead leaves. The disease has been reported from Seychelles, Reunion, Antigua, and Mauritius.

The disease can be controlled by burning the diseased refuse which has fallen to the ground, and by careful drainage.

Other fungi which have been reported on the vanilla are, *Vermicularia vanillae*, Delacroix; *C. oligochaetum*, *Gloeosporium lagenarium*, *G. affine*, Sacc.; *G. bussei*, Hemm.; *Uredo scabies*, Cooke (from Colombia); *Uromyces Joffrini*, Delacroix, and *Nectria borgoriensis*, Bernard. More definite information will doubtless prove some of the above names to be synonyms.

CLOVE

The clove trees are comparatively free from disease, or at least if subject to diseases there is very little available information on the subject.

Mildew.—An undetermined fungus, which apparently belongs to the *Peronosporeae*, has been reported from the Malay and Straits Settlements. It originates as a dark-red irregular spot, more or less rounded, and $\frac{1}{20}$ to $\frac{1}{5}$ inch in diameter. It is scattered irregularly over the leaf, usually most abundant near the edge and visible on both sides. It attacks the leaves before they are fully opened or have attained their full green colour.

The centre of the spot becomes hard and black, and the oil glands swollen and protuberant. At length on the under (rarely upper) surface may be seen with hand lens a fine white hair-like mildew. This is made up of sporophores, bearing three to nine short arms, and at the apex of each arm a yellow sporangium.

This disease is very severe on seedlings, and will also kill trees which are 12 or 14 feet in height. It can be easily controlled by the use of Bordeaux.

Root Disease.—A root disease due to a fungus has been reported as destructive from Malacca, but the literature concerning it is so meagre that the writer cannot give a discussion at this time.

Irpex flavus, Klotsch, has been reported on the cloves for Malacca (see pp. 65, 168, 196).

GINGER

Very little has been written about the diseases of this plant, but what is, or may prove to be, a very serious trouble has been reported from Jamaica.[1] It is due to a fungus which attacks the rhizomes or underground parts of the plants. Although there is no satisfactory description of this fungus it is recommended that where very destructive the old plants should be burned, and the new rhizomes be soaked in Bordeaux before planting.

NUTMEG

A bark disease due to *Eutypa erumpens*, Massee, has been reported from the Barbadoes, Grenada, and Trinidad. It also occurs on the cacao.

A root disease due to *Corticium javanicum*, Zimm., has been reported from Java.

RAMIE—CINCHONA

Both ramie and cinchona are subject to the attacks of *Corticium javanicum*, Zimm., in Java.

PEPPER (*Piper nigrum*)

Wilt Disease.—This disease, which is well known in parts of the East Indies, is caused by a species of *Nectria*. Both the fungus and the general character-

[1] *Jamaica Bulletin* for November and December of 1901 and February of 1902.

istics of the disease as it occurs on the pepper, so far as known, are the same as on the pigeon-pea (see page 98). The pepper plants are also attacked by the nematode gall worm (*Heterodera radicicola*), which, in addition to the injuries which it causes, no doubt facilitates infection by the *Nectria*.

A root disease of the pepper has also been reported from Mysore, but without satisfactory data for discussion.

A soil fungus, which is said to be related to *Dematophora necatrix*, Hartig., is also reported from the East Indies, and the destruction of the plants by fire is recommended for its control.

MULBERRY

Twig Disease.—This disease is due to the fungus *Coryneum mori*, Mom., and so far as known occurs only in India and Japan. It affects nursery stock and full-grown trees, but seldom attacks trunks or branches of more than one inch in diameter. It produces a canker which may spread along the branch for as much as three inches before completely girdling it. The part of the branch beyond the point of attack dies, but the disease does not spread backward. It stunts the growth of the larger trees and frequently attacks and girdles young trees near the ground. It becomes visible externally by a bursting out through cracks in the bark of a number of hard black cushions of fungus tissue, after which the affected area becomes depressed and dark. It grows upon dead parts of the plant fully as well as, or better than, on the living parts. The mycelium of the fungus is confined to the bast cells and inner bark cells until it breaks through to form its fruiting structure. It is a wound parasite, and it is very doubtful if it can gain entrance through heathy bark. It also occurs on *Celtis caucasica*.

The only satisfactory remedy is to cut and burn the diseased parts, and also all dead wood. Pieces of dead wood, prunings, etc., if allowed to remain on the ground, form suitable places for the fungus to grow and fruit, and thus aid the spread and perpetuation of the disease.

The **Leaf Spot** (*Septogloeum mori*, (Lev.) Briosi and Cavara) occurs also in Europe, where it is sometimes called rust. It occurs chiefly on the younger leaves, where it produces angular spots, pale-brown in the centre and surrounded by dark reddish brown bands. These spots may be $\frac{1}{4}$ inch in diameter. On the upper surface are little raised pustules. In moist weather these pustules swell into rounded, pale-coloured blisters, which contain numerous spores. The leaves drop, and in very moist weather the loss is sometimes 10 per cent of the foliage. The spores are elongated, colourless, rounded at the ends, and segmented by three to five cross walls, usually curved. They germinate readily in water.

The disease can be controlled readily by the use of Bordeaux where practicable to use it.

The **Mildew** of the mulberry (*Phyllactinia corylea*, (Peri) Karst.) occurs in India, Japan, and Madagascar. It occurs on the under sides of the leaves, and produces the characteristic effect. It is not serious.

The **Mulberry Trunk** Rot (*Polyporus hispidus*, (Bull.) Fr.) also occurs on the apple, plum, and apricot in Kashmir and many other trees in Europe. It is a wound parasite which attacks the trunk and large branches, causing the heart wood to undergo decay and become soft, spongy, and yellowish-white. In discussing this disease, Butler says :—

> Separating the outer healthy layers of young wood from the rotten central portion is a hard brown zone, consisting of cells filled with a brown gummy matter; in this the parasite takes its main development. It is nourished in the brown zone mainly by the cell contents, while the walls are at first left unaltered. Only at a later period, when the cell contents are exhausted, is the wall crowded and the wood itself softened.

The diseased branches usually die, but the trunk may become hollow, due to the decay of the heart wood, and still live. The sporophores are at first pale-yellow, soft, watery rounded knobs about one inch in diameter, but grow into large hemispherical bodies which are sometimes six inches across. The upper surface is convex and the lower almost flat. The upper surface is a chestnut colour and covered with soft hairs. The lower surface is filled with long yellowish-brown tubes, which exude water while forming, even in dry weather. The sporophore remains soft until quite old, and then becomes hard, black, shrunken, and cracked. However, the inner part retains its deep-yellow or chestnut-brown colour. The diseased parts should be cut and burned.

OTHER DISEASES

Spike Disease.—This is a disease of the sandal wood which has been reported from Coorg, Mysore, and other places in the East. It may attack all or only a part of a tree, causing a peculiar deformity. The leaves become narrow, pointed, and stiff, and very much crowded together, and the internodes much shorter than in the normal plants. As each successive growth is produced the above characters become more and more intensified, until eventually the new shoots have the appearance of spikes with bristles. This excessive growth continues the year round without cessation. All studies up to the present time have failed to demonstrate the presence of any specific organic parasite which will account for this unsightly and destructive disease. The failure to discover any organism which will account for the disease has led some investigators to consider it a physiological disease, due to an "intensified carbon assimilation." The only satisfactory treatment which can be recommended at this time is to cut and burn the diseased trees.

Bastard Woods.—Trees which differ from others of their kind, and for which there have been numerous unsatisfactory explanations, have been found in various places. The most notable instance of this kind is the so-called bastard logwood (*Haematoxylon campechianum*) of Jamaica. This peculiarity, for it cannot properly be called a disease, has been studied by Professor F. S. Earle, who came to the conclusion that it was simply a variation from the ordinary or normal type.

CHAPTER VIII

DISEASES OF FOREST AND ORNAMENTAL TREES

The diseases of forest trees are among the last to receive the attention of man, partly because nature has grown them without his interference, and partly because the cost of applying remedies is usually so great as to preclude all efforts at control, except those which are carried on by the government as problems in national economics. However, when any particular forest tree for which there is a great commercial demand, or our shade and ornamental trees are suffering from an epidemic, the public comes to fully appreciate that the trees, whether planted by mother nature or by the hand of man, are subject to numerous diseases which reduce their vitality and their value, and destroy great numbers of them.

It is no wonder that the diseases of the forest trees of tropical countries, where nature has been so prodigal, have received little or no attention. However, the numerous diseases which occur on coffee, tea, cacao, rubber, coco-nut, and other trees, and which have been discussed in previous chapters, are ample proof that an enormous number of diseases occur on the trees of our native forests. It is also well known that some of these diseases of forest trees are transmitted to certain of our cultivated plants of other species, thus being a double menace to the productiveness and welfare of the country.

Although most, if not all, of these diseases have been considered in the preceding chapters, it appears wise to give some special attention to the subject at this time.

The organisms which cause these diseases attack the leaves, stems, and roots, but in a state of nature those on the leaf rarely become destructive, although they draw upon the tree's strength, reduce its vitality, and frequently make it more susceptible to other and more dangerous parasites.

The diseases of the roots, trunks, and branches may be due to many causes, which may be grouped under the following heads :—

1. Diseases caused by flowering plants.
2. Diseases caused by algae, bacteria, slime-moulds, lichens, and fungi.
3. Diseases caused by mechanical injuries.
4. Diseases caused by unsuitable soil.
5. Diseases caused by unsuitable climate.
6. Diseases due to unknown causes.

Wound Parasites.—Many of the parasites which cause very destructive diseases of our trees are unable to attack the plants unless they gain entrance through wounds. This is especially true of the organisms which attack the trunks, stems, or branches of trees, and cause both disease of the living trees and decay of the timbers. Many of these organisms are primarily saprophytic and live on old logs, stumps, dead branches, etc., but when they gain entrance to the living plant through wounds they become partially parasitic and frequently cause the death and destruction of the entire plant.

This class of organisms and the diseases which are caused by them are especially destructive to forests and to fruit trees.

Under natural conditions these wounds may be caused by wind-storms, hail-storms, insects and other animals. Under cultivation the wounds may also be the result of careless cultivation, pruning, tapping, and of accidents in gathering the fruit.

The organisms live in the dead logs, stumps, twigs, and debris of the forest or orchard where they reach maturity and produce their spores. In fact, many species produce spores only on the dead and decaying materials, but these spores will grow on either dead or living plants. When wounds occur these spores are readily transferred by means of wind, insects, etc., to the injured parts. Of course not all wounds are inoculated with these germs of disease; in fact very few of them are, otherwise it would be practically impossible to grow tree crops of any kind.

Prevention.—It would at first appear absurd to attempt prevention of this class of diseases, but a little thought shows that much can be done, and that much more will be done in the future. (1) The destruction of injurious insects, where possible, will have a twofold value in that it will prevent the injuries by the insects which make the entrance of the organisms of disease possible, and also reduce the distribution of the organism; (2) careful pruning and the painting of the wounds will prevent the entrance of the organisms of disease; (3) the removal of logs, stumps, dead twigs, and other debris; (4) the cutting out and burning of diseased parts as soon as the disease appears, and painting the resulting wounds; (5) the absolute removal and destruction of badly diseased plants; (6) greater care in cultivation, tapping, and gathering of fruits of both wild and cultivated plants.

As timber becomes more scarce and more expensive it will no doubt be found to be profitable to make use of certain orchard methods in the care of forests, and these methods can always be used to advantage on shade and ornamental trees.

The most important of these wound parasites are the fungi. So little has been written on these diseases, with special reference to tropical plants, that it will be necessary in most cases to make these discussions very general.

Fomes.—This genus includes some of the most destructive species known in the tropics. They are wound parasites, and require considerable moisture; for that reason they are most abundant and most destructive in dense, damp forests, and rather uncommon in open forests, orchards, and shade trees. The sporophores are hoof-shaped, woody, and may be either sessile or stalked, and the pores are narrow. *Fomes semitostus*, Berk., has been reported as a root disease on the Para rubber tree (*Hevea braziliensis*) in the Straits Settlements and Federated Malay States (see page 195). It has been also reported on the cacao in Ceylon, and probably attacks many other trees.

Polyporus.—The various species of this genus are also very destructive in the temperate zones and have been frequently reported from the tropics, but have not been thoroughly studied. They are also wound parasites, and the sporophores are very similar to *Fomes*, except that these are at first fleshy and later become hard. They also vary greatly in shape.

P. hispidus, (Bull.) Fr., is the best known. It occurs on the trunk of the mulberry trees in Europe. It is a wound parasite, and attacks the trunk and larger branches, causing the heart wood to rot. *P. obliquus* and *P. fumosus* are reported as parasitic on the orange in Malta, *P. flavus* on coffee, and an undetermined species has been reported on the stems of rubber, tea, and other plants, but has not been studied.

Agaricus.—Many of the species belonging to the genus *Agaricus* are the causes of parasitic diseases and saprophytic rots. This genus is characterised by gill or leaf-like structures over which are spread the basidia or spore-bearing bodies. The genus also includes many species that live on the decaying matter in the soil, some of which are edible.

Corticium. — The fruiting bodies of the genus *Corticium* have smooth surfaces, on which the basidia are borne. It is widely distributed in tropical countries, and attacks many plants. Among the most important on cultivated trees are *C. javanicum*, Zimm., and *C. Zimmermanii*, (Sacc.) Syd., which attack coffee, tea, cacao, and rubber trees. Further knowledge of this genus will no doubt prove that its species attack a very large number of our forest and shade trees.

Nectria.—Very few tropical fungi have received as much attention as the species which belong to the genus *Nectria*. At least two species (*N. cinnabarina*, (Tode) Fr., and *N. ditissima*, Tul.) are widely distributed throughout both tropical and temperate regions. They are strictly wound parasites which attack various parts of the plants.

The mycelium penetrates the tissues, living primarily in the tracheary tissues of the host. The bark on the part which is suffering from the attack becomes shrivelled and dies. Eventually, wart-like bodies, about the size of millet seed, and of a yellowish, brownish, or reddish colour, are produced. On the surface of these bodies are grown great numbers of the conidia spores by which the fungus spreads rapidly. After a time these bodies cease to produce the conidia and become somewhat firmer in texture, and bear the perfect fruit or spores of the fungus. In this later condition they contain more or less flask-like cavities within which are borne the little sacs or asci. Each ascus contains eight 2-celled spores which are usually hyaline and elliptical. These organisms are most destructive on the cacao on which are recorded *N. theobromae*, *N. cinnabarina*, *N. ditissima*, *N. coffeicola* on the stems; *N. Bainii* on the pods; and *N. striatospora* on both stems and pods; *N. ditissima* occurs on both coffee and tea. *N. diversispora* and *N. funtumia* occur on rubber.

Exoascus.—The species of this genus attack leaves (see page 42), fruits, and buds. When they attack the buds they usually cause the formation of witches' brooms. The most important of these witches' brooms which has been reported is the one on cacao, which is caused by *E. theobromae* (see page 183). These unsightly growths should be removed and burned so as to prevent the formation of spores and the spread of the disease.

Witches' Brooms are also caused by several other fungi and by insects,—more especially the mites. They are not only injurious to trees, but are very unsightly.

These brooms frequently die in advance of the tree, which then assumes a very ragged and ugly appearance. While it may not be practical to treat this class of diseases in a forest, they can be treated in orchards and on ornamentals. They should be pruned out and burned.

Other Fungi.—There are many other fungi which attack the roots and stems, some few of which have been referred to in previous chapters. Our limited knowledge of these organisms and the diseases caused by them make it impossible to give a discussion of them at this time, even were it advisable to do so in a work of this kind.

Epiphytes.—These plants grow upon many of our forest and cultivated trees, using them as supports, but not feeding upon them. They are not parasites in any sense of the word, but do cause considerable injury by interfering with the normal physiological activities of the trees.

Climbing and Smothering Plants.—Climbing plants sometimes destroy young trees and kill parts of matured trees by compressing the parts to which they cling, and interfering with or shutting off the passage of the plant fluids and foods through its growing parts, in which case all of that part of the plant beyond the point of compression dies.

Many tropical trees are checked in their growth or killed by other plants which grow over and smother them. In some cases the seed of a rapid-growing plant germinates on some part of its victim and sends out root growths which eventually reach the ground. In the American tropics the seeds of certain species of *Ficus* frequently lodge at the base of the leaves of the palms, germinate, sending roots to the ground and branches upward and eventually completely enclose the trunk of the palm, which continues to grow, giving the appearance of a double tree.

Mistletoe.—These partly green, flowering plants are common not only in the tropical, but also in semi-tropical and temperate climates. They are only partially parasitic. The seeds are carried by birds, and having lodged on a suitable host plant, they germinate and produce haustoria or root-like processes which penetrate the host. In a short time there is a definite and inseparable union between the two plants. However, the mistletoe being a green plant is not dependent upon its host for carbohydrate foods, but may be considered as a water parasite.

These plants are often so abundant as to give a characteristic aspect to the scenery of the country in which they exist. However, they are detrimental to the health of the trees, causing them to be stunted, sometimes irregular in shape, and sometimes killing parts. Frequently the mistletoe dies in advance of the host, leaving rough holes through which insects, fungi, bacteria, and other causes of disease gain entrance to the plant. They should be removed and the wounds painted with coal tar.

Other Seed-Bearing Parasites.—There are a great many other flowering plants which have assumed a partially parasitic habit. Many of these plants live in the soil but produce haustorial growths which penetrate the roots of their hosts. In some species (of which the *Orobanche* of the tobacco, hemp, etc. (page 159), is an example), the seeds cannot grow well unless in close contact with the roots of the host to which they are restricted; but the seeds of other species will grow equally well whether in direct contact with the host or absolutely removed from it.

Bacterial Diseases.—The bacterial diseases of plants are quite common on the succulent parts, such as the leaves, fruits, bulbs, fleshy roots, and young growths. Since they do not often attack the hard parts of plants, the trees are comparatively free from this class of diseases. Probably the most conspicuous and best known of these organisms attacking a tropical or rather semi-tropical tree is *Bacterium savastanoi*, which causes the tubercle or knot disease of the olive. Further study will doubtless reveal many others.

Lichens.—These plants are very common on trees of all kinds. They are epiphytic or semi-saprophytic in nature, but they interfere to a greater or less extent with the normal physiological activities of the plants. When they prove a pest or give an unsightly appearance to fruit, shade, or ornamental trees, they should be treated in the manner described on page 123.

Soil and Climate.—The diseases due to soil and climatic conditions are many. Sometimes they can be recognised and remedied, while in other cases they are difficult to recognise and often more difficult to remedy. In a state of nature these troubles are not so noticeable, since if the conditions are unfavourable for a certain species of plants, they naturally give way to those plants which find the conditions favourable.

In the case of plantings, the unfavourable conditions of either soil or climate usually so weaken the vitality of the tree as to make it especially susceptible to organic troubles which frequently result in its death. Many of the diseases of fruit and ornamental trees are due to attempts to grow these trees under unfavourable conditions, thus causing them to be weak and unable to resist the attacks of root fungi and other organisms.

Diseases of Foliage.—This class of diseases has been treated under other heads, so that it is not necessary to take it up at this time. The native foliage diseases to which the species of trees of any part of the world may be subject are usually of comparatively little importance, but diseases may be introduced which may prove very destructive. Foliage diseases may be treated upon many classes of cultivated trees, but it is not practicable to give treatment to forest trees for such troubles.

Diseases of Roots.—The diseases of roots of trees are very poorly understood, but they doubtless do considerable damage to forest trees as well as of cultivated trees. They have been referred to in connection with other subjects.

Mycorrhizas.—The roots of many plants are frequently, and with some species usually, found to be infested with fungus mycelium, which penetrates between and into the cells, but which does not, to all appearance, seriously affect the vitality of the plants. These organisms have been the subject of considerable study, and many students of botany believe that there is a definite symbiotic relationship between the two plants; that the fungus receives certain food substances and in turn performs certain services for the host plant. This has been disputed, but it nevertheless means that the presence of a fungus on the roots of a plant is not necessarily a cause of disease.

Nematodes.—These little pests, which are known to be so widely distributed with reference to both flora and locality, are known to attack coffee and orange trees. They doubtless attack many of our forest, orchard, and ornamental trees. They are not only the cause of serious injuries, but they facilitate the attacks of many root fungi. They can be guarded against in the nursery by the proper rotation of crops, and orchard and ornamental trees can be protected to some extent by the use of carbon bisulphide.

Pruning.—No hard and fast rules can be given for pruning any tree, but there are certain precautions that should be observed in making the cuts in pruning. All cuts should be made in such a way as to make a wound that will heal easily. All cuts should be made parallel to the trunk or limb from which a branch is cut. If large limbs are to be cut, an undercut should first be made, in order that the weight of the limb when being severed does not cause it to fall before the cut is completed, and in so doing to tear the bark down on the trunk. Such wounds are very common and are dangerous sources of disease infection. Such wounds are entirely avoidable, and are always an ear-mark of careless pruning (Figs. 84, 85).

Wounds under two inches in diameter usually heal readily without further care, providing the cut has been perfectly made. Wounds of larger size than two inches should be painted over so as to prevent entrance of disease spores during the long time of exposure necessary before healing over has been completely accomplished.

For treatment of such large wounds many substances have been recommended, but in general an ordinary stiff white lead paint will suffice. Too much oil in the paint should be avoided as the free oil will often seriously injure the cambium layer of the wound and prevent healing.

If a paint is too thin it may be thickened by the addition of ochre.

Coal tar may be used, and the ordinary grafting

FIG. 84.—Tree showing proper method of removing a branch. (Photo by J. J. Taubenhaus.)

waxes are sometimes used, but they usually peel off after the the first season.

If a wound is rough, carefully pare it off smooth, especially the edges. Very large wounds can often be protected by tacking a piece of tin, that has been cut to fit, over the wound. Such a piece of metal should be a little smaller than the surface of the wound, thus allowing a layer of new wood to form over its edges.

When large decayed spots are formed in either trunks or limbs of trees they can often be successfully filled with concrete. In concreting a cavity great care must be used to clean out all decayed and decaying wood before putting in the filling.

DISEASES OF SEEDLINGS

The seedlings of all classes of plants are especially susceptible to the attacks of fungi, which destroy great numbers in Nature's garden and become especially destructive in seed-beds.

Phytophthora omnivora, De Bary, is one of the

FIG. 85.—Tree showing improper method of removing a branch. (Photo by J. J. Taubenhaus.)

most widely distributed organisms, and is known to be very destructive to seedlings. It has been reported on *Acer*, *Alonsoa*, *Abies*, *Aralia*, *Cleome*, *Clarkia*, *Cereus*, *Epilobium*, *Fagopyrum*, *Fagus*, *Gilia*, *Larix*, *Lepidium*, *Melocactus*, *Oenothera*, *Picea*, *Pinus*, *Solanum*, *Sempervivum*, *Salpiglossis*, etc.

Pythium De Baryanum, Hesse, is another very widely distributed organism which is very destructive to seedling trees. It has previously been referred to in this work.

The *Rhizoctonias* are also very destructive to many species of seedling and also to plants which are quite large. They are especially injurious to nursery stock.

ENTOMOGENOUS FUNGI

The fungi are not only the causes of diseases among plants, but many of them are also the cause of diseases of animals. Fish are attacked by Saprolegnia, and young fish are frequently destroyed in great numbers; the higher animals are attacked by certain fungi which cause diseases of the skin, and other parts; but by far the greatest sufferers are the insects, which are subject to the attacks of a large number of species of fungi. No doubt many insects are held in check by their inconspicuous fungus enemies, most of which are unknown to us.

Some of the earliest observations on these interesting fungi were made in the tropics. In 1754, Father Torrubia collected specimens in the vicinity of Havana, Cuba, and wrote a popular description of what is now supposed to have been *Cordyceps sphecocephala*. Since that time many species have been reported and described, and many efforts have been made to turn our knowledge of these species to some advantage in combating certain species of injurious insects.

The entomogenous fungi are most common on the larva of insects, but some species also attack the adults. Aquatic and other insects which live in moist places are especially susceptible to the attacks of these fungi. Among the most conspicuous of these entomogenous fungi are the species belonging to the genus Cordyceps (see page 46). However, this genus is of no very great economic importance in the control of insects.

Of the many efforts which have been made to use the entomogenous fungi in combating insect pests, the most satisfactory results have been obtained by P. H. Rolfs and H. S. Fawcett of the Florida Agricultural Experiment Station in the control of certain *Coccidae* and *Aleyrodidae.* Some of the most important of these fungi and the insects on which they prey are as follows :—

The genus *Aschersonia,*[1] belonging to the Sphaeropsidales (page 61) contains several species which attack insects, among the most important of which are *A. aleyrodis*, Webber, which is well known in Florida and Jamaica, where it destroys *Aleyrodis citri*, and in Cuba, where it attacks *A. citri* and *A. Howardii.* It has been reported on several undetermined species in Ceylon, while uncertain reports have indicated that in Java it occurs on *A. longicornus* and in Brazil on *A. horridus.*

Fawcett says—

The first indication of the effect of the fungus on the larva of the white fly is the appearance of slightly opaque, yellowish spots unusually near the edge of the larva. In the early stages of infection the larva becomes noticeably swollen, and appears to secrete a greater abundance of honey-dew than normally. As the fungus develops, the interior organs of the larva appear to contract away from the margin, leaving a narrow circle, which becomes filled with hyphae. Shortly after this the hyphae burst out around the edge, forming a dense marginal fringe. This may form all around the larva at about the same time, or develop at one portion of the margin sooner than the others. Death usually ensues, it is believed, before the hyphae burst out. The fungus does not spread over the leaf to any extent, but grows upward in a mass, gradually spreading over the larval scale. It is not uncommon to find the pycnidia, with their bright, coral-red masses of sporules, formed in a circle around the edge of the larva while it is yet visible. As the Aschersonia develops, the hyphae spread over the larva, forming a dense compact stroma, which ultimately entirely envelops the larva. The stroma in this stage is thin and disc-like, the fructification being usually borne in a circle near the edge. The hyphae, which make up the main mass of the stroma, are from

[1] Some species of *Aschersonia* are supposed to be the imperfect stage of *Hypocrella*, an Ascomycete.

3·5 to 7·5 micro-millimetres in diameter. Within the body of the insect, and near the pycnidia, they are somewhat smaller.

The spores can also be mixed in water and sprayed on to the trees that are infested with these pests. The spray pump which is used for this purpose should not be used for spraying with chemicals, and should not be fitted with copper parts.

A. flavo-citrina, P. Henn., has been reported on *A. citri* in Florida and Cuba, and has also been reported from Brazil. *A. turbinata* has also been reported as parasitic on *Ceroplastes floridensis* in Florida and *A. sclerotioides*, Henn., has been reported on scale insects of the rubber trees.

Verticillium, a genus belonging to the Hyphomycetes (see page 53), contains a number of species which are parasitic on insects. The most important tropical species is *V. heterocladum*, Penz, which attacks *Aleyrodes citri*, *Mytilaspis citricola*, *M. Gloverii*, *Lucanium* sp. of orange and *Diaspis* sp. (from *Enonymus americanus*) in Florida, and *Leucanium hesperidum* of lemon in Italy. It has also been reported from the West Indies, South America, and Africa.

Fawcett describes it as follows :—

> *Verticillium heterocladum*, in general appearance, resembles the brown fungus of Webber (Plate IV., Fig. 31). On close examination, however, it is found to be strikingly different. The pustules, which are cinnamon-coloured, are powdery on the surface. Under the hand-lens they appear brush-like in form, bristling with hyphae. From the edge of the pustules there grows out a creeping layer of white, delicate, interwoven hyphae.

There are a number of other species of *Verticillium* which are parasitic on insects.

Sphaerostilbe coccophila,[1] Tul., is one of the most widely distributed and important of the entomogenous fungi. It belongs to the Hypocreales and occurs in nearly every tropical and temperate country of the world, and attacks a much larger number of insects than any

[1] Syn. *Micocrocera coccophila*, Desmaz.

other member of this group. It has been reported as follows[1] :—

Aleyrodes citri, R. & H.	Florida.
Aspidiotus ancylus, Putnam	Florida.
Aspidiotus articulatus, Morgan	Jamaica. West Indies. West Africa.
Aspidiotus aurantia, Mask.	Australia. Natal. Ceylon.
(*Chrysomphalus aurantia*), Mask.	Transvaal.
Chrysomphalus conidum, Linn.	Transvaal.
Aspidiotus ficus, Comst.	Florida.
Aspidiotus hederae (Vall.)	Florida.
Aspidiotus obscurus, Comst.	Florida. Alabama.
Aspidiotus perniciosus, Comst.	Florida. Japan. Ceylon.
Chionaspis citri	Cuba.
Diaspis pentagona, Targ.	Japan.
Fiorinia fioriniae, Targ.	Mauritius.
Ischnaspis filiformis	West Indies.
Mytilaspis citricola, Pack	Ceylon. Cuba. Porto Rico. Florida.
Mytilaspis Gloverii, Pack.	Florida.
(*Lepidosophes*) *Gloverii*, Pack	Transvaal.
Parlatoria pergandii, Comst.	Florida.

It has also been reported on insects from Southern Europe, and on *Chionaspii citri* from Dominica, St. Lucia, St. Vincent, and Grenada.

The diseased insects die, become dry and easily detached. The fungus forms a very small, red, more or less elongated out-growth from one end of the insect, on the upper surface of which numerous conidia spores are borne. This outgrowth eventually becomes darker red in colour and produces a red stroma on which numerous small, hemispherical perithecia are produced. The fungus is inconspicuous, and is capable of destroying a very large number of insects without being noted by the casual observer.

[1] Table copied from Fawcett.

Microcera, sp., is a fungus belonging to the Hyphomycetes which has been reported as attacking the *Aleyrodes citri* in Florida. It appears to be of considerable importance, but has not been fully studied.

Aegeritia Webberi, Fawcett, which is commonly known as brown fungus has been reported from Florida as important in the control of the *Aleyrodis citri.* It was first reported by Webber, and later described by Fawcett, who says that "it sends out long, straight, colourless hyphae, which grow not only over the under surface of the leaf, but around the edges and upon the upper surface." It is brownish in colour and of considerable importance.

Ophionectria cocicola, E. & E., which is commonly known as the white-headed fungus, belongs to the Hypocreales. It has been reported from Florida and Dominica, where it is said to be very efficient in its work on *Mytilaspis citricola* and *Chionaspis citri.* It forms white knob-like outgrowths on the dead insects, on the surface of which numerous conidia are borne.

Myriangium duriaci, Mont, is a fungus belonging to the Plectascineae which is commonly known as the black fungus. It has been reported on *Mytalaspis citricola* and *Chionaspis citri* from Florida, St. Lucia, St. Vincent, Barbadoes, and Dominica. When the insects are very abundant and the weather favourable, the fungus spreads from insect to insect, forming a black crust containing softer areas in which the asci are borne. This disease should not be confused with the black blight disease of the lime and other citrus trees.

The Shield Scale Fungus, so far as the writer knows, has not been determined, but is said to attack *Lecanium hemisphericum*, *L. hesperidium*, *L. viride*, *L. nigrum*, and *L. oleae*, and has been reported from Barbadoes, St. Vincent, Grenada, Antigua, Dominica. The dead insects become dry and papery, and covered with a buff-coloured fungal growth which produces numerous spores.

CHAPTER IX

PREVENTION AND CONTROL

THE discussion in this and the following chapter must necessarily be very general. Success in treatment for prevention or eradication of any pest depends largely upon an INTELLIGENT, PROGRESSIVE, PUBLIC-SPIRITED POPULATION. Success depends not only on the intelligence and progressiveness of a few individuals, but upon the patriotism of the populace. Although the individual working alone can accomplish enough to amply repay for the time, labour, and money expended in much of this work, the greatest good to the largest number will be accomplished by *co-operation*—co-operative work not only in the treatments for these pests, but in securing the enactment and enforcement of necessary laws.

Experiment Stations.—All progressive agricultural countries are now provided with agricultural experiment stations, for the study of all problems of agriculture in which the country is interested. Experimental work can usually be carried on in these stations to much better advantage than by the individual agriculturist. However, co-operative work between the stations and the people is always desirable, and frequently necessary, especially in countries where the environmental conditions vary. The progressive agriculturist will find it greatly to his advantage to keep in close touch with the experiment station of the country in which he is working.

Commonness and Destructiveness of Plant Diseases.—It is the prevailing opinion that plant diseases are becoming more and more abundant and more destructive, and this belief is in a great measure true. While the species of organisms which cause the diseases may not have increased in number, they have become more widely distributed. This wide distribution is due to the improvements in the facilities for travel, and to commerce, immigration, increased agricultural interests, increased commerce in agricultural products, the introduction of plants from one part of the world to another, and the development of new varieties of plants.

The emigrant carries the plants which he has been accustomed to use for food and ornamentation into his new home, and on some of these plants are introduced the organisms which cause plant diseases. Improved facilities for transportation have developed a commerce in perishable fruits and vegetables on which organisms of disease, especially those which cause decay, are introduced from one place to another. The increase in transportation, commerce, and population has been accompanied by an increase in agriculture throughout the world. This increase in agriculture has necessitated the introduction of useful plants from one part of the world to another, and these introduced plants have carried with them the various organisms of disease to which they were subject in their original habitat. These diseases may have proved more or less destructive in their new environments than in their old homes, or they may have spread to other plants, on which they have become more destructive than on their original hosts. This is well illustrated by the mildew of the American gooseberries, which has been introduced into Great Britain and become very destructive on the English varieties, although it is of little consequence on the American varieties, and by the mildew of the American grape which has been introduced into Southern Europe and proved so destructive, although of little consequence on the American grapes.

It is also true that the introduced plant may meet with organisms of disease on related plants in its new home which it cannot withstand. The European plums, when introduced into America, met with a very severe disease known as black knot (*Plowrightia morbosa*), which is of comparatively little importance on American plums. It is said that coffee when growing wild in its original habitat was not subject to the rust (*Hemileia vastatrix*), but that the fungus is a native of some part of the East Indies, where it is parasitic on some wild rubiaceous plant, from which it passed to the coffee on its introduction into the locality of the parasite.

Furthermore, the introduced plant frequently meets new climatic and soil conditions which decrease its vitality, and make it more susceptible to organisms of disease than it was in its original habitat.

The practical agriculturist has also selected plants with reference to the marketable value of the products, and without regard to the susceptibility of the plants to disease. This has frequently resulted in the growing of varieties which could not resist the diseases.

The increase in population and in agriculture has also given opportunities for diseases to spread with ease from farm to farm, and from one locality to adjoining communities.

Prevention of Disease.—In the adoption of methods for the prevention of disease it must be remembered that the plant is the central factor, and that the interests of the practical agriculturist centres round a healthy plant rather than the diseases of the plant. The diseases and the organisms causing them receive very little or no attention unless circumstances make a study of them imperative. Therefore, from the standpoint of the agriculturist, it is much more important to grow strong, vigorous plants that are resistant to diseases than to care for sick plants. This idea has led to experimental studies for the purpose of selecting or developing *immune varieties*. It is well known that plants are subject to great variations, and that by selecting those varieties which were the most suitable for our purposes, agricultural and horticultural interests have been greatly advanced. If it is possible to select or develop varieties which produce improved fruits, grains, etc., it is also possible to secure immune varieties in the same manner. In a state of nature, many species of plants have been able to resist disease and maintain themselves, while under cultivation, varieties of these same species suffer considerable loss and are sometimes destroyed.

In fact, in recent years certain wild species known to be resistant to diseases have been selected and grown with the idea of improving them and supplanting closely-related cultivated varieties which were subject to disease, only to find that after a few generations the progeny were as great sufferers from the disease as the varieties that had been cultivated for many generations. This is because in a state of nature those wild individuals or varieties which were non-resistant have been destroyed, while the resistant ones have survived. For many generations cultivated plants have been selected with reference to the market values of their products and without regard to their power to resist diseases. In recent years the plant breeders have demonstrated that it is as possible to develop and select varieties which are immune to certain diseases, as it is to develop and select varieties which possess any other character. Notable instances of this is the development in the United States of a variety of cotton which is resistant to root rot and a variety of clover resistant to anthracnose.

Much of this work can be done by the individual grower. If a particular crop is seriously diseased, the grower should examine it carefully for healthy or comparatively healthy plants, which should be reset or from which the seed should be kept for use the following year. These plants or this seed should be used on the same land as the preceding crop, so that it may be grown as nearly as possible under the same conditions and have all possible opportunity to contract the disease. This new crop should be carefully examined, and plants selected or seed saved from the healthiest and most desirable plants. Continuation of this method from year to year will in many cases prove extremely helpful in the prevention of some diseases. However, the grower should bear in mind the necessity for selecting plants which possess a combination of desirable characters, characters which give us the desired commercial product as well as characters which give healthy plants.

Removal of Diseased Individuals.—In some cases plant diseases can be held in check by the removal of diseased plants, thus preventing the rapid spreading of the disease. This method is especially useful in orchards, and can also be used to great advantage in combating corn smut and mosaic diseases of tobacco. The diseased plants should be burned, and care should be taken not to bring them in actual contact with healthy plants, since many diseases can be readily transmitted by contact.

The pruning out and burning of diseased parts of trees is a very successful method of holding certain diseases in check. However, since many organisms of disease will continue to live and produce spores on the part that has been removed, it becomes especially important that these diseased parts should not be thrown on the ground and left unburned, unless the grower is thoroughly familiar with the disease and the organisms that produce it, and knows that these organisms will perish after removal from the host plant. The wounds which are made as a result of this pruning should be painted with white lead, tar, or other antiseptic preparations, to prevent infection by the same or different organisms of disease. In some cases it is also desirable that the workmen's tools should be disinfected.

Cleaning of Fields.—Some organisms of disease persist from year to year on the dead plants and debris of the fields. When a disease of this kind has been very abundant in a field, precaution should be taken after the harvesting of the crop to collect and burn the debris and waste parts of the plants, thus destroying great quantities of spores and mycelium. This precaution is especially necessary where the field is used repeatedly for the same crop.

Roadways, fence-rows, waste fields, etc., should be kept free from debris and plants on which a disease may thrive and be passed to the cultivated plants. A single old and neglected tree may foster enough diseases to seriously injure a large orchard, and a few stray tobacco or tomato plants may serve as a nursery for a host of diseases for the field and garden. Weeds and many other wild plants, both native and introduced, are frequently the carriers of the organisms of disease. Old stumps and logs in newly-cleared ground are frequently the finest of nurseries for fungi which attack coffee, cacao, and many other plants.

Rotation of Crops.—Certain classes of diseases, especially root and tuber troubles and diseases caused by Fusariums and bacteria, live in the soil, sometimes for many years. When such diseases become destructive, a new field should be selected for the crop, and a crop of an entirely different character placed in the old field, thus removing the host plant and allowing the disease organisms to perish for want of satisfactory nourishment.

Stock Feeding.—The spores of certain organisms of disease will pass through the digestive tract of an animal and then grow. Therefore, when the host plant is used for stock feed and the animals allowed to run at large or the manure used on the fields which are intended for this same crop, the animals involuntarily become the disseminators of the disease. The manure containing these spores may also be carried on the wheels of wagons and farm implements, and on the feet of labourers. Such manure should be used on fields intended for crops of an entirely different character. Corn smut and rots of various kinds which are prevalent on fleshy roots and fruits are frequently scattered by these methods.

Clean Seeds. — The progressive agriculturist will always take the precaution to use clean seed, if possible selecting the seed from the healthiest, most desirable plants. Seed may carry the organisms of disease in two ways: the spores may cling to the seeds and be planted with them, germinate in the soil and penetrate the young plant; or the organisms may have penetrated the seeds, sometime during their development, and lie dormant, ready to start into activity and grow with the growth of the young plant.

Sterilization of Seed.—Where the spores of the organism cling to the seeds, it is frequently possible to destroy the spores without injuring the germinating qualities of the seeds by dipping the seeds in certain solutions (see page 280). This method may also be used with certain diseases of tubers (potato scab), but cannot be used successfully where the disease organisms penetrate the seeds during their development.

Clean Plants.—Where the young plants are grown in the seed beds and then transplanted to the fields, care should be taken that none but healthy plants are used. These plants can also be sprayed to advantage with fungicides before the plants are pulled.

The soil of the nursery beds can also be treated to destroy the organisms of disease (see page 149).

Nursery Stock.—Nursery stock should be carefully guarded by the nurserymen and by the buyer. It is much easier to care for healthy than for diseased trees, and no man can be justified in knowingly selling or in planting diseased trees or shrubs. The fact that the disease is already prevalent in the community is no excuse for furthering its distribution.

Destruction of Insects.—Insects are frequently the carriers of organisms of disease, and also make wounds through which these organisms penetrate. While it is impractical to take preventative measures against some of these insects, others can be held in check very advantageously. Flea beetles not only cause direct injury to the plants, but also make favourable conditions for many fungi. This is especially true in tropical countries.

Drainage.—Poor drainage frequently results in weak plants which are especially susceptible to disease, and at the same time makes conditions especially favourable for the growth of the organisms of disease. Improvement in the drainage system where the character of the soil will permit will usually give the desired results in such cases.

Fertilizers.—The use of fertilizers presents a much more complicated problem than the mere supply of plant food to the agricultural crop. The proper use of fertilizers depends upon the experience and good judgment of the farmer, and no definite rules can be given for all countries, all soils, all crops, and all conditions. In general we believe that strong rapid-growing plants are more vigorous, and therefore more resistant to diseases. However, in some cases a rapid growth means a soft plant which is more susceptible to the diseases than if the same plant were grown more slowly. Over-fertilization, or rather the improper use of fertilizers, may also result in soft fruits and vegetables which are especially susceptible to rots and very unsuitable for long shipments. Fertilizers may also act upon the soil in such manner as to make it unfavourable for the growth and development of certain organisms of disease. Lime is detrimental to many soil fungi, and is used as a remedy for *Plasmodiophora brassicae*, Wor., the cause of club root on cabbage and related plants. Lime has also been recommended for use in trenches around trees suffering from root diseases, to prevent the spread of the organisms through the soil; but its value has been questioned by some persons with whom the writer has corresponded.

Spraying.—Spraying is medicine. When people are sick they want medicine, although the proper application of the laws of sanitation and health will frequently give much better results. So when the crops are diseased the grower usually wants to spray, although the application of the preceding rules of this chapter might give much better results.

However, in many cases we must spray for the reduction and destruction of certain classes of disease organisms. Spraying should be done at the proper time and in the proper manner, and not only for the purpose of curing the diseased plants, but for the protection of the healthy ones; in fact, the protection of the healthy plants is usually of much greater importance than the curing of diseased plants.

When the organism of disease is confined to the surface or very near the surface of the plant, it may be possible to effect a cure by the use of the spray, but when the organism penetrates the tissues of the plant it is beyond the reach of the spray so far as curing that individual plant is concerned. However, the spray will kill the spores which may be formed on that plant, and thus in a measure prevent the spread to neighbouring plants and other parts of the same plant. The spray on healthy plants will also prevent the germination of the spores which may have been carried from diseased plants. Spraying is of no value whatever in the treatment of diseases due to bacteria.

The use of a fungicidal spray may also be detrimental if applied at such times as to interfere with the fungi which are destructive to injurious insects. Fungicides and spraying apparatus and their uses will be considered in the next chapter.

Quarantine.—Diseases are frequently introduced from one country to another on plants and seeds, and even upon commercial products. Some of the most destructive diseases have been carried in this manner. Plants or seeds should never be transplanted from one country to another without being subjected to rigid inspection and quarantine. In fact, it is sometimes advisable to institute inspection and quarantine between districts of the same country. To this end, such laws should be enacted as will be protective but not burdensome to the population.

The experiment station or individual who may be interested in the introduction of foreign plants should also provide a quarantine garden where the new plants can be subjected to observation and study for a considerable period of time. THE MISCELLANEOUS, UNDIRECTED INTRODUCTION OF PLANTS MAY RESULT IN GREATER LOSS THAN GAIN.

CHAPTER X

FUNGICIDES AND SPRAYING APPARATUS

A FUNGICIDE is any substance which will destroy or prevent the growth of the spores or the mycelium of fungi. They are usually used only against fungi which cause diseases, especially those which cause the diseases of plants, but they are also used to prevent the decay of timbers. They must be of such a character as to destroy or hold in check the injurious parasites, and at the same time not be injurious to the host plants, nor prove injurious to human beings or lower animals which may use the plants for food. The fungicide must also be of such character as will not discolour or injure the beauty of fruits and vegetables, and thus reduce the market value. It must be remembered that the market value of many plant products depends fully as much upon the appeal to the eye as to the palate.

Since the fungicide must be harmless to the host plant, it is self-evident that it will be most effective when used against those organisms which are confined to the surface of the plant. But since the internal parasites must come to the surface of the host plant to produce their spores, the fungicide can be used to destroy the spores as rapidly as formed, and thus prevent their spread to the neighbouring plants and to other parts of the same plant. It can also be used to prevent the germination of the spores on the surface of healthy plants.

The time and number of applications must depend upon the character of the host plant, character and life-history of the disease organism, and the local climatic conditions. Therefore, much depends upon the intelligence and experience of the agriculturist.

Only the most general rules for the use of fungicides can be given in a work of this character. In warm, moist climates and seasons, the applications should usually be more frequent than where the humidity is less. If there is any uncertainty as to the effect of the fungicide on the plants, it should be tried on a very few and the plants observed for 24 or 48 hours, before it is used on the other plants. Some trees (peach) cannot be sprayed with the ordinary fungicides while in foliage.

FUNGICIDAL MIXTURES

Bordeaux Mixture.—This is one of the oldest and best remedies, and is used more extensively than any other. It derives its name from Bordeaux, France, from whence it originated. The discovery of its importance as a fungicide was due to an accident. It was first used on grape vines in order to make petty thieves think that the fruit had been poisoned, but it was soon discovered that the vines on which it was used were much healthier than those which were not so treated. It is a mixture of copper sulphate, lime, and water, in which the copper sulphate is the real fungicide, the lime being used to change the copper sulphate into a form which will not be injurious to the host plant, and to prevent the injurious effects of free copper sulphate; and the water is used as the solvent and carrier. The proportions generally used are:—

Copper sulphate . . .	4 or 5 lbs.
Unslaked lime . . .	6 lbs.
Water	50 gallons.

Put twenty-five gallons water in a barrel or other suitable container, tie the copper sulphate in a bag, and suspend just beneath the surface of the water and allow to dissolve. Always use a wooden or brass vessel for this purpose; the copper sulphate will attack iron.

Put the lime in another vessel, and add a little warm water. Continue to add small quantities of water until the lime is thoroughly slaked and in a smooth paste. Now add enough water to make a total of twenty-five gallons, and stir thoroughly. Pour the two preparations together slowly into a third container, and stir thoroughly.[1]

The mixture should now be tested to determine if there is enough lime to counteract the injurious effects of the copper sulphate on the foliage. This can be done as follows:—Pour a little of the mixture on a porcelain plate or saucer, hold between the light and the eyes, and blow the breath gently upon the surface for a minute or longer. If the mixture is properly made a thin pellicle, having the appearance of oil on water, will form on the surface; or, add a drop of potassium ferrocyanide (poison) to the mixture, and if it changes colour it will be necessary to add more lime. The second is better than the first, and, in fact, is the only strictly reliable method.

The mixture should be *strained* before using, but if the lime has been strained and all the preparations made and kept in clean vessels, this will not be necessary.

The proportions of lime and copper sulphate are varied in amount for different purposes. Sometimes as much as six pounds of copper sulphate is used, while in other cases only one pound is used with one and a half pounds of lime.

Considerable difficulty is experienced in climates where the humidity is great from air-slaking of the lime. Air-slaked lime will not make good Bordeaux mixture. However, the difficulty can be overcome by slaking a quantity of lime and keeping it in concentrated stock for use. It keeps well if kept moist, but is worthless if allowed to become dry. In fact, the two preparations are frequently made separately in concentrated form and kept in stock, to be diluted and

[1] If desirable, only one preparation need be diluted previous to mixing. *Never mix the two in a concentrated form.*

mixed when needed. The mixture will not keep. The mixture can be combined with insecticides and the two used as a single spray.

This mixture discolours the plants, and for that reason cannot be used on fruits which are nearly ready for market. Therefore, it is frequently necessary to use some other preparation for the last spraying of certain crops.

Copper Sulphate.—Copper sulphate may be dissolved in water in proportions of one pound of the copper sulphate to twenty-five gallons of water, and used on trees when not in foliage to remove lichens and to kill the spores and mycelium of fungi, but cannot be used in trees in foliage without danger.

Burgundy or Copper-Soda Mixture.—This mixture is recommended as a substitute for Bordeaux by Mr. George Quinn, of South Australia. It consists of

Copper sulphate	6 lbs.
Sodium carbonate (washing soda) . .	9 lbs.
Water	50 gallons.

It is made in the same manner as Bordeaux mixture. This mixture has been recommended by the English workers in Australia, who claim that it is efficient in protecting many plants against their fungus parasites, and that it is not so severe on young foliage as the Bordeaux mixture. The writer is not familiar with its use.

Ammoniacal Copper Carbonate.—

Copper carbonate . .	5 oz.
Ammonia	3 pints.
Water	45 gallons.

Dissolve the copper carbonate in the ammonia. This solution can be kept and diluted for use at any time, but it spoils easily after dilution with the water. It is a clear blue liquid, and is used as a substitute for Bordeaux when fruit is near maturity, and also on green-house plants. It is not so good as Bordeaux, but it does not discolour the fruit, and thus reduce its market value. Many plants are more susceptible to this mixture than to Bordeaux, and it should be used with caution. It should never be used without first making a test on a few plants.

Potassium Sulphide.—

Water	10 gallons.
Potassium sulphide . .	3 oz.

Heat a few quarts of water and dissolve the potassium sulphide in it, then add enough cold water to make a total of ten gallons. It is used to control powdery mildews and rusts.

Iron Sulphate and Sulphuric Acid.—

Hot water . . .	100 pints.
Iron sulphate . .	as much as will dissolve.
Sulphuric acid . .	1 pint.

Put the iron sulphate in a wooden vessel, pour on the acid and then the water. Use fresh and apply with a swab. It is used for anthracnose and cankers on stems, for disinfecting wounds, etc. It must not be used on the foliage.

Carbolic Acid.—Equal parts of crude carbolic acid and water is sometimes used as a wash in the treatment of the gummosis of citrus and other fruits.

White Lead.—It is used to paint wounds in order to prevent the entrance of fungi.

Coal Tar.—Its use is to paint wounds to prevent the entrance of fungi.

STICKER

It is very difficult to make spray mixtures stick to some plants, but this difficulty can usually be overcome by using a sticker made as follows :—

Resin	2 lbs.
Sal soda (crystals) . .	1 lb.
Water	1 gallon.

Mix and boil until the preparation is a clear brown ; about $1\frac{1}{2}$ hours. *Avoid danger from fire by boiling in the open, in an iron kettle.* Dilute with from 50 to 100 gallons of Bordeaux mixture.

STEEPS

Formalin for Oat Smut and Stinking Smut of Wheat.—Put one half-pound of formalin in thirty gallons of water. Immerse the grain for two hours and then spread out to dry. The solution may also be sprinkled on the grain, which is then piled up and covered for two hours, after which it is spread out to dry. This is only successful against those species of smut in which the spores cling to the seeds. It is not successful against corn smut, nor against the loose smut of wheat.

Formalin for Potato Scab.—Put one half-pound of formalin in fifteen gallons of water, and immerse the tubers for two hours. Cut and plant in the usual manner.

Hot Water for Smuts.—This treatment can be used for the same species of smuts as the formalin treatment. Provide two large vessels with warm water, one at a temperature of 110° to 120° F., and the other 132° to 133° F. These are to be used for dipping the grain. Also provide extra vessels of hot and cold water, to be added to the first two when necessary to maintain the correct temperature. Put the grain in a closely-woven basket or wire cage or loose woven bag, and dip in the first vessel (110° to 120° F.) until thoroughly wet, then dip in the other, and lift out about six or eight times in the course of ten minutes. Spread the grain out to dry. The operator should be careful to keep the water at the required temperature; use a vessel that will hold six or eight times (by volume) as much water as seed to be dipped at any one time; and also be careful that the basket or bag is not entirely filled for dipping.

Corrosive Sublimate for Potato Scab.—

Corrosive sublimate . .	2 oz.
Water	15 gallons.

Dissolve the corrosive sublimate in a small amount of water, using a wooden vessel. Then add the entire fifteen gallons. Put the potatoes in a bag and immerse for one and a half hours. Dry and cut and plant. CAUTION.—*Corrosive sublimate* is a *poison*, and should be handled with care.

Seed-Bed Treatment.—The treatment of seed beds for protection against "damping off" and other fungi has been discussed in connection with the seed-bed diseases of tobacco (page 149).

SULPHUR

Sulphur is one of the cheapest fungicides that we have. It has a fungicidal value either in the pure form or combined with other substances. For many years sulphur has been the favourite remedy for mildews on plants grown in artificially-heated glass houses, the sulphur being made into a paste and placed upon the steam or hot-water pipes, and thus allowed to give off sulphur fumes.

Owing to the fact that sulphur seemed to be of but small efficiency in controlling organisms other than mildews, it soon fell into disuse in combating diseases of field crops. Bordeaux mixture proved more efficient and easier to handle, and practically replaced all other commercial fungicides. However, the foliage and fruits of many plants proved to be susceptible to serious injury from applications of Bordeaux mixture, and many investigators were on the look-out for a new fungicide which would be as efficient as Bordeaux mixture and still harmless to the tenderest of foliage.

Peach diseases were particularly hard to handle, Bordeaux mixture practically defoliating the trees. In 1907 W. M. Scott, of the United States Department of Agriculture, was successful in checking some peach disease with a combination of lime and sulphur. Lime sulphur had been used for years as a remedy for scale insects on dormant trees, but was entirely too caustic in its action for use upon trees in full leaf. From Scott's experiments there have grown up two good sulphur fungicidal compounds, one known as self-boiled lime sulphur, and the other as commercial or boiled lime sulphur. The first is used upon plants that have a very delicate foliage, while the second can be used upon plants where foliage or fruits are not easily injured by fungicides.

Self-Boiled Lime Sulphur.—

Caustic lime (unslaked) . .	8 lbs.
Flowers or Flour of Sulphur .	8 lbs.
Water	50 gallons.

Place the lime into a barrel or other convenient receptacle. Start to slake with cold water. Add the sulphur, which has previously been made into a paste with a little cold water, and cover the barrel up at once with either a wooden cover or some coarse sacking in order to hold the heat. Usually it will be necessary to add two or three gallons of cold water when the slaking is most vigorous. Keep the mixture well stirred throughout the operation. When all boiling has ceased add enough water to make up to fifty gallons, and carefully strain into the spray tank. Work all the free sulphur possible through the strainer. If larger or smaller amounts are desired use proportionate parts or multiples of the above formula, and proceed in the same manner. Sometimes it will be found necessary to start the lime to slaking with hot water. A mixture made with hot water will be found to be much more caustic upon foliage than one made with cold.

Arsenate of lead or arsenate of lime may be used with this spray as an insecticide; but Paris green should not be used in connection with any of the lime-sulphur mixtures.

Boiled Lime Sulphur.—This material has been used for a number of years as an insecticide for scale insects upon dormant trees. However, it has been found that it is an efficient remedy for many plant diseases, and can be applied to a large number of trees in full leaf if proper dilutions are made.

Home Boiled Lime Sulphur.—

Caustic Lime (unslaked) .	50 lbs.
Flowers or Flour of Sulphur .	100 lbs.
Water to make . . .	50 gallons of finished product.

This formula requires external heat to prepare, so that it must be prepared either by means of fire or with live steam. If fire is used direct, a large iron kettle that holds over 50 gallons will answer the purpose. If steam is available, a wooden tank or barrel can be used. Make the sulphur into a thick paste with either warm or cold water. Put the lime into the kettle or barrel and pour the sulphur paste over it. As soon as slaking begins, add more water until 15 or 20 gallons are in the receptacle. As soon as slaking and mixing is over, make up to 50 gallons. Bring to a boil and keep boiling for one hour. The material should be kept well stirred, especially during the early stages of the process.

The finished product should be strained at once into a barrel or other container, and is regarded as a stock solution. This material should have a specific gravity of about 1·24 or 28° Beaume scale.

Commercial Boiled Lime Sulphur.—This material is the same as above, only that it is prepared by manufacturing chemical companies and put upon the market as a highly concentrated form. The commercial article will usually have a specific gravity of about 1·28 or about 32° Beaume scale.

Stock solutions of lime-sulphur, either home-made or commercial, should be kept in closed containers to prevent chemical changes due to contact with the air.

The amount that the stock solutions should be diluted for treatment of plant diseases varies according to season and tenderness of foliage. As no two stock solutions are necessarily of the same strength, we have to rely upon a density test in order to dilute our sprays intelligently. This is done with a little instrument known as a hydrometer (which may be obtained from any large chemical supply house).

Most plants will stand some certain strength without danger to foliage, as, for example, the apple will stand a solution of 1·01 specific gravity.

Every variety of plant should be tested by treatment of one or two plants before any wholesale spraying is done. As soon as a solution is formed that is safe, its specific gravity should be taken and whole numbers of plants treated with a solution of like density.

The process of dilution is well described by J. P. Stewart in Bulletin No. 99 of the Pennsylvania Experiment Station, and is as follows:—

THE PROCESS OF DILUTION

In the application of any concentrate, either home-made or commercial, it is essential that a definite method of dilution be followed. Two solutions may look exactly alike and yet differ widely in density, so that any accurate method must be based primarily on the density of the concentrate that is being diluted. Moreover, we believe that recommendations based on the density of diluted spray are preferable to those based on the number of dilutions, even when accompanied by a statement of the concentrate's density.

Accurate dilution is very simple and easily accomplished with the aid of a hydrometer having a specific gravity scale. (The presence of foreign soluble materials or of much roily sediment in the sample will vitiate the test, a fact which may be taken into account—the former especially in solutions of unknown preparation. Also, for exact work the temperature of the concentrate should be within about 10° of that stated on the outside of the instrument.) Sprays of any desired density may be obtained from any concentrate by simply getting the reading of the concentrate and dividing the decimal of this reading by the decimal of the spray desired. For example, if the reading of the concentrate is 1·27 (about 31° Beaume), to get a spray of 1·03 density we divide the ·27 by ·03 and obtain 9, which is the number of dilutions required, and which of course is obtained by adding eight volumes of water. In this we are simply applying the general fact that the density of the solution heavier than water varies inversely with the number of dilutions. The workings of the process may be seen further in the following :—

(A) To determine number of dilutions.

Rule :

$$\frac{\text{Decimal of concentrate}}{\text{Decimal of spray desired}} = \text{No. of dilutions.}$$

Examples :

$$\frac{(1)\cdot 24}{(1)\cdot 03} = 8, \text{ or } \frac{(1)\cdot 25}{(1)\cdot 01} = 25, \text{ or } \frac{(1)\cdot 30}{(1)\cdot 03} = 10, \text{ or } \frac{(1)\cdot 30}{(1)\cdot 003} = 100.$$

(B) To determine density of spray used.

Rule :

$$\frac{\text{Decimal of concentrate}}{\text{Number of dilutions}} = \text{Decimal of spray.}$$

Examples :

$$\frac{(1)\cdot 26}{10} = \cdot 026, \therefore \text{ Spray} = 1\cdot 026 \text{ specific gravity.}$$

$$\frac{(1)\cdot 27}{50} = \cdot 0054, \therefore \text{ Spray} = 1\cdot 0054 \text{ specific gravity.}$$

This method gives final sprays of definite density, and the importance of this is obvious when we consider the relatively small margins between safe and unsafe densities in the use of these solutions on foliage.

The following is a table which gives readings of equal value for either specific gravity scale or Beaume scale of density.

[Table

READING ON HYDROMETER.

Degrees Beaume.	Specific Gravity.	Degrees Beaume.	Specific Gravity.
35	1·3181	24	1·1983
34	1·3063	23	1·1885
33	1·2946	22	1·1788
32	1·2831	21	1·1693
31	1·2719	20	1·1600
30	1·2608	19	1·1507
29	1·2500	18	1·1417
28	1·2393	17	1·1328
27	1·2288	16	1·1240
26	1·2184	15	1·1153
25	1·2083		

SPRAYING APPARATUS

For properly combating plant diseases some sort of spraying apparatus is needed if satisfactory results are to be obtained. There are many manufacturers of spraying apparatus, and practically all manufacture spraying equipment that is efficient.

There are several types of spraying equipment upon the market, and the grower has a large range to choose from. Spraying machinery may be roughly divided into two classes, "hand-sprayers" and "power-sprayers."

Hand-sprayers consist of some sort of a force pump installed in a barrel or tank. In purchasing a spray pump there are several points in the construction that should be examined into. Every pump should be furnished with some sort of an air-chamber in order that a steady uniform pressure may be obtained. The working parts of the pump that come into direct contact with the spraying solution should be constructed of brass or bronze, as these metals are not likely to be corroded readily.

The pump should be compact and have no projecting parts to catch upon limbs. It should be of simple construction that can easily be taken apart for cleaning or repairs. The suction portion of the pump should be provided with a good brass screen. Some provision should be made for agitation. Jet agitators should be avoided on hand-pumps as they are too wasteful of power. In short, a good spray pump should be simple of construction, easy to operate, maintain equal pressure, be non-corrosive, and furnish good agitation.

Power-sprayers may be roughly divided into two classes—(1) those in which the power is applied to a powerful pump by means of some sort of an engine, (2) those where the power is supplied by a compressed gas. Carbon dioxide or air are the two gases most commonly used.

Engine-Sprayers.—The most popular engine used is the gasoline engine, although a steam engine can be used. Gasoline engines have a great advantage over steam engines in that they are much lighter and can be built more compactly, thus occupying but little space. Gasoline engines are easy to operate, and give the most general satisfaction of all types of power-sprayers. The engine should have at least $1\frac{1}{2}$ horse-power, but a 2 horse-power will be found to be more satisfactory.

Gas Sprayers.—Gas sprayers may be traction or non-traction. A traction sprayer is one where the spraying power is derived from the wheels of the spray wagon or cart. The wheels are attached to power-pumps which handle either liquid or air, and the spray mixture is pumped into a strong air-tight chamber, from whence it is driven by the compression of the air in the chamber. Such sprayers are very satisfactory for spraying garden crops, such as tomatoes, potatoes, etc., where a continuous spray is maintained as the outfit moves across the field. Some of them are also very satisfactory for orchard work.

Non-traction gas sprayers are operated by compressed gas that has been compressed in tanks that are attached to the spray tank. They furnish the ideal spray, but they are as yet far from perfect and have many faults. In large orchard operations where a central air-compressing plant can be maintained and compressed air be used for power, this type of machine has proved very satisfactory.

Spraying Accessories.—Every spray outfit should be supplied with two lengths of good rubber hose at least twenty-five feet in length. Bamboo extension rods are a necessity where trees are to be sprayed. Good brass strainers should be provided. Extra nozzles and hose should always be kept on hand. The nozzles should be of a type that furnish a mist-like spray at a minimum pressure. Nozzles of the Vermorel or Cyclone type are most desirable. A good nozzle should not dribble, and should be of such construction that it can be easily cleaned when clogged.

LITERATURE

GENERAL

BANCROFT, C. K. Fungi causing Diseases of Cultivated Plants in the West Indies. West Indian Bulletin 10, pp. 235-268 (1910).

BARBER, C. A. Studies in Root Parasitism. Memoir of the Department of Agriculture in India, vol. i. No. 1, 1906 (Botanical Series), and vol. ii. Nos. 4 and 5, December 1907.

BARCLAY, A. Rust and Mildew in India. Journal of Botany, vol. xxx. (1892).

BENNETT, ARTHUR. Host Plants of Brown Rape (*Orobanche*). Naturalist, London, 1904 (25).

BUTLER, E. J. An Account of the Genus *Pythium* and some Chytridiaceae. Memoir of the Department of Agriculture in India, vol. i. No. 5, February 1907.

Some Diseases of Cereals caused by *Sclerospora graminicola*. Memoir of the Department of Agriculture in India (Botanical Series), vol. ii. No. 1 (1907).

COBB, N. A. Letters on the Diseases of Plants. Department of Agriculture, New South Wales, Miscellaneous Publications, No. 149.

COOK, MEL. T., and HORNE, WM. T. Primer Informe Anual de la Estación Central Agronomica de Cuba, pp. 147-207 (1906).

Insects and Diseases of Vegetables. Estación Central Agronomica de Cuba, Bulletin 12 (1908).

DUGGAR, B. M., and STEWART, F. C. The Sterile Fungus Rhizoctonia, etc. New York, Cornell Agricultural Experiment Station, Bulletin 186 (1901).

EARLE, F. S. Health and Disease in Plants. Journal of the New York Botanical Garden, vol. iii. pp. 195-202.

EVANS, I. B. POLE. Notes on Plant Diseases. Transvaal Agricultural Journal, vol. v. pp. 580-682 (1907).

GREEN, E. E. Tropical Agriculturist and Magazine, Ceylon Agricultural Society, Colombo, October 1905.

HORNE, W. T. Report of the Standing Committee on Insects and Diseases. Annual Report of the Cuban Horticultural Society, vol. iii. pp. 59-67 (1909).

HEALD, F. D., and WOLF, F. A. New Species of Texas Fungi. Mycologia, vol. iii. pp. 5-22 (1911).

KIRK, T. W. Bacterial Diseases of Plants. New Zealand Department of Agriculture, Bulletin 23 (1909).

KRISCHEEWSKY, O. Krankheiten tropischer Nutzpflanzen. Zeit. f. Pflanzenkrankheiten, vol. xviii. 276-285 (1908).

LOUNSBURG, C. P. Pears and Pear Blight, Prune Rust, Dry Rot of Potato, Potato and other rejections by the Transvaal (5 papers). Agricultural Journal of Cape Town, 1908–9 (30 pp.).

MAY, D. W. Annual Report of the Porto Rico Agricultural Experiment Station, 1904.

M'ALPINE, D. Rusts of Australia.

Systematic Arrangement of Australian Fungi, 1895.

M'CARTHY, GERALD. The Diseases and Insects affecting Fruit Trees and Plants. North Carolina Experiment Station, Bulletin 92 (1893).

PETCH, T. Brown Root Disease. Circulars and Agricultural Journal of the Royal Botanical Garden, Ceylon, v. (1910), No. 6, pp. 47-54.

Tropical Agriculturist and Magazine, Ceylon Agricultural Society, April 1906.

RACIBORSKI, M. Parasitische und epiphytische Pilze Javas. Bull. de l'Acad. des Sc. de Cracovie, Cl. des Sc. Mathém. et Nat. (1909), pp. 346-394.

SMITH, J. G. Annual Report of the Hawaii Agricultural Experiment Station, 1904.

SOUTH, F. W. Fungus Diseases of Ground Nuts in the West Indies. West Indian Bulletin, vol. xi. No. 3 (1911).

Report on the Prevalence of some Pests and Diseases in the West Indies for the Year 1909–10: I. Fungoid Diseases. West Indian Bulletin, vol. ii. (1911), No. 2, pp. 73-85.

TRYON, HENRY. Report on Insects and Fungus Pests, No. 1 (Queensland 1889), pp. 144-145.

WARD, H. MARSHALL. On some Relations between Host and Parasite in certain Epidemic Diseases of Plants. Proceedings of Royal Society, xlvii. pp. 393-443.

ZIMMERMANN, A. Tropische Pflanzenkrankheiten. Br. Landw. Ost-afrika, Heidelberg, vol. ii. p. 1900, 11-36.

SUGAR-CANE

BARBER, C. A. Sugar-cane in Godavery and Ganjam Districts. Bulletin of the Madras Department of Agriculture, vol. ii. Bulletin 43.

Report on the Diseases affecting the Sugar-cane in the Barbadoes, 1893.

BUTLER, E. J. Fungus Diseases of the Sugar-cane in Bengal. Memoirs of the Department of Agriculture in India (Botanical Series), vol. i. No. 3, Pusa, 1906.

The Selection of Sugar-cane Cuttings. Agricultural Journal of India, vol. ii. part ii. pp. 1-9 (1907).

COBB, N. A. The Inspection and Disinfection of Cane-cuttings. Hawaiian Sugar-Planters' Association Experiment Station, Bulletin 1 (1905).

Cobb, N. A. Fungus Maladies of the Sugar-cane. Hawaiian Sugar-Planters' Association Experiment Station, Bulletin 6 (1909).

Fungus Maladies of the Sugar-cane. Hawaiian Sugar-Planters' Association Experiment Station, Bulletin 5 (1906).

Notes on some Diseases of the Pine-apple. Hawaiian Forester and Agriculturist, vol. iv. pp. 123-144 (1907).

Fungus Maladies of Sugar-cane. Pilzkrankheiten des Zuckerohrs, 1906.

Gumming of the Sugar-cane. Hawaiian Sugar-Planters' Association Experiment Station, Bulletin 2 (1905).

Cook, Mel. T., and Horne, Wm. T. Insects and Diseases of Corn, Sugar-cane, and Related Plants. Estación Central Agronomica de Cuba, Bulletin 7 (1907).

Edgerton, C. W. Some Sugar-cane Diseases. Agricultural Experiment Station of Louisiana, No. 120 (1910).

Colletotrichum falcatum in the United States. Science, N.S., vol. xxxi. pp. 717-718 (1910).

The Diseases of Sugar-cane. The Louisiana Planter, vol. xliv. pp. 484-485 (1910). Also The Modern Sugar-Planter, i. No. 4, pp. 9-10 (1910).

Fawcett, H. S. The Red Rot of Sugar-cane. Florida Experiment Station, Press Bulletin 150 (1908).

Ferro, E. T. The Enemies of the Sugar-cane in Cuba. The Louisiana Planter and Sugar Manufacturer, vol. xlii. p. 233 (April 1909).

Fulton, H. R. The Root Disease of Sugar-cane. Louisiana Experiment Station, Bulletin 100 (1908).

Gage, A. T. Diseases of Sugar-cane in Bengal. Agricultural Ledger, No. 5 (1901).

Howard, Albert. On *Diplodia cacaoicola*, P. Henn., a Parasitic Fungus on Sugar-cane and Cacao in the West Indies. Annals of Botany, vol. xv. pp. 673-700.

On Cane Diseases in the West Indies.

Lewton-Brain, L. Rind Disease of the Sugar-cane. Hawaiian Sugar-Planters' Association Experiment Station, Bulletin 7 (1907).

Red Rot of the Sugar-cane Stem. Hawaiian Sugar-Planters' Association Experiment Station, Bulletin 8 (1908).

Lyon, H. L. Iliau, an Endemic Cane Disease. Bulletin No. 11, Hawaiian Sugar-Planters' Association, pp. 1-32 (1912).

Massee, George. On *Trichosphaeria sacchari*, Mass., as Fungus causing a Disease of the Sugar-cane. Annals of Botany, vol. vii. pp. 515-532.

Root Diseases of Sugar-cane. Kew Bulletin vol. lxxxiv. (1893).

Stockdale, F. A. A Root Disease of the Sugar-cane. West Indian Bulletin 9, pp. 103-116 (1908).

Stubbs, W. C. Note on Rind Disease. Louisiana Planter, xliv. (21st May 1910).

Thiselton-Dyer, Sir Wm. T. Note on the Sugar-cane Disease of the West Indies. Annals of Botany, vol. xiv. pp. 609-616 (1909).

Tryon, H. Some Obstacles to successful Sugar-cultivation. Queensland Agricultural Journal, vol. ix. p. 85 (1901).

WENT, F. A. F. C. Het Root-Snot. Mededeelingen van het Proofstation, West Java, Kagok-Tegal, 1893.

Notes on Sugar-cane Diseases. Annals of Botany, vol. x. pp. 583-600 (1896). Reports of the Experiment Station of the Hawaiian Sugar-Planters' Association.

COTTON

ATKINSON, GEO. F. The Cotton Worm and other Enemies of the Cotton Plant. South Carolina Department of Agriculture, Monthly Report (October 1888), p. 91.

South Carolina Experiment Station, Bulletin 4, p. 60 (January 1889).

A New Ramularia on Cotton. Botanical Gazette, vol. xv. pp. 166-8 (July 1890).

A New Root Rot Disease of Cotton. Alabama Experiment Station, Bulletin 21, pp. 1-11 (December 1890).

Black Rust of Cotton ; a Preliminary Note. Botanical Gazette, vol. xvi. pp. 61-5 (March 1891). A Paper read before the Association of Agricultural Colonies and Experiment Stations at Champaign, Illinois, November 1890.

Black Rust of Cotton. Alabama Experiment Station, Bulletin 27, pp. 1-16, with two plates (May 1891).

Sphaerella gossypina, n. sp.—the Perfect Stage of *Cercospora gossypina*, Cke. Bulletin Torr. Bot. Club, 18, pp. 300-301.

Anthracnose of Cotton. Journal of Mycology, vol. vi. pp. 173-8.

Some Leaf Blights of Cotton. Alabama Experiment Station, Bulletin 36, pp. 1-32, with two plates (March 1892).

Some Diseases of Cotton. Alabama Experiment Station, Bulletin 41, pp. 1-65.

Methods for obtaining Pure Cultures of Pammel's Fungus of Texas Root Rot of Cotton. Botanical Gazette, vol. xviii. pp. 16-19 (January 1893).

Damping off. Cornell Experiment Station, Bulletin 94, pp. 265-8.

Diseases of Cotton. The Cotton Plant, Office of Experiment Station, United States Department of Agriculture, Bulletin 33, pp. 279-316.

Some Fungi from Alabama. Cornell University Bulletin, vol. iii. No. 1, pp. 1-50 (June 1897).

Nematode Root Galls. Alabama Experiment Station, Report 1889, Bulletin 9.

BARRE, H. W. Cotton Anthracnose. Science, N.S., vol. xxxi. No. 785 (1910).

Cotton Anthracnose Investigation. Twenty-Second Report of the South Carolina Agricultural Experiment Station (Division of Botany), pp. 89-118 (1909).

BUTLER, E. J. The Wilt Disease of Pigeon-Pea and the Parasitism of *Necosmospora vasinfecta*, Smith. Memoir of the Department of Agriculture in India, vol. ii. No. 9 (1910).

COOKE, M. C. Blights of Tea and Cotton. Grevillea, i. p. 90 (December 1872).

CURTIS, GEO. W. Texas Experiment Station, Bulletin 22, pp. 211-216 (September 1882).

DELACROIX, G. Sur la Maladie du Cotonier de l'Égypte. L'Agriculture Pratique des Pays-Chauds, vol. ii. p. 135.

DELOACH, R. J. H. Some Studies on the *Colletotrichum gossypii.* Technical Series No. 3, Georgia Experimental Station, Bulletin 85 (1909).

EDGERTON, C. W. The Perfect Stage of Cotton Anthracnose. Mycologia, i. No. 3 (May 1909), pp. 115-120 (includes drawings of asci of the fig anthracnose).

EARLE, F. S. Cotton Rust. Alabama Experiment Station, Bulletin 99, pp. 281-309 (December 1898).

Diseases of Cotton. Alabama Agricultural Experiment Station, Bulletin No. 107, pp. 289-330 (1899).

FLETCHER, F. Notes on Two Diseases of Cotton. Journal of the Khedivial Agricultural Society and School of Agriculture, vol. iv. p. 238.

FULTON, H. R. Cotton Wilt. Louisiana Agricultural Experiment Station, Bulletin No. 96 (1907).

GALLOWAY, B. T. Anthracnose of Cotton. Annual Report of the United States Department of Agriculture (1890), pp. 407-8.

GASPARRINI, G. Observationi sopra una Malattia del Cotone, etc. Instit. d' Incorag., Napoli, 1865.

GLOVER, TOWNSEND. Accidents and Diseases of the Cotton Plant. Annual Report of the United States Department of Agriculture (1855), pp. 230-234.

HUBBARD, R. B. Cotton Diseases in Mississippi. Mississippi Agricultural Experiment Station, Bulletin No. 140 (1910).

LAGERHEIM, G. Observations on New Fungi from North and South America. Journal of Mycology, vol. vii. pp. 44-50 (September 1891).

A New Cotton Rust in Ecuador. Journal of Mycology, vol. vii. p. 47.

LEWTON-BRAIN, L. West Indian Anthracnose of Cotton. West Indian Bulletin, vol. v. p. 178 (1904).

Fungoid Diseases of Cotton. West Indian Bulletin, vol. iv. No. 3 and No. 4.

LYMEN, JOS. B. Enemies of the Cotton Plant. Annual Report of the United States Department of Agriculture (1866), p. 199.

M'CALL, J. S. J. Notes on Bacterial Blights in Cotton. Nyasaland Agriculture and Forestry Department, Bulletin 2 (1910).

ORTON, W. A. Cotton Wilt. United States Department of Agriculture, Farmers' Bulletin No. 333 (1908).

PAMMEL, L. H. Root Rot of Cotton or Cotton Blight. Texas Experiment Station, Bulletin 4, pp. 1-18 (December 1888).

Cotton Root Rot. Texas Experiment Station, Bulletin 7, pp. 1-30, with 5 plates (November 1899).

SHEAR, C. L., and MILES, G. F. The Control of Texas Root Rot of Cotton. Bur. Plant Ind., U.S., Department of Agriculture, Bulletin 102 (1907).

SCRIBNER, F. LAMSON. Cotton Leaf Blight. Annual Report of the United States Department of Agriculture (1887), p. 355.

SMITH, ERWIN F. The Water-Melon Wilt and other Wilt Diseases due to *Fusarium*. Proc. A.A.A. Sci., xliv. p. 190 (May 1896).

The Spread of Plant Diseases. Transactions of the Massachusetts Horticultural Society, 1897, pp. 128-9.

Wilt Disease of Cotton, Water-Melon, and Cow-Pea. United States Department of Agriculture, Division of Vegetable Physiology and Pathology, Bulletin 17, pp. 1-53.

SOUTHWORTH, Miss E. A. Anthracnose of Cotton. Journal of Mycology, vol. vi. pp. 100-105, with 1 plate (1890).

Journal of Mycology, vi. pp. 173-178.

STEDMAN, J. M. Cotton Boll Rot. Alabama Experiment Station, Bulletin 55, pp. 1-12.

STELLE, J. P. Cotton Blight. Fourth Report of the United States Entomological Commission, App. 3, p. 25 (1885).

TRYON, HENRY. Report on Insects and Fungus Pests, No. 1 (Queensland, 1889), pp. 144, 145.

VOSSELER, F. Die Krauselkrankheit der Baumwolle. Der Pflanzer, i. (1905).

WATT, G. Dictionary of Economic Products of India. In the chapter on cotton several diseases are mentioned under their native names. They are mostly ascribed to unfavourable weather conditions, but they do not seem to have been scientifically studied.

WAILES, B. L. C. The Cotton Plant: its Origin and Varieties and its Enemies and Diseases. Agriculture and Geology of Mississippi, 1st Report (1854), pp. 146-148.

TEA

BAILLON, H. Tea in Assam.

BARBER, C. A. A Tea Eel-worm Disease in Southern India. Bulletin of Agriculture, Madras, vol. ii., Bulletin 45.

BERNARD, C. A Disease of Tea Seedlings. Bulletin of the Department of Agriculture, Indes Néerland. (1910), No. 40, pp. 39-48.

Bulletin of the Department of Agriculture, Indes Néerland., No. 6 (1907).

COOKE, M. C. Journal of the Agri-Horticultural Society of India, vol. iv., Proceedings, February 27, 1873 (?).

The Blights of Tea and Cotton. Grevillea, i. p. 90 (1872).

CUNNINGHAM, D. D. On *Mycoidea parasitica*, a new Genus of Parasitic Algae, and the part which it plays in the formation of certain Lichens. Transactions of the Linnean Society of London (2nd Series), vol. i. (1880), pp. 301-316.

HUTCHINSON, C. M. *Cephaleuros virescens*, Kunze. Memoirs of the Department of Agriculture of India, vol. i. No. 6 (Botanical Series), April 1907.

HOPE, G. D. Report on a Disease in the Tea Seed Nurseries. Indian Tea Association, vol. v. (1909), p. 6.

M'Rae, W. The Outbreak of Blister Blight on Tea in the Darjeeling District in 1908–9. Agricultural Journal of India, vol. v. (1910), No. 2, pp. 126-137.

Maublanc, C. Agri. des Pays-Chauds, vol. viii. pp. 91-102, 227-241 (1908).

Mann, H. H. The Blister Blights of Tea. No. 3, Indian Tea Association, 1906.

Indian Tea Association Report, 1900.

Red Rust: A Serious Blight of the Tea Plant. Report to Indian Tea Association, 1901.

Mann, H. H., and Hutchinson, C. M. Red Rust: A Serious Blight of the Tea Plant (2nd Edition), Calcutta, 1904.

Cephaleuros virescens, Kunze, the Red Rust of Tea. Memoirs of the Department of Agriculture in India (Botanical Series), vol. i. No. 6 (1907).

Massee, George. Tea Blights. Kew Garden Bulletin, 1898.

Patouillard, N. Maladies du Théier, Funtumia et Hevea à Java. Journ. d'Agric. Trop., vol. viii. p. 380 (1898).

Petch, T. Root Diseases of Tea. Tropical Agriculture and Magazine of the Ceylon Agricultural Society, xxviii. pp. 292-293 (1907).

A Stem Disease of the Tea. Circular and Agricultural Journal of the Royal Botanical Garden, Ceylon, vol. iv. No. 4, July 1907.

Tea Root Disease. Indian Planters' Magazine, vol. li. pp. 795-796 (1909).

Root Diseases of Tea. Circular and Agricultural Journal of the Royal Botanical Garden, Ceylon, vol. v. (1910), No. 11, pp. 95-114.

Shaw, F. J. F. The Copper Blight of Tea. Agricultural Journal of India, vol. vi. (1911), No. 1, pp. 78, 79.

Ward, H. Marshall. On the Structure, Development, and Life-History of a Tropical Epiphyllous Lichen (*Strigula complanata*, Fée, *fide* Rev. J. M. Crombie). Transactions of the London Linnean Society (2nd Series), Botany (1881–1887), vol. ii. pp. 87-119.

Watt, George, and Mann, H. H. The Pests and Blights of the Tea Plant (2nd Edition), 1903.

Watt, George. The Pests and Blights of the Tea Plant, Calcutta, 1898.

COFFEE

Brick, C. Einige Krankheiten und Schädigende tropischer Kulturpflanzen. Ver. angewand. Bot. Jähresber., vi. (1908), pp. 223-258 (6 figs.).

Cooke, M. C. Coffee Diseases in South America. Linn. Soc. Journ. Bot., xviii.

D'Herelle, F. H. Maladie du Caféier au Guatemala. Bull. Soc. Myc. France, xxv. pp. 171-185 (1909).

A New Coffee Disease (*Phthora vastatrix*). Ann. Soc. Rural Argentina, xliv. (1910), No. 68, pp. 40-45.

A New Coffee Disease (*Phthora vastatrix*). Ann. Mus. Nac. (San Salvador), iv. (1910), No. 28, pp. 182-189.

DUBARD, MARCEL. The Immunity of *Coffea congensis* to *Hemileia vastatrix*. Journ. Agri. Trop. viii., pp. 363, 364.

DUSSERT, P. Note on Coffees resistant to *Hemileia vastatrix*. Agri. Prat. Pays-Chauds, x. (1910), No. 91, pp. 337-338.

DYBOWSKI, J. The Resistance of *Coffea congensis* to *H. vastatrix*. Agri. Prat. Pays-Chauds, ix. pp. 159, 160 (1909).

EVANS, I. B. POLE. Coffee Rust (*H. vastatrix*, Berk. et Br.). Annual Report of the Transvaal Agricultural Department (1906–7), p. 165.

Report of the Acting Botanist and Plant Pathologist. Annual Report of the Transvaal Department of Agriculture (1907), pp. 155-172.

FABER, F. C. VON. Die Krankheiten und Schädlinge des Kaffees. Cent. f. Bakt. Paras. u. Infek., xxi. pp. 97-117, and xxiii. pp. 193-219.

Einiges über die Hemileia - Krankheit der Kaffeepflanze und die Widerständsfahigheit verschiedener Kaffeearten gegen dieselbe. Tropenpflanze, Bd. xiii. p. 235 (1909).

The Diseases and Insect Injuries of Coffee. Centbl. Bakt. xxi. Abt. (1908), Nos. 4-6, pp. 97-117, and xxiii. Abt. (1909), Nos. 6-9, pp. 193-219.

On the Infection and Germination of the Uredospores of *Hemileia vastatrix*. Ber. Deut. Bot. Gesell., xxviii. (1910), No. 5, pp. 138-147.

LOCK. Coffee : its Culture and Commerce.

MASSEE, GEORGE. Coffee Diseases of the New World. Kew Bull. Misc. Inf. (1909), pp. 337-341.

PATOUILLARD, N. The Root Rot of Coffee in Guadeloupe. Journ. Agri. Trop., vol. x. pp. 58, 59 (1910).

RIDLEY, H. N. Coffee Diseases. Agricultural Bulletin of Malayan Peninsula (1897), No. 7, p. 146.

WARD, H. MARSHALL. Researches on the Life - History of *Hemileia vastatrix*. Journal of the Linnean Society, vol. xix. p. 299 (1882).

On the Morphology of *Hemileia vastatrix*. Quarterly Journal of the Microscopical Society, vol. xxi. pt. i. (1881).

WURTH, TH. Heeft *Coffea robusta* een grooter weestandsvermogen tegen Ziekten en plagen dan *C. arabica* en *C. liberica*. Vortrag (S.-A.) Malang, 1908.

CACAO

BANCROFT, C. K. New West Indian Cacao Pod Disease. West Indian Bulletin, vol. xi. No. 1, pp. 34-35.

BARRETT, O. W. Cacao Pests of Trinidad. Proceedings of the Agricultural Society of Trinidad and Tobago, vii. pp. 281-304.

CHARLES, VERA K. Occurrence of Lasiodiplodia on *Theobroma cacao* and *Mangifera indica*. Journal of Mycology, vol. xii. pp. 145-146.

EVANS, I. B. POLE. The Citrus Fruit Rot, caused by the Blue Mould, *Penicillium digitatum*. The Transvaal Agricultural Journal, vol. vii. pp. 60-62 (1908).

FABER, F. C. VON. Die Krankheiten und Parasiten des Kakaobaumes. Arb. Kais. biol. Wust- Land- und Forstwirtsch., vii. pp. 193-351 (1909).

Untersuchungen über die Krankheiten des Kakaos. Biolog. Anstalt f. Land- und Forstwirtschaft, Bd. vi. Heft 3 (1908).

Some Diseases of Cacao. Arb. k. Biol. Anst. Land- und Foresten, vi. pp. 385-406 (1908).

GRIFFON, E., and MAUBLANC, C. A Disease of the Cacao. Bull. Trimest. Soc. Mycol. France, xxv. pp. 51-58 (1909).

GUEGUEN, F. A Disease of Cacao Fruits. Compte Rend. Soc. Biol. (Paris), lxviii. pp. 221, 222 (1910).

A Disease of the Cacao. Bull. Trimest. Soc. Mycol. France, xxv. pp. 51-58 (1909).

Sur une maladie du cacaoyer. Bull. Trimest. Soc. Mycol. France, xxv. pp. 51-58 (1909).

HALL, C. J. J. VAN, and DORST, A. W. Les Balais de sorcière du cacaoyer, provoqués par *Colletotrichum luxificum*, n. sp. Recueil des travaux botaniques néerlandais, iv. pp. 243-321 (1908).

(Translated by Fredholm.) The Witches' Broom Disease in Surinam, its Cause and Treatment. Proceedings of the Agricultural Society of Trinidad and Tobago, ix. pp. 475-564 (1909).

Witches' Broom of Cacao. Bulletin of Miscellaneous Information, Kew Royal Botanical Garden, No. 5, pp. 223-224 (1909).

HART, J. H. Studies in Cacao Diseases. Agricultural Society, Trinidad, Society Paper 343, pp. 1-6 (1908).

Cacao Diseases. Proceedings of the Agricultural Society of Trinidad and Tobago, viii. pp. 503-508 (1908).

Diseases of Cacao. West India Commercial Circular, xxiv. pp. 509-513, 533-537 (1909).

Cacao Disease, etc. Botanical Department, Bulletin of Miscellaneous Information, Trinidad, No. 30, August 1901.

HOWARD, ALBERT. Suggestions for the Removal of Epiphytes from Cacao and Lime Trees. Imperial Department of Agriculture for the West Indies, 1902.

JONGE, A. E. DE, and DORST, A. W. The Dieback Disease of Cacao Trees and the Brown Rot of Cacao Fruit, caused by *Diplodia cacaoicola*. Rec. Trav. Bot. Néerland., vi. pp. 233-250 (1909); Bull. 21, Dept. van den Landb. Suriname, 1909.

JONGE, A. E. DE. Canker of Cacao. Rec. Trav. Bot. Néerland., vi. pp. 37-61 (1909); Bulletin 20, Dept. van den Landb. Suriname, 1909.

MÜLLER, J. Yellowing of Citrus Trees. Agricultural Journal, Cape of Good Hope, vol. xxxiv. pp. 149-157 (1909).

REINECKE, F. Gefahrdung der Kakaokultur auf Samoa. Der Tropenpflanzer (1902), p. 632.

RORER, J. B. Pod-Rot, Canker and Chupon-Wilt of Cacao caused by *Phytophthora* sp. Bulletin of the Department of Agriculture, Trinidad, 9 (July 1910), No. 65, pp. 79-103.

STOCKDALE, F. A. Fungus Diseases of Cacao and Sanitation of the Cacao Orchards. West Indian Bulletin, vol. ix. pp. 166-189 (1908).

Fungus Diseases of Cacao and Sanitation of Cacao Orchards. Imperial Department of Agriculture, West Indies, Pamphlet 54 (1908).

Fungus Diseases of Cacao and Sanitation of Cacao Orchards. West Indian Bulletin, 9.

Cacao Diseases in Trinidad. Agricultural News, 25th August 1906, Barbadoes.

WENT, F. A. F. C. Die Zieteverschijnselen van Cacao-plant in Surinam.

WRIGHT, HERBERT. *Thebroma cacao* or Cocoa, its Botany, Cultivation, Chemistry, and Diseases. Colombo: Messrs. A. M. and J. Ferguson (London Office: 52 Gracechurch Street, E.C.), 1907.

TOBACCO

BEIJERINCK, M. W. Verhandelingen der Koninklijke Akademie von Wetenschappen te Amsterdam, Deel vi. No. 5.

GARMAN, H. The Brown Rape of Hemp and Tobacco. Kentucky Agricultural Experiment Station, Bulletin 20 (1890).

HORNE, WM. T. Soil Sterilization, Bordeaux Mixture, and Poisons for Tobacco Seed-beds. Estación Central Agronomica de Cuba, Circular No. 30.

HUNGER, F. W. T. De Mozaïekziekte bij Deli-tabak. Deel i. Verslag van de op Deli met betrekking tot de Mozaïekziekte genomen proeven in de jaren 1901–1902. Med. s' Lands Plantentuin, lxiii., Batavia, 1903.

KOCH, Dr. LUDWIG. Entwickelungsgeschichte der Orobanchen, 1887.

KONING, C. J. Die Fleckon- oder Mosaik-krankheit des holländischen Tabaks. Zeitschrift für Pflanzenkrankheiten, Band ix. pp. 65-80.

LOEW, O. Physiological Studies of Connecticut Leaf Tobacco. Report 65, United States Department of Agriculture, pp. 11-25.

MAYER, ADOLPH. Über die Mosaik-krankheit des Tabaks. Landb. Versuchsstation, 32, pp. 451-467. Reviewed in Journal of Mycology, vol. vii. pp. 382-385.

PETCH, T. Diseases of Tobacco in Dumbara. Circulars and Agricultural Journal of the Royal Botanical Garden, Ceylon, vol. iv. No. 7, October 1907.

SMITH, E. F. The Granville Tobacco Wilt. Bulletin 141, part ii., Bureau of Plant Industry, United States Department of Agriculture, 1908.

STEVENS, F. L., and SACKETT, W. G. The Granville Tobacco Wilt, etc. North Carolina Agricultural Experiment Station, Bulletin 188 (1903).

STURGIS, C. W. Connecticut Experiment Station Report for 1898, pp. 252-253.

TRYON, H. Report of the Plant Pathologist. Annual Report of the Department of Agriculture and Stock (Queensland), 1897–8, pp. 89-92.

Woods, A. F. The Destruction of Chlorophyll by Oxidizing Enzymes. Centbl. f. bakt. Par., Supk. 2 Abt. vol. v. pp. 745-754 (1899).

Observations on the Mosaic Disease of Tobacco. Bulletin of the Bureau of Plant Industry, United States Department of Agriculture, 18, pp. 1-24.

CITRUS FRUITS

Bernard, Dr. Chr. Sur quelques maladies de Citrus, sp. *Castillo elastica*, *Thea assumica*, M.S.W. (Einige Krankheiten von Citrus, *Castilloa*, *Thea*). Notes de pathologie végétale. Bulletin du Départ. de l'Agriculture aux Indes Néerland., No. 11.

Borg, J. Culture and Diseases of the Orange Trees.

Diseases of the Orange Trees and their Treatment. Malta Archaeological and Scientific Society.

Butler, O. A Study of Gummosus of Prunus and Citrus, with Observations on Squamosis and Exanthema of the Citrus. Annals of Botany, vol. xxv. (1911), No. 97, pp. 107-153.

Coit, J. E. Citrus Culture in the Arid South-west. Arizona Agricultural Experiment Station, Bulletin 58 (1908).

Cook, Mel. T., and Horne, W. T. Insects and Diseases of the Orange. Estación Central Agronomica, Bulletin 9 (1908). In both English and Spanish.

Essig, E. O. Wither-tip of Citrus Trees. Pomona Journal of Economic Botany, vol. i. (1911), No. 1, pp. 25-56.

Dieback or Exanthema of Citrus Trees. Pomona Journal of Economic Botany, vol. i. No. 2 (1911).

Evans, I. B. Pole. On the Structure and Life-History of *Diplodia natalensis*, n. sp., the cause of the "Black Rot" of Natal Citrus Fruit. Transvaal Department of Agricultural Science, Bulletin 4 (1910).

The Citrus Fruit Rot, caused by the Blue Mould, *Penicillium digitatum*, (Fr.) Sacc. Transvaal Agricultural Journal, vol. viii. No. 5 (October 1908), pp. 60-62.

Farlow, W. G. On a Disease of the Olive and Orange Trees. Bulletin of the Bussey Institution, vol. i. (1876), pp. 404-414.

Fawcett, H. S. *Cladosporium citri*, Mass., and *C. elegans*, Penz, confused. Mycologia, vol. ii. pp. 245, 246.

Webber's Brown Fungus of the Citrus White Fly. Science, 10th June 1910, p. 912.

Scaly Bark or Nail-head Rust of Citrus. Florida Agricultural Experiment Station, Bulletin 106 (1911).

Gandara, C. The Diseases of the Orange. Estación Agri. Cent. (Mexico), Bol. 31, pp. 1-17, 43-51.

Howard, Albert. Suggestions for the Removal of Epiphytes from Cacao and Lime Trees. Imperial Department of Agriculture for the West Indies, 1902.

Hume, H. H. Anthracnose of the Pomelo. Florida Agricultural Experiment Station, Bulletin 74 (1901).

Kirk, T. W. The Diseases of Lemon and other Trees in New Zealand, 1885.

Verrucosis of Lemon and other Citrus Trees. New Zealand Department of Agriculture, Leaflets for Garden and Fruit Grower, No. 33 (1908).

M'Alpine, D. Fungus Diseases of Citrus Trees in Australia, and their Treatment. Department of Agriculture of Victoria, 1899.

Müller, John. Yellowing of Citrus Trees. The Agricultural Journal of the Cape of Good Hope, vol. xxxiv. No. 2, May 1909, pp. 149-157.

Noack, F. Zeitschr. f. Pflanzenkr., x. p. 321 (1900).

Parish, S. B. Teratological Forms of Citrus Fruits. Torreya, vol. ix. pp. 227-229 (1909).

Rolfs, P. H. Wither-tip and other Diseases of Citrus Trees and Fruits. United States Department of Agriculture, Bureau of Plant Industry, Bulletin 52 (1904).

Wither-tip and other Diseases of Citrus Trees and Fruits caused by *Colletotrichum gloeosporioides.* Jamaica Bulletin, Department of Agriculture, vol. iii. part ii. (1902).

Smith, C. O. Cottony Mold of Lemon. California Culture, vol. xxxv. (1910), No. 9, pp. 196, 197.

Smith, R. E., and Butler, O. Gum Disease of Citrus Trees in California. California Agricultural Experiment Station, Bulletin 200, pp. 235-272.

Webber, H. J. Sooty Mold of the Orange and its Treatment. United States Department of Agriculture, Division of Vegetable Physiology and Pathology, Bulletin 13 (1897).

Woodworth, C. W. Orange and Lemon Rot. California Agricultural Experiment Station, Bulletin 139 (1902).

BANANA

Dorst, A. W. De Surinaamsche Panamaziekte in de Cros Michel bacoven. Dept. van den Landbouw Suriname, Bulletin 26 (1912).

Essed, E. The Panama Disease (1). Annals of Botany, vol. xxv. pp. 343-353 (1911).

The Panama Disease (2). Annals of Botany, vol. xxv. pp. 353-362 (1911).

The Surinam Disease. A Condition of Elephantiasis of the Banana caused by *Ustilaginoidella oedipigera.* Annals of Botany, vol. xxv. pp. 363-366 (1911).

Higgins, J. E. The Banana in Hawaii. Hawaii Agricultural Experiment Station, Bulletin 7 (1904).

Korff, G. A Banana Disease due to Nematodes. Prakt. Bl. Pflanzenbau u. Schutz, N.S., viii. (1910), No. 6, pp. 61-67.

Levy, H. Q. The Banana Disease and other Enemies of the Plant in Costa Rica. Journal of the Jamaica Agricultural Society, vol. xiv. (1910), No. 7, pp. 241-247.

M'Kenny, R. E. B. Banana Blight. Science, N.S., vol. xxx. No. 802, p. 750.

Rorer, J. B. A Bacterial Disease of Bananas and Plantains. Phytopathology, i. pp. 45-49.

Smith, E. F. A Cuban Banana Disease. Science, N.S., vol. xxxi. pp. 754-755.

PINE-APPLE

Cobb, N. A. Notes on some Diseases of the Pine-apple. The Hawaiian Forester and Agriculturist, vol. iv. pp. 123-154 (2907).

Hendrickson, H. C., and Iorns, M. J. Pine-apple Growing in Porto Rico. Porto Rico Agricultural Experiment Station, Bulletin 8 (1909).

Larsen, L. D. Diseases of the Pine-apple. Hawaiian Sugar-Planters' Station, Pathology and Physiology, Bulletin 10, pp. 9-70.

Patterson, Flora W., and Charles, Vera K., and Veihmyer, F. J. Some Fungous Diseases of Economic Importance, Bul. No. 171, U.S. Bureau of Plant Industry.

Stockdale, F. A. Fungous Diseases of Pine-apples. West Indian Bulletin, 8, pp. 158-166 (1907).

FIG

Edgerton, C. W. Two New Fig Diseases. Pathology, vol. i. (1911), No. 1, pp. 12-17.

Massee, G. A Fig Disease. Gardeners' Chronicle (3rd Series), xxviii. p. 5 (1900). (A Disease due to *Cercospora bolleana.*)

Price, R. H., and White, E. A. The Fig. Texas Agricultural Experiment Station, Bulletin 62 (1902).

Starnes, H. N. The Fig in Georgia. Georgia Agricultural Experiment Station, Bulletin 61 (1903).

Stevens, F. L. Note on *Cercospora* disease of Figs. North Carolina Experiment Station, 30th Annual Report, 1907, pp. 65-66 (1908).

Stevens, F. L., and Hall, J. G. Eine neue Feigen-Anthraknose. Zeitschrift f. Pflanzenkr., xix. pp. 65-68 (1909).

OLIVE

Farlow, W. G. On a Disease of the Olive and Orange Trees. Bulletin of the Bussey Institution, vol. i. (1876), pp. 404-414.

Montemartini, L. A New Disease of the Olive. Riv. Patol. Veg., iv. (1910), No. 11, pp. 161-164.

Petri, L. Observations on some Diseases of the Olive. Atti R. Accad. Lincei, Rend. Cl. Sci. Fis. Mat. e Nat., v. Series xviii. (1909), 2, No. 13, pp. 635-642.

MANGO

Cardui, P. P. Bloom Blight of Mango in Cuba. Cuba Review, vol. viii. (1910), No. 5, pp. 28, 29.

GRAPE

Evans, I. B. Pole. The Mildews of the Grape Vine. Transactions of the Agricultural Society, vol. vii. pp. 213-214 (1909).

APPLE

Evans, I. B. Pole. Bitter Pit of the Apple. Transvaal Department of Agriculture, Technology, Bulletin 1 (1909).

FRUITS

Campbell, A. G. Constitutional Diseases of Fruit Trees. Journal of the Victoria Department of Agriculture, vol. iii. (1905), pp. 463-465.

PALMS

Bancroft, Keith. The Dieback Fungus of the Para Rubber and of Cacao. Department of Agriculture, Federated Malay States, Bulletin 9 (1911).

A Root Disease of the Para Rubber Tree, *Fomes semitosus*, Berk. Department of Agriculture, Federated Malay States, Bulletin 13 (1812).

Barnard, Dr. C. H. A. A propos d'une maladie des cocotiers causée par *Pestalozzia palmarum*, Cooke. Bulletin du Département de l'Agriculture aux Indes Néerlandaises, No. 2 (1906).

Barrett, O. W. Diseases of the Coco-nut. Philippines Agricultural Review, vol. v. No. 5, pp. 262, 263 (1912).

Busck, August. Report of an Investigation of Diseased Coco-nut Palms in Cuba. United States Department of Agriculture, Bureau of Entomology, New Series, Bulletin 38, pp. 20-24. Also West Indian Bulletin, p. 307 (1905).

Butler, E. J. Report on Coco-nut Palm Diseases in Travancore. Agri. Res. Inst. Pusa., Bulletin 9, Calcutta (1908).

The Bud-rot of Palms in India. Memoir of the Department of Agriculture in India, Botanical Series, vol. iii. (1910), No. 5, pp. 221-280.

Some Diseases of Palms. Agricultural Journal of India, vol. i. part iv. pp. 299-319 (1906).

Coleman, L. C. Diseases of Areca Palm : (1) Koleroga. Department of Agriculture, Mysore, Mycological Series, Bulletin 2 (1910).

Copeland, E. B. Bud-rot of the Coco-nut. Philippines Agricultural Review (English Edition), i. (1908), No. 5, pp. 210-220.

Earle, F. S. Report on Trip to Jamaica. Journal of New York Botanical Garden, January 1903, p. 4.

Fawcett, Wm. Report on the Coco-nut Disease at Montego Bay. Bulletin of the Botanical Department, Jamaica, No. 23, p. 2 (2nd September 1891).

Fredholm, Dr. A. *Diplodia* Disease of the Coco-nut Palm. Proceedings of the Agricultural Society of Trinidad and Tobago, vol. ix. part 3 (March 1909), Paper No. 367, pp. 159-175.

Hart, J. H. A Note on one of the Coco-nut Diseases. Proceedings of the Agricultural Society of Trinidad and Tobago, vol. ix. (1909), No. 2, pp. 60-61.

Bud-rot Disease of Coco-nuts, etc. Trinidad Botanical Department, Bulletin of Miscellaneous Information, October 1905, p. 240. Also Kew Bulletin, 1903, p. 41.

Horne, Wm. T. The Bud-rot and some other Coco-nut Troubles in Cuba. Bulletin No. 15, Estación Central Agronomica de Cuba, 1908.

Petch, T. A Stem Disease of Coco-nut Palm. Circular and Agricultural Journal of the Royal Botanical Garden, Ceylon, vol. iv. pp. 47-53 (1907).

The Coco-nut Stem Diseases. Tropical Agriculturist and Magazine, Ceylon Agricultural Society, vol. xxx. pp. 73-75 (1909).

The Bleeding Stem Disease of the Coco-nut Trees in Ceylon. British Mycological Society's Translation, vol. iii. pp. 108, 109 (1908).

Stem-bleeding Disease of the Coco-nut. Circular and Agricultural Journal of the Royal Botanical Garden, Ceylon, pp. 194-305 (1909).

Ridley, H. N. Coco-nut Palm Disease. Agricultural Bulletin of the Straits and Federated Malay States, vol. ix. (1910), No. 5, pp. 178-180.

Smith, Erwin F. Bud-rot of the Coco-nut Palm in the West Indies. Science, N.S., vol. xxii. No. 535, p. 500 (March 31, 1905).

Stockdale, F. A. Coco-nut Palm Diseases in Trinidad. Jamaica Bulletin of Department of Agriculture.

Fungus Diseases of Coco-nuts in the West Indies. West Indian Bulletin, vol. ix. pp. 361-381 (1909).

Report on Diseased Coco-nut Palms from Mahaicomy (British Guiana).

Torre, Dr. Carlos de la. Enfermedad de las Cocoa. Revista de la Facultad de Letras y Ciencias, Universidad de la Habana, vol. ii. No. 3, p. 629 (Mayo de 1906).

Watts, L. A. Diseases of Coco-nuts. Journal of Jamaica Agricultural Soc., xiii. pp. 434-436 (1909).

Anonymous. Coco-nut Stem-bleeding Disease. Tropical Agriculturist, Ceylon, vol. xxx. p. 197 (1908).

Bud-rot Disease of Coco-nut Palm. West Indian Bulletin, vol. vi. p. 307 (1905).

Bulletin of the Department of Agriculture of Jamaica, June and July 1907, pp. 114-122.

RUBBER

Anstead, R. D. Pink Disease of Para Rubber and Bordeaux Mixture. Planters' Chronicle, vol. vi. (1911), No. 8, pp. 98-101.

Baker, C. F. A Serious Disease of Plants in Para. American Review of Tropical Agriculture, vol. i. (1910), Nos. 3 and 4, pp. 99-101.

CARRUTHERS, J. B. On Para Rubber. Bulletin of Straits and Federated Malay States, vol. ii. (1903).

FUNK, B. A Fungous Parasite of Rubber. Tropical Agriculturist and Magazine, Ceylon Agricultural Society, xxxii. p. 502 (1909). Agricultural Bulletin of Straits and Federated Malay States, viii. p. 312 (1909).

GALLAGHER, W. J. A Preliminary Note on a Branch and Stem Disease of *Hevea brasiliensis.* Department of Agriculture, Federated Malay States, Bulletin, vol. vi. (1909).

Root Disease of *Hevea brasiliensis*, the Para Rubber Tree. Department of Agriculture, Federated Malay States, Bulletin No. 2, p. 13 (1909).

HALL-DE-JONGE, A. E. VAN. A New Leaf Disease of *Hevea* from Surinam. Dept. Landb. Suriname, Bulletin 24, p. 6.

MASSEE, G. A Funtumia Disease. Royal Botanic Garden, Kew, Bulletin of Miscellaneous Information, pp. 147, 148 (1909).

PATOUILLARD, N. The Diseases of *Hevea brasiliensis.* Journal of Tropical Agriculture, x. (1910), No. 108, pp. 170, 171.

PETCH, T. Cacao and *Hevea* Canker. Circulars and Agricultural Journal of the Royal Botanical Garden, Ceylon, vol. v. (1910), No. 13, pp. 143-180.

A Root Disease of *Hevea.* Circulars and Agricultural Journal of the Royal Botanical Garden, Ceylon, vol. v. (1910), No. 8, pp. 65-71.

Dieback of *Hevea brasiliensis.* Circulars and Agricultural Journal of the Royal Botanical Garden, Ceylon, vol. iv. (1910), No. 23, pp. 307-321.

Abnormalities in *Hevea brasiliensis.* Circulars and Agricultural Journal of the Royal Botanical Garden, Ceylon, vol. iv. pp. 147-154, 155-164 (1909).

A Bark Disease of *Hevea*, Tea, etc. Circulars and Agricultural Journal of the Royal Botanical Garden, Ceylon, vol. iv. pp. 189-196 (1909).

The Fungi of *Hevea brasiliensis.* Zeitschr. f. Pflanzenkrank., xviii. pp. 81-92 (1909).

RIDLEY, H. N. Some Diseases of Rubber Plants. Agricultural Bulletin of the Straits and Federated Malay States, vol. vii. pp. 439-443 (1908).

A New Fungus Pest of Para Rubber. Agricultural Bulletin of the Straits and Federated Malay States, vol. viii. pp. 310-312 (1909).

A Disease of Para Rubber. Agricultural Bulletin of the Straits and Federated Malay States, vol. viii. pp. 570, 571 (1909).

Another Para Rubber Fungus. Agricultural Bulletin of the Straits and Federated Malay States, vol. ix. (1910), No. 6, pp. 216-218.

RIDLEY, H. N., and DERBY, R. Pests of the Para Rubber Trees. Agricultural Bulletin of the Straits and Federated Malay States, vol. ix. (1910), No. 8, pp. 289-297.

MULBERRY

Butler, E. J. The Mulberry Disease caused by *Coryneum Mori*, Nom., in Kashmir, with Notes on other Mulberry Diseases. Memoir of the Department of Agriculture in India (Botanical Series), vol. ii. No. 8 (1909).

ALMOND

Amand, G. Diseases of the Almond. Prog. Agri. et Vit. (Ed. 1, Est-Centre), xxx. pp. 451-456 (1909).

VANILLAE

Massee, Geo. Vanilla Disease, Royal Gardens, Kew, Bulletin of Miscellaneous Information, Nos. 65, 66 (1892), p. 111.

SANDALWOOD

Butler, E. J. "Spide" Disease among Sandalwood Trees, Calcutta, 1903.

CABBAGE

Collings, W. E. The Use of Lime in Agriculture, with Special Reference to its Application to Finger and Toe Disease in Turnips. Journal of Cooper Research Laboratory, No. 1, pp. 15-27 (1909).

Eycleshymer, A. C. Club Root in the United States. Journal of Mycology, vol. vii. p. 79.

Halstead, B. D. Club Root of Cabbage and its Allies. New Jersey Agricultural Experiment Station, Bulletin 98 (1893).

Hedgecock, G. G. A Disease of Cauliflower and Cabbage caused by *Sclerotinia*. Sixteenth Report of the Missouri Botanical Garden, 1905.

Kirk, T. W. Diseases of Turnips. New Zealand Department of Agriculture, Division of Biology, Bulletin 14 (1909).

Schrenk, Hermann von. On the Occurrence of *Peronospora parasitica* on Cauliflower. Sixteenth Report of the Missouri Botanical Garden, 1905.

Smith, E. F. The Effect of Black Rot on Turnips. United States Department of Agriculture, Bureau of Plant Industry, Bulletin No. 29 (1903).

Woronin, M. *Plasmodiophora Brassicae*, Urheber der Kohlflanzen Hernie. Prüss. Jahr. f. wiss. Bot., Bull. 11 (1878).

BEANS, ETC.

Briosi, G., and Cavara, F. *Colletotrichum lindemuthianum*, (Sacc. & Magn.) Br. & Cav., I. Funghi parasiti delle piante coltivate ed utili, 50, Pavia, Italy, 1889.

EDGERTON, C. W. Anthracnose or Pod Disease of Beans. Louisiana Agricultural Experiment Station, Bulletin 116 (1909).

The Bean Anthracnose. Louisiana Agricultural Experiment Station, Bulletin 119 (1910).

FULTON, H. R. Diseases of Pepper and Beans. Louisiana Agricultural Experiment Station, Bulletin 101 (1908).

HALSTEAD, B. D. Bean Diseases and their Remedies. New Jersey Agricultural Experiment Station, Bulletin 15 (1901).

WHETZEL, H. H. Some Diseases of Beans. Agricultural Experiment Station, Bulletin 239 (1906).

TOMATO

BANCROFT, K. A Bacterial Disease of Potato and Tomato. Agricultural Bulletin of Straits and Federated Malay States, vol. ix. (1910), No. 12, pp. 478-480.

EARLE, F. S. Black Rot or Blossom End Rot. Alabama Agricultural Experiment Station, Bulletin 109, p. 19 (1900).

FROGGATT, W. W. Tomatoes and their Diseases. Agricultural Gazette of New South Wales, Miscellaneous Publications, No. 954 (1906).

GALLOWAY, B. T. Notes on Black Rot of the Tomato. United States Department of Agriculture, Report for 1888, p. 339.

ROLFS, P. H. The Tomato and some of its Diseases. Florida Agricultural Experiment Station, Bulletin 21 (1893).

Tomato Diseases. Florida Agricultural Experiment Station, Bulletin 91 (1907).

SMITH, E. H. Blossom End Rot of Tomatoes. Massachusetts Agricultural Experiment Station, Technical Bulletin No. 3 (1907).

SMITH, RALPH E. Tomato Diseases in California. Agricultural Experiment Station, Bulletin No. 175 (1906).

POTATOES

HUME, H. H. Potato Diseases. Florida Agricultural Experiment Station, Bulletin No. 75 (1904).

KIRK, T. W. Diseases and Insect Pests of the Potato. New Zealand Department of Agriculture, Division of Biology and Horticulture, Bulletin 7 (1905–1907).

MORSE, W. J. Black Leg: A Bacterial Disease of the Irish Potato. Maine Agricultural Experiment Station, Bulletin 174 (1909).

Potato Scab. Maine Agricultural Experiment Station, Bulletin 141 (March 1907).

ORTON, W. A. Potato Diseases in San Joaquin County, California. United States Department of Agriculture, Bureau of Plant Industry, Circular No. 23.

ROLFS, F. M. Potato Failures. Colorado Agricultural Experiment Station, Bulletin 70 (1902).

Smith, E. F., and Swingle, D. B. The Dry-rot of Potatoes due to *Fusarium oxysporum*. United States Department of Agriculture, Bureau of Plant Industry, Bulletin 55 (1904).

EGG-PLANT

Twelfth Report of the New Jersey Agricultural Experiment Station, 1891.

PEPPER

Butler, E. J. The Wilt Disease of Pigeon Pea and Pepper. The Agricultural Journal of India, vol. i. pt. i., January 1906 (good Plates).

SWEET POTATO

Halstead, B. D. Some Fungus Diseases of the Sweet Potato. New Jersey Agricultural Experiment Station, Bulletin 76 (1890).

Townsend, C. O. Some Diseases of the Sweet Potato, and How to Treat them. Maryland Agricultural Experiment Station, Bulletin 60 (1899).

Wilcox, E. M. Diseases of Sweet Potatoes in Alabama. Alabama Experiment Station, Bulletin 135 (1906).

TARO

Barrett, O. W. The Yautias, or Taniers, of Porto Rico. Porto Rico Agricultural Experiment Station, Bulletin 6 (1905).

Massee, Geo. Disease of Colocasia in Jamaica. Linnean Society Journal of Botany, vol. xxiv. pp. 45-49.

Sedgwick, T. F. The Root-rot of Taro. Hawaii Agricultural Experiment Station, Bulletin 2 (1902).

RICE

Breda de Haan, J. van. Nematode Diseases of Rice. Meded. uit's Lands Plantentuin, 1902, No. 53, p 65. Abs. in Bot. Cent. 90 (1902), No. 8, pp. 209, 210.

Farneti, Rodolfo. Il Riso da semina, modo di selezionarlo, mondarlo e disinfettarlo con una sola operazione. L' Alba Agricola, ii., No. 26, pp. 257-258 (1904).

Intorno al brusone del riso ed ai possibili rimedi per combatterlo. Atti dell' Ist. Bot. della R. Univ. di Pavia, sez. ii. vol. x. (1904).

Il Brusone del riso. Riv. Patol. Veg., ii. 2-3, pp. 17-43 (1906).

Ferraris, Teodoro. Il "Brusone" del riso e la "Piricularia Cryzae" Br. e Cav. Nota preliminare. Malpighia, xvii. pp. 129-162 (1903).

Fulton, H. R. Diseases affecting Rice in Louisiana. Louisiana Bulletin 105 (April 1908).

Garovaglio, Santo. Del Brusone o carolo del riso. Arch. Trien. d. Lab. di Bot. critt. R. Univ. di Pavia, i. pp. 173-202 (1874).

Gobbetti, Vittorio. Il Riso: come si dovrebbe coltivare in Italia. Casale Monferrato, 1908.

Ideta, Arata. Jitsuyo Shokubutsu Byorigaku, Tokyo 1903 (Japanese).

Kawakami, Takiya. *Imochi* Disease of Rice (Japanese). Journal of the Sapporo Agricultural Society, vol. ii. pp. 1-49 (1901).

Metcalf, Haven. A Preliminary Report on the Blast of Rice, with Notes on other Rice Diseases. S.C. Bulletin 121 (May 1906).

The Pathology of the Rice Plant. Science, N.S., vol. xxv. No. 633, pp. 264-265 (1907).

The Present Status of Rice Blast. Science, N.S., vol. xxix. No. 753, p. 911 (1909).

Miyake, Ichiro. Studien über die Pilze der Reispflanze in Japan. Journal of the College of Agriculture, Tokyo, ii. p. 4 (1910).

Studies on the Parasitic Fungi of Rice in Japan. The Botanical Magazine, xxiii. pp. 127-145 (1909).

Speshney, N. N. Gribnie Parasiti Risa Posevnago (*Oryza sativa*, L.) (Russian). Trudi Tifliskago Botanischeskago Sada ix., i. pp. 23-73 (1906).

PIGEON PEA

Butler, E. J. The Wilt Disease of Pigeon Pea and Pepper. The Agricultural Journal of India, vol. i. part i., January 1906.

CLOVER

Ridley, H. N. A Disease of Clover. Agricultural Bulletin of the Straits and Federated Malay States, No. 7, pp. 263-264 (1908).

COW-PEA

Orton, W. A. The Wilt Disease of the Cow-Pea and its Control. Bureau of Plant Industry of the United States Department of Agriculture, Bulletin 17, part i.

NEMATODES

Atkinson, Geo. F. Nematode Root-Galls. Journal of the Elisha Mitchell Scientific Society, vol. vi. part ii. pp. 81-140 (1890).

Nematode Root-Galls. Bulletin No. 9, Alabama Agricultural Experiment Station.

Bonquet de la Grye. La Génération des plantations de caféières dans les Antilles. Bull. des Séances de la Soc. Nationale de l'Agri. de France, 1899.

Cobb, N. A. Root-Gall. The Agricultural Gazette of New South Wales, vol. xii. p. 1046 (1901).

Garman, H. Carnation Root-knot. Bulletin 142, Kentucky Agricultural Experiment Station, 1909.

KIRK, T. W., and COCKAYNE, A. H. Eel-worms. Bulletin No. 20, New Zealand Department of Agriculture, Division of Biology.

NEAL, J. C. The Root-knot Disease of the Peach, Orange, and other Plants in Florida. Bulletin No. 20, United States Department of Agriculture, Division of Entomology, 1889.

STONE, GEO. E., and SMITH, R. E. Nematode Worms. Bulletin 55, Massachusetts Agricultural Experiment Station.

WEBBER, H. J., and ORTON, W. A. A Cow-Pea resistant to Root-knot. Bureau of Plant Industry of the United States Department of Agriculture, Bulletin No. 17, part ii.

WILFARTH, Prof. Dr. H. Ein neuer Gesichtspunkt zur Bekämpfung der Nematoden. Zeitschr. d. Ver. d. Deut. Zucker-Industrie, Lieferung 529, pp. 195-204 (1900).

ZIMMERMAN, A. Het Groepsgewijs afsterven der Koffie heesters in gesloten plantsoenen. Teysmannia, 1897.

De Nematoden der Koffiewortel, I. Mededeelingen uit's Lands Plantentuin, 1898.

ENTOMOGENOUS FUNGI

BERGER, E. W. White Fly Control. Florida Station, Bulletin 103, pp. 5-28.

FAWCETT, H. S. An Important Entomogenous Fungus. Mycologia, ii. pp. 164-168.

Webber's Brown Fungus of the Citrus White Fly. Science (June 10, 1910), p. 912.

PARKIN, JOHN. Fungi Parasitic upon Scale Insects. Annals of the Royal Botanical Garden, Peradeniya, vol. iii. (1906).

ANONYMOUS. The Parasitic Fungi of Scale Insects in the West Indies. Agricultural News, Barbadoes, vol. viii. p. 299.

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