may find himself bewildered by such an attitude: he says in effect "here are schools, here are teachers, here are children to be taught. They must be taught something: why not teach them agriculture ?." It is perhaps natural, but it is wrong, and can do no good, and if the results of the discussion at this Conference, serve to emphasize the impossibility of teaching Agriculture except under very special circumstances in Primary or even Secondary Schools, it will have justified its existence.

Fungi chiefly with relation to Plant Diseases.*

Fortunately in a tropical land like India, this subject requires but little introduction, for all are familiar with fungi in some of their aspects. Fungi are low forms of plant life. All being devoid of chlorophyll, none of them are green. Chlorophyll, as you know, is the green substance in the leaves of plants by means of which, in the presence of sun-light, they can take the salt-solutions absorbed from the soil by the roots and the gases of the air and from them can manufacture food to build up their own structure. Plants that do not contain chlorophyll are unable to do this and therefore must make use of nutriment already manufactured by the plants possessing the requisite chorophyll. Fungi, then, cannot make their own food from simple substances but are entirely dependent on other plants or on animals. They may get it either out of living plants or from dead and decaying vegetation. In the latter case, where the nourishment is obtained from leaf-mould, cow-dung, bread, wood and such like substances, fungi really do useful work in decomposing the dead matter and rendering it again available as plant food although when they attack bread or timber in houses they are looked on from an economic point of view as destructive agents. In the first case, the fungi which derive their food directly from living plants are called parasites or parasitic fungi while the plants on which they live get the name of host-plants.

*Extracted from paper read by W. McRae Esq.. M. A., B. Sc., F. L. S., at the Madras Exhibition on 5th January 1916 and illustrated by lantern slides.

When a green plant becomes infected by a parasitic fungus, it has additional work to perform having to provide food for itself and also for its self-invited guest. In some instances it is quite capable of doing this and remains unharmed but in other cases the extra work is beyond its power and it succumbs. The fungus may devour all the food destined for its host-plant's necessary functions or it may derange the starch-making machinery of the leaves and the host-plant dies of starvation. It may stop up the water-conducting tubes of the stem and the host-plant dies of thirst or by weaving a covering completely over the leaves it may prevent air from getting access to the tissues and the host-plant dies of suffocation.

Parasitic fungi, then, are the renegades of the vegetable world. They are all dependents. Many are thieves, stealing openly for all the world to see or secretly in dark places. Some are murderers and fratricides bringing lingering or sudden death. They have given an evil reputation to the whole group of fungi, in some cases well merited but in others quite undeserved, for fungi are not wholly bad. Some have redeeming features, for instance a few are edible; many, notably those that live in the soil, transform the dead matter into humus which forms a rich store of food for our crop-plants. And even the worst of them have developed a degree of resourcefulness that gives cause for admiratian. As examples of the diseases caused by parasitic fungi, leaf-spot in tumeric, fruit spot of chillies, long smut on cholam, ephellis on paddy, red-rot of sugarcane, canker in white Babul may be mentioned as familiarly found in the Presidency.

These six examples show the appearance of diseased plants and now we wish to know what the fungi themselves are like. We shall begin with a fungus that is well known to every one and is large enough to be seen by the naked eye, even though it does not cause disease, viz., an edible mushroom so common in grassy fields and by hedgerows during the monsoom. It consists of two main parts; one is an umbrella-like structure and is above ground, while the other consists of a mass of threads and is below ground. These two parts have different functions to perform. The umbrella-like part is the fruit and contains the

seeds or spores. If we lay a fresh mushroom from which the stalk has been cut on a sheet of paper, in an hour or two we shall see radiating lines of a light brown powder on the paper. The powder consists of little round things. Each one is a seed, which, if it gets into suitable soil with plenty of organic matter, the right amount of moisture and a suitable temperature, will germinate and grow into another mushroom plant. The mass of threads in the soil composes the rest of the fungus plant. They bore among the dead roots, leaves and stems of plants in the soil and absorb food from them. This is the vegetative part of the fungus. All fungi have these two parts, a more or less complex fruit and a simple vegetative body composed of threads.

Different fungi vary greatly in the form and size of the fruit body while the absorbing part, the threads, is comparatively simple. The complexity of the one part and the simplicity of the other are corelated with the function which each part has to perform. The fruit, or spore-bearing part is pushed up into the air above the stuff on which the fungus is growing in order that the seeds or spores may have a better chance of being blown or carried away to other places. Hence this is the part of the fungus we generally see. The thread-like part of the fungus absorbs food and is embedded in the stuff on which the fungus grows whether it be soil, bread, chillie fruit, cumbu leaves or the branches or roots of trees. Hence this part of the fungus we seldom see, unless we look carefully for it.

Reproduction. The fungi do not produce seeds in the sense in which we use the term when we speak of cholam seed, mango seed or cotton seed but they produce exceedingly small bodies which answer the same purpose and these we call spores. Spores originate in two ways, either as sexual spores in which two germs unite and form a new individual or as non-sexual spores in which a part of the body of the fungus is separated off as a spore.

The Sexual method of reproduction involves the fusion of two parts and thus gives the new fungus-plant the advantages of a double parentage. The sexual spores are usually resting spores i. e., they remain dormant for a time and germinate only after a period of rest

They serve to carry the fungus over unfavourable seasons and thus perpetuate its existence from year to year.

By the non-sexual method of reproduction a small fragment of a thread is cut off and this may be accomplished in many ways.

1. Spores may be produced at the ends of simple or branched stalks singly or in chains.

2. They may be produced at the ends of simple or branched stalks inside small cases or boxes.

3. They may be produced in little sacks embedded in the tissue of the host plant.

4. They may be produced in little bags inside a flask-shaped cavity, the number of spores in each bag being constant usually 8, sometimes 4 but always constant for one and the same fungus. These are but a few of the arrangements according to which spores are produced by fungi.

The spores themselves vary much in size, in shape and in ornamentation of their surfaces. Some spores of one of the fungi causing rust on wheat are so small that 5,000 of them placed in a line touching one another would measure only one inch. While if those of another rust on a grass were placed end to end in the same way only 300 of them would occupy an inch. They show great diversity of form varying from the simple sphere to the spiral and the many-celled spore. The ornamentation on the spores is also diversified and the roughnesses, hairs and hooks may all serve to attach the spore more readily to leaves or branches or wherever their suitable environment may be. Some spores have long cilia which lash backwards and forwards and propel the spore through drops of water. Naturally these fungi are water-loving plants and grow best either submerged in water or in those places where the monsoon is heavy. e. g., the spores of the bud-rot fungus on palms and of the Mahali fungus on arecanuts are swimming spores though, of course, each of these fungi has another type of spore as well. As a rule there is one kind of spore for quick distribution from host-plant to host-plant during the growing season and another kind of spore (a resting spore) made to lie dormant during

that part of the year when the host-plant is not growing. Certain fungi have carried this development of different types of spores to a remarkable extent as for example in one of the rust fungi where there are four different kinds of spores each for a particular function in the life history of the fungus besides a fifth kind of spore that has quite lost the power to perform its function.

Some fungi on the other hand can reproduce themselves without forming spores at all. A few threads of the fungus weave themselves tightly into a little ball which becomes separated from the fungus plant and, later on, when it gets into a suitable place, the threads grow again. This is a lazy method of reproduction but it is quite effective as is seen in the damage done to potatoes by such a fungus.

Dissemination of Spores. Just as the higher plants utilize many agencies for the purpose of distributing their seeds over as wide an area as possible so the fungi make use of these same agencies for the dissemination of their spores. For the majority of fungi the *wind* is the agent for carrying spores away and enabling them to reach a suitable situation. Thus it is, that most fungi produce their fruit-bodies exposed to the air, e. g., the mushroom raises its umbrella-like fruiting body into the air and at maturity sheds its spores when they can be caught by light puffs of wind and carried off. The spores of smut on cholam are shaken out into the wind by the movement of the host plants. Their position in the ear-head is of advantage as the height gives them an increased radius of distribution. Such fungi usually produce spores in enormous numbers. Hundreds of thousands usually fail to develop where one or two find suitable conditions and give rise to mature plants. This is because the spores being so very minute cannot contain a great deal of nourishment and cannot therefore withstand unfavourable conditions of germination for any length of time. These fungi make up for the danger of failure by a prodigal formation of spores. *Man* is also an important agent in the distribution of spores. During his commericial transactions in moving commodities, shipping grain, and in introducing plants to other countries, fungi are also introduced and spread over great areas. e. g., rust spores are

spread in straw packing, and smut spores on grain. In a more restricted area spores and diseased plants are carried from field to field adhering to cart wheels, implements, animals and clothing and are even borne along in the water channels. *Insects* also distribute spores very successfully. An effective device has been invented by the fungus that causes sweet-ear disease of cholam. In the young grain a mass of much.branched threads produces numerous spores and also a sugary solution which attracts insects. As the insects sip the sweet liquid the spores become attached to their bodies and are carried off to other flowers thus rapidly spreading the disease.

The fungi that have swimming spores are dependent for their distribution on water either in streams or in rain running over the surface of the host-plant. These are but a few of the many ingenious ways which individual fungi have discovered for dissemination of their spores in order to secure the prepetuation of their kind.

Germination of Spores. When a spore of a fungus gets into a moist warm place, it sends out a thin thread and, if there is a sufficiency of suitable food, the thread branches and grows into a full fungus-plant which again produces spores. If the fungus is a parasitic one and the spore rests on a suitable part of the host-plant the thread may either remain on the outside of the host-plant or go inside it. In the former case, the fungus always remains outside and only sends little sucking tubes into the outer cells of the host-plant to get nourishment e. g., the mildews, a familiar example of which is the mildew on tobacco which causes so much loss. Most parasitic fungi, however, penetrate the tissues of the host-plant. The thread that grows from the spore goes in, either through one of the small breathing pores, or through an open wound or it actually bores in by secreting a ferment which dissolves the tissue of the host-plant and makes a way for the advancing threads of the fungus. Once inside, the threads of the fungus ramify between the cells of the host-plant or actually penetrate them and live inside. Some fungi live in a happy symbiotic relationship with their hosts. The host may simply supply food to the fungus

without detriment to itself, or the fungus, especially some root fungi may even help the host to absorb food material from the soil. On the other hand, parasitic fungi may kill the cells of the host-plant either locally or to such a degree as to destroy the whole of the infected plant. Most of these fungi, after a period of vigorous growth, come to the surface and again produce spores for their further increase.

The changes in the host plant. Parasitic fungi often cause abnormal growths of their host-plants and it is by these, that we usually recognise the disease.

A few cells only may be infected and minute leaf-spots may be formed. If such spots are numerous and in those instances where the whole leaf is infected great harm may be caused to the plant by interference with the starch-making processes of the leaves.

The fungus may cause various organs of the plant to rot e. g., the fruit-rot of chillies and of areca-nuts and the bud-rot of palms.

A fungus, attacking coconut and palmyra palms softens and rots the young leaves in the crown and ultimately kills the bud. This is a deadly form of disease in the case of those two palms because each tree has only one bud and after it is destroyed the tree can never produce a single new leaf. In a year or two it is quite dead and reduced to a bare pole.

The fruits of the host plant may be entirely replaced by the fungus e. g., in the short smut of cholam where instead of a ripe seed we find a mass of black powder which is but the spores of the smut fungus. This fungus has an interesting life history. It gains entrance to the cholam plant when the latter is in the seedling stage and never at any other time. It remains near the growing point keeping pace with its growth without affecting it detrimentally until the grain is beginning to fill. Then the fungus penetrates all the grain tissues, appropriates the food material and forms its smut spores.

On the branch of a tree a boil or canker may be formed which remains open for years. The tree produces healthy tissues to try to

heal up the open sore but the fungus as persistently destroys the tissue. Some of these cankers reach huge dimensions e. g., on the white babul the cankered surface may extend to five feet.

Control measures for the prevention of fungus diseases may be applied along one or more different lines, i. e., good cultivation, seed selection, general sanitation, growing disease-resistant varieties and application of chemicals that are fungicides.

The first and most important thing to do, is to maintain the host-plant in a thoroughly favourable environment and so keep it vigorous and healthy. This is done by *good cultivation.*

2. *Seed selection.* Then we must choose seed for sowing from healthy plants only; and in most cases this is the easiest and most natural means of controlling a disease e. g., the fruit disease of beans and the fruit-rot of chillies are carried over from crop to crop by diseased seed. Diseased pods almost always contain diseased seed even though no spot is visible on the seed. Thus in selecting seed for sowing either of these crops we should choose only those from pods that have no discolouration on their surfaces and discard all from discoloured pods. Cuttings and tubers taken from diseased plants should not be used for propagation because they will only reproduce the disease e. g., every ryot who cultivates sugarcane is familiar with the red-rot that causes so much loss. The disease is carried on from crop to crop by planting cuttings or setts from affected plants. Any cane with the characteristic red colouration should not be used for planting the new crop.

3. *General sanitation.* It is well known that some diseases live over the dry weather in fallen leaves or fruits or dead branches. The destruction of such diseased material is an important means of keeping a disease from spreading. Sometimes whole plants should be destroyed, at others only infected parts need be. To burn the infected material is the safest way of rendering it innocuous but this may be impracticable, then it should be buried in trenches to a sufficient depth. By doing this we lessen the number of spores and so reduce

the chances by which the fungus causing disease may infect the plants of the new crop.

4. *Growing resistant varieties.* Just as it is possible to select or develop varieties which produce improved fruits or grains so it is possible to secure varieties resistant to disease. The individuals of a variety or the varieties of a species are not always attacked to the same extent by any given parasitic fungus. Some individuals or varieties, often those of best quality, are always affected, others only occasionally. By patient unremitting labour these resistant plants may be selected and bred season after season till a definite variety is produced which combines the advantages of superior quality with resistance to disease. This method can be applied properly only by a skilled plant-breeder. In northern India this has been done successfully for wheat. There a variety of wheat quite suitable for those purposes for which wheat is used, has been produced which is resistant to the rust-fungus that causes such immense loss in this crop.

5. *Application of fungicides.* A fungicide is a substance that will kill or prevent the growth of a fungus or the germination of its spores. It must be strong enough to destroy or hold in check the injurious fungus but not enough to harm the host-plant nor the human beings or the animals that may use the plants as food. Fungicides are applied usually either to the seed or to the growing plant. In the former case the intention is to destroy spores attached to the seed that would germinate at the same time as the seed and infect the seedlings e. g., cholam seed from a crop affected with smut is steeped in a weak solution of copper sulphate. This kills the smunt spores adhering to the seed and the seedlings are protected. After the seedling stage is passed this smut cannot infect a cholam plant. During this season in the Nandyal and Kurnool districts, seed for 17,000 acres of cholam was treated so with good results.

When a fungicide is applied to a healthy plant, the latter receives a coating of fungicide in order to prevent the germination of spores that may subsequently fall on it e. g., on the West coast arecanuts are subject to a fruit-rot called Mahali that causes immense loss during the

monsoon. If the nuts are sprayed with a mixture of lime and copper sulphate they get complete protection. Spores landing on nuts thus covered do not germinate. This year the bunches of nuts on 40,000 trees in Malabar were sprayed with excellent results. This particular fungicide is called Bordeaux Mixture. It is one of the oldest and best medicines and is used more extensively than any other. It derives its name from Bordeaux in France where it was first used on grape vines in order to make petty thieves think the grapes were poisoned. It was noticed that vines so treated were less affected by the dreaded vine mildew. It is a mixture of copper sulphate, lime and water. Many other fungicides such as formalin, corrosive sublimate and sulphur are utilised to combat specific diseases.

In order to get an even coating of the fungicide on a plant some kind of spraying machine is required. The small sprayer used by the people in Malabar to spray arecanuts is typical.

It is usually necessary to combine two or more of these ways of combating disease and it is always well to have the co-operation of one's neighbours. It is not of much use getting one's own crops free from disease if they are liable to be infected from surrounding fields. Generally it is not an easy matter to get a disease under control. It requires patient and persevering effort but the result well repays the trouble.

The treatment of some diseases presents particular difficulties to be overcome. The mildew of tobacco can be easily and effectively kept under control by dusting sulphur on the leaves but there is a fatal objection to this remedy in that the least trace of sulphur in the cured tobacco is intolerable both to the man who chews and to the smoker. Sulphur then is ruled out as a remedy and so are other chemicals. What then can be done to prevent loss from this fungus? The Mildew fungus hates light and fresh air and loves a moist still atmosphere. By planting the tobacco plants wider apart and attending carefully to irrigation the plants are in a position where they get plenty of fresh air and sun-shine and the air round them is not moist. Thus the tobacco plant is favoured and the fungus is discouraged.

Another example is the bud-rot of palms. As it is not practicable to spray palmyra trees with a fungicide, recourse must be had to the surgeon's knife. So familiar have the Tahsildars, Revenue Inspectors and Village Officers, who carry out in the field the operations against this disease, become with the symptoms that, in the majority of cases, they can detect a diseased tree before the central bud is killed. If they cut off every leaf base that shows the diseased spots, the fungus is completely removed and the tree grows a new set of leaves that are quite healthy. It is not possible to save every infected tree because the first outward sign of disease in some cases appears only after the growing point is dead and the tree is beyond recovery. When the central expanding leaf becomes yellow it is possible to save the tree by promptly cutting off all the diseased leaf-bases but unless this is done within the first 3 or 4 days it is useless as the bud is killed by the fungus meantime. In other cases rows of spots appear on the leaves and such a tree can be saved by prompt surgical treatment in every case.

In 1910 when we were not so familiar with the disease the number of trees that died was 74,000 and there were very few recoveries. In 1914, 33,000 untreated trees died and 41,000 recovered after treatment, while in 1915, 20,000 untreated trees died and 32,000 treated ones recovered. Thus in the last two years 73,000 palmyra trees have been saved from death and this means a considerable gain to the cultivators, besides which the disease is now more in hand than it has ever been.

Manuring of Sugar Cane in Godavari and Vizagapatam Districts.

In the deltaic tracts of the Godavari district cane fields are usually crowbarred in January after paddy harvest when the land cracks fairly deep. The work is generally done on contract at Rs. 10/- to 12/- per acre. When the clods dry fairly well the