PRESIDENTIAL ADDRESS.

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ECONOMIC MYCOLOGY AND SOME OF ITS PROBLEMS.

Economic Mycology—or the study of Fungous Diseases of cultivated plants—is a branch of Mycology which has only very recently received any serious attention in this country. The economic importance of a thorough and systematic control of the fungous diseases of our cultivated plants—carried out both by the State and by the individual grower—is indeed hardly yet recognised in this country, whereas in the United States, and also in our Colonies, this fact has been realised and energetic action taken, for the past twenty years. It is satisfactory to be able to record that at last steps are being taken in this country in the same direction. The first recognition by our Government of the importance of controlling fungous diseases was shown in 1907, in which year the "Destructive Insects and Pests Act" became law. Under this Act powers are given to our Board of Agriculture to deal with insect and fungous diseases of *plants* by measures similar to those employed by them against such contagious diseases of *animals* as foot-and-mouth disease, swine fever, glanders, &c. There are now some half-dozen special Inspectors attached to the Board of Agriculture, and an increasing number of similar Inspectors employed by County Councils, who travel about the country making investigations and collecting statistics with regard to certain scheduled fungous diseases of plants. The *educational* effect of this Act during the four years since it has been in force has already been considerable; both on farmers and fruit growers and also on the Board of Agriculture itself. When the scientific side of the Board of Agriculture has been strengthened, so that this Act is administered with more scientific judgment, this recent piece of legislation will prove of direct *practical* importance. The chief fungous disease which has been proceeded against under the Act is the American Gooseberry-mildew (*Sphaerotheca mors-uvae*). Orders have been issued prohibiting the importation of all gooseberry bushes from foreign countries, and putting in force such measures as the compulsory pruning in winter of affected bushes, the prohibition of the sale of diseased stock, or its removal except under license. In several counties—though not, it can be said to its credit, in Kent—a few growers have failed to carry out the prescribed measures, and have been summoned before magistrates and fined. Although perhaps it may seem somewhat brutal to view it in such a light, a public fine is an excellent educational instrument. When such a thing happens, and is duly reported in the press, that important person, "the man in the street," hears of plant diseases and the possibility of combating them, and an enlightened public opinion is gradually created. That no protests against the infliction of these fines have been made by growers generally, shows perhaps that as a body they have come to recognise the economic necessity for compulsory measures for the protection of their crops from new contagious diseases.

It is within the last five years or so, too, that serious attention has been given by the individual grower to the question of combating fungous diseases. It is true that for many years past in certain districts potatoes have been sprayed against potato "blight," but it is only quite recently that this practice is becoming widespread, and that spraying against fungous diseases generally on a commercial scale is being adopted by the grower of fruit and vegetables in county after county. The fruit grower is just realising—to take two instances—that the very existence of commercial apple-growing depends on his learning how to deal successfully with two fungous diseases—Apple "Scab" *(Venturia pomi)* and Apple "Canker" *(Nectria ditissima)*, and that he will lose his plantation of "Victoria" plums, tree by tree, unless he takes steps to prevent the "Silver-leaf" fungus *(Stereum purpureum)* from fruiting and spreading.

Before a scientific audience such as this I do not intend to dwell on the purely economic side of the subject; such matters as statistics which show the heavy losses caused annually by fungous diseases, or points such as the various methods of spraying, and the results obtainable,—or whether it is equitable or not to pay compensation out of public funds for crops compulsorily destroyed,—all such points which are concerned with the commercial side of the subject, while of vital importance to the practical man, must necessarily be comparatively uninteresting to the scientist.

The problems to which I wish to refer on this occasion are purely scientific ones, and among them are some to whose elucidation members of our Society, as well as those of local Natural History Societies, could, I think, bring assistance.

One important problem may be stated thus:—what is the *economic* importance of that specialisation of parasitism now proved to exist in many fungi? We find this specialisation carried to a high degree in the "powdery mildews" *(Erysiphaceae)* and in the "rusts" *(Uredineae)*. I will select a few examples from the first group to show the nature of the problem with which we are confronted. If we take a species of the *Erysiphaceae* which occurs on a number of host-species, it can be shown by inoculation experiments that any one form on a given host-species *a* possesses different powers of infection from the form on host-species *b*. Such forms of a species are identical *morphologically*, but differ *physiologically* or *biologically*, as is shown by their different powers of infection. These forms are termed "biologic forms." Now with this discovery it follows that before the real nature of any immunity to disease shown by a plant can be determined, the extent of the specialisation of parasitism reached by the parasitic fungus must be ascertained. Let us take an actual case to illustrate this point. I have shown* by repeated inoculation-experiments that spores of the forms of *Erysiphe Graminis* on *Bromus commutatus*, *B. interruptus*, *B. hordeaceus*, *B. velutinus*, and *B. secalinus* when sown on the leaves of *B. racemosus* are totally unable to cause any infection. Thus we might have plants of *B. racemosus* surrounded by a belt of mildewed plants belonging to the five species of *Bromus* mentioned above remaining completely "immune," although spores of *E. Graminis* were blown on to its leaves night and day. An observer of this fact might naturally infer that *B. racemosus* was "immune" to the attacks of the morphological species *E. Graminis*, but he would be wrong. We find that *B. racemosus* is in nature often virulently attacked, but only by its own specialised "biologic form." If then to that belt of mildewed grasses surrounding the plants of *B. racemosus* which remained "immune" were added one mildewed plant of *B. racemosus*, the "immunity" would at once disappear. It is probable that such cases of partial resistance, i.e., resistance to most, or all but one, of the numerous specialised forms of a fungus are not uncommon. Such cases appear inexplicable—or are falsely explained—until the specialisation of parasitism reached by the fungus is investigated.

Now the problem is: what is the exact *economic* importance of this specialisation of parasitism? The "biologic form" of a parasitic fungus has its limited powers of infection as sharply defined in all the stages of its life-history (conidial and ascigerous, in the case of the *Erysiphaceae*) and must obviously therefore be considered an important "entity" for the economic mycologist. For if a particular host-species of a morphological species of fungus remains *under all conditions* "immune" to all but its own "biologic form," then the combating of certain plant-diseases will be simplified. Take the case of the Hop-mildew *(Sphaerotheca Humuli)*, which in many years is the cause of very heavy losses to the hop-grower. The morphological species *S. Humuli* occurs on a large number of wild plants, many of them weeds likely to occur in the neighbourhood of hop-gardens, e.g., *Potentilla reptans*, *Spiraea Ulmaria*,

* "On *Erysiphe Graminis* DC., and its adaptive parasitism within the genus *Bromus* (Annal. myc., II. (1904)).

Alchemilla arvensis, *Epilobium* spp. We know now* that *S. Humuli* consists of a number of "biologic forms," each confined to one or more species of a particular genus of host-plants. If it is a fact that none of these "biologic forms" can ***under any circumstances*** infect the hop, the removal or spraying of weeds affected with "hop-mildew" is totally unnecessary.

Certain facts are known, however, which show that the "immunity" of some host-species may be affected in various ways. Thus, to take an actual instance, the spores of the "biologic form" of *Erysiphe Graminis* found in nature on *Bromus racemosus* are unable to infect *B. commutatus;* they can, however, infect *B. hordeaceus.* Now the spores of the "biologic form" found in nature on *B. hordeaceus* are able to infect *B. commutatus.* Actual experiment has proved† that if spores are taken from *B. racemosus* and sown on *B. hordeaceus,* and the spores of the resulting generation sown on *B. commutatus,* infection readily results.

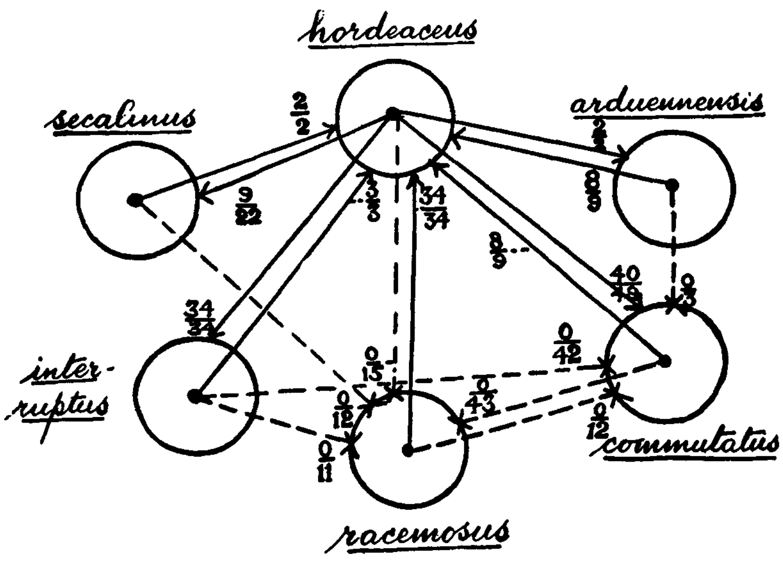

Diagram illustrating the position of *B.* "*hordeaceus*" as a "bridging species." *B.* "*hordeaceus*" is infected by the forms of *E. Graminis* on *B. racemosus*, *B. interruptus*, and *B. arduennensis*, and the fungus occurring on *B.* "*hordeaceus*" is able to infect *B. commutatus.* (The number of inoculations made, and the results obtained are expressed in the form of a fraction, in which the numerator indicates the number of times in which infection resulted,

* *Salmon, E. S.*, in The New Phytologist, vol. III. (1904); *Idem*, in Journ. Agric. Science, vol. II. (1907).

† *Salmon, E. S.*, Recent Researches on the Specialisation of Parasitism in the *Erysiphaceae* (The New Phytologist, vol. III. (1904) where a bibliography of the subject is given.

and the denominator the number of leaves inoculated.) Assuming that the fungus produced on *B.* "*hordeaceus*" by inoculation with conidia from *B. racemosus*, *B. interruptus*, and *B. arduennensis* is able to infect *B. commutatus*, *B.* "*hordeaceus*" will serve as a "bridging species" enabling the forms of the fungus on these three host-plants to pass on to *B. commutatus*, a species which they are unable to infect directly. That such is actually the case with regard to *B. racemosus* and *B. commutatus* has been proved by experiments—see Diagram below.

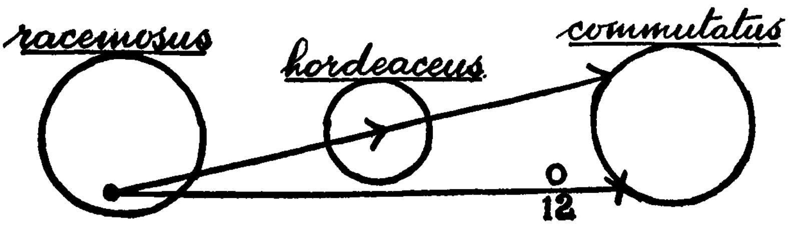

Diagram illustrating the result of experiments. *B.* "*hordeaceus*" is here shown to serve as a "bridging species," affording the fungus on B. *racemosus* a passage to *B. commutatus*, a species which this fungus is unable to infect directly.

So that *B. hordeaceus* acts as a "bridge"—or "bridging species" as I have termed it—enabling the form of the fungus on *B. racemosus* to pass on to *B. commutatus*—a species safe against its direct attacks. The "immunity of *B. commutatus* would remain absolute if surrounded by a belt of mildewed plants of *B. racemosus*, but if a perfectly healthy plant of *B. hordeaceus* were placed among them, *B. commutatus* would soon become infected. The facts presented graphically in the first diagram given above render it almost certain that the existence of such a species as *B. hordeaceus* will considerably affect the "immunity" of other host-species. It seems possible that the intervention of "bridging species" accounts for the fact that we have powdery mildews in the conidial stage present year after year on species of plants which never show the ascigerous stage of these fungi, e.g., the common garden species of *Myosotis* become mildewed each season, although so far as is known no perithecia are formed on this host-genus.

Another direction in which "biologic forms" may acquire wider powers of infection lies possibly in the lessened "vitality" of the cells of a host-plant. I have shown by experiments† that if the "vitality" of a leaf of a host-plant is affected by subjecting it to heat, or to anaesthetisation, or if the leaf is mechanically injured by pressure or by having pieces cut out of it, or eaten out of it by slugs, &c., then that leaf, or certain of its cells, are able to

† *Salmon, E. S.*; Cultural Experiments with "biologic forms" of the *Erysiphaceae* (Phil. Trans. Royal Society, vol. 197 (1904); *Idem*, in "Annals of Botany" vol. 19 (1905).

be infected by "biologic forms" which under normal circumstances are unable to do so. To what extent, if at all, does this happen in nature? Do plants whose leaves are injured in any way—and it is rare to find a fully-grown leaf that does not show some minute injury—become infected by "strange" "biologic forms"? Does, for example, the practice of rolling wheat, whereby many of the leaves are bruised, render this plant liable to the attacks of the "biologic forms" on barley and on oats, which we know are unable to infect uninjured leaves of wheat? A case came under my observation* where, apparently, plants of *Hordeum secalinum* became susceptible only when the health of the plants was impaired by unfavourable cultural conditions. In other cases there has been some evidence that susceptibility has been induced by the attacks of "green fly" *(Aphis)* on a plant. In the case of the hop, and of a number of other cultivated and also wild plants, it is noteworthy how frequently an attack of powdery mildew is coincident with an attack of "green fly."

In leaving the subject of specialisation of parasitism, it must be pointed out that with regard to the majority of diseases caused by parasitic fungi—many of them of great economic importance—we are still in ignorance as to whether this specialisation occurs or not. Until this knowledge is obtained, the economic mycologist is at a loss to answer many questions put to him by the practical grower. For example, the fungus *Nectria ditissima,* which is the cause of the "canker" disease of the apple—a disease which has ruined many a plantation and indeed put many varieties of apples out of cultivation—occurs also on the pear and on a large number of our wild trees, such as the ash, beech, oak, hornbeam, and others. Whether this fungus has become specialised to its different host species we do not know. An instance occurred recently where a fruit grower planted up a field with apple-trees, and then found in the hedges surrounding this field ash-trees badly infested with *Nectria ditissima.* In our present state of knowledge it is impossible to say what danger to the health of the apple-trees was incurred by the proximity of the "cankered" ash-trees.†

Another problem which confronts the economic mycologist is this: what degree of importance, from the economic point of view, is to be attributed to the *saprophytic* stage in the life-history of any fungus causing a plant disease. As an instance typical of this class of diseases, I would cite the Apple and Pear

* *Salmon, E. S.*; Cultural Experiments with the Barley Mildew (Annal. myc. vol. 2 (1904).

† Goethe records (Landwirt. Jahrb., IX (1880)) that ascospores of *N. ditissima* obtained from the Beech infected the Apple, and conversely; also that conidia of this fungus taken from the Apple infected the Beech and *Acer Pseudoplatanus*, but not the Horse-Chestnut nor *Ulmus montana.*

"Scab" *(Venturia pomi* and *V. pirina)*, which ruins tons of apples and pears every season in this country. In the life-cycle of these species the conidial stage is *parasitic* on the fruit, leaves and young wood; the ascigerous stage develops as a *saprophyte* in the dead, fallen leaves. This saprophytic stage has been recorded from the United States, and from the Continent, where it is said to be not uncommon, but it has not, as yet, been recorded from this country, although very probably it occurs here. In such a life-history as this—which obtains in a fairly large class of plant diseases—what importance, in connection with the annual outbreaks of the disease, is to be attributed to this saprophytic stage? I have shown* that at any rate in mild seasons in this country the parasitic, conidial stage winters over on the young shoots of the apple or pear, but have we as well centres of infection from these fungi existing as saprophytes? Another case is that of the common and often destructive disease of the Gooseberry known as "Die-back" or "Collar-rot," caused by *Botrytis cinerea*, which is ubiquitous as a saprophyte. To what extent *parasitic* outbreaks of this disease proceed from *saprophytic* centres of infection is at present quite unknown.

Another very important question is: what are the conditions under which some saprophytic species of fungi become parasites. Exact knowledge on this point is much wanted at the present time with regard to the most destructive disease known as "Silver-leaf"—which is laying waste whole plantations of plums and, indeed, beginning to threaten the very existence of one of the best varieties of cultivated plums, viz., the "Victoria." Through the work of Prof. J. Percival,† and of Mr. Spencer Pickering,‡ we know that this disease is caused by the fungus *Stereum purpureum*. Now *S. purpureum* is accounted a very common saprophyte, occurring on the trunks and branches of dead trees, particularly on dead firs and on birch stumps. Under what conditions does this fungus become parasitic—does it need merely the proximity of a Plum tree to make it change its habits? Is this fungus as a rule entirely saprophytic, or has it previously killed those trees on whose dead wood its fructifications so commonly occur? Or are there two strains, or races, of *S. purpureum*—a saprophytic and a parasitic one?§ A careful

* Journ. S. E. Agric. Coll., vol. 15 (1896).

† *J. Percival*, "Silver-leaf Disease" (Journ. Linn. Soc. vol. 35 (1902).

‡ *S. U. Pickering* (Woburn Experimental Fruit Farm, Sixth and Twelfth Reports 1906 & 1910).

§ Grossenbacher and Duggar have recently stated (New York Agric. Exper. Station, Bull. 18 (1911)) that they consider, from the results obtained in comparative inoculation experiments, that *Botryosphaeria Ribis* (which kills the shoots of Currants in the United States) is made up of two *physiologically distinct* fungi within the morphological species. "Both forms are present on the bushes of a blighted plantation, yet only one of the forms is an active parasite."

study by field mycologists of the prevalence and habits of *S. purpureum* in different districts would be of the greatest help to the economic mycologist.

Another interesting problem—the solution of which would probably throw considerable light on the nature of the parasitism of certain fungi—may be stated thus: What are the conditions under which a parasitic fungus attacks a new host-species? Two striking instances among the *Erysiphaceae* have recently occurred in this country. The European Gooseberry-mildew (*Microsphaera Grossulariae*), which has been known in this country, probably for over a hundred years, as a common and comparatively harmless pest of the cultivated Gooseberry, was noticed, four years ago, in one of the fruit-plantations at Wye College, Kent, on a number of Red Currant bushes. In the following years I observed it again on the same Red Currants, and also on Red Currants on three different fruit-farms in other parts of Kent. Now the European Gooseberry-mildew has never before been recorded in any country as attacking the Red Currant. It is scarcely conceivable that had it done so, its occurrence could have been passed over, as it is very conspicuous, and these "powdery mildews" have always been collected assiduously. It must be noted, too, that this fungus has had the opportunity—as regards the proximity of this new host-species—for a very long time, since Red Currants and Gooseberries are commonly grown side by side in fruit plantations and gardens, yet until lately it has not, apparently, been able to attack the Red Currant. Does this indicate some change on the side of the fungus; or is it that in the course of the cultivation of the Red Currant new varieties have been produced which are susceptible to this mildew; or is it, possibly, that the older varieties of the Red Currant have, through continued cultivation, arrived at a state in which they are no longer immune? The second case is that of the American Gooseberry-mildew (*Sphaerotheca mors-uvae*) attacking the Black Currant. In North America, the home of this mildew, it attacks, besides the native and introduced species of Gooseberries, the Red Currant, but no case has ever been recorded of its attacking the Black Currant. On the introduction of the mildew into Europe, a little before 1900, it began almost immediately to attack the Black Currant; I have seen it on this host in several localities in Kent, where apparently it had spread from badly-infested Gooseberry-bushes, and it has been found also in several places on the Continent. A case somewhat related to the last is that of the "downy mildew," *Plasmopara viticola*, and certain species of *Vitis*. When this mildew invaded Europe, certain American species of *Vitis*, which in their native country suffer but little from the attacks of this mildew, proved very susceptible when cultivated in Europe. What is, apparently, another case of a new host-plant being attacked has lately occurred with consequences likely to be of the greatest economic importance. One of the "scheduled" plant diseases now being proceeded against —or at any rate watched—in this country under the new Act is the "wart disease" or "black scab" of the potato,—a disease which is capable of completely destroying the potato crop in badly infected soil. This disease is due to the fungus *Synchytrium endobioticum*, which was first described a few years ago on the potato in Hungary. It seems probable, however, that this parasite has existed previously somewhere on the Continent, on some native plant as yet undiscovered, and has recently passed from this plant to the potato as a new host.

One other case may be mentioned where we find, apparently, a fungus learning to attack—so to speak—new host species. *Stereum purpureum*—the Silver-leaf fungus, referred to above, has it seems, according to the testimony of growers, during the last ten years or so extended its attacks to Apple and Cherry trees. One particular variety of apple, "Lord Suffield," is now attacked by "Silver-leaf" with increasing frequency.

I should like to mention also a set of problems connected with the methods of combating fungous diseases. The methods of combating disease can be divided into three, (1) external treatment of the plant; (2) internal treatment of the plant; (3) selection or breeding for resistance to disease.

In the first method the plant is sprayed with a chemical substance, or combination of chemical substances, which either directly kills the fungus—e.g., sulphur and copper sulphate—when it may be called a *direct fungicide;* or which protects the parts sprayed against external infection, e.g., Bordeaux mixtures, which are *protective fungicides.* In each case we require exact knowledge on *(a)* the chemical nature of the fungicide, and *(b)* the effect of the fungicide on the vital activities of the fungus and (if any) on those of the host-plant. It must be admitted that our knowledge here is still very incomplete. Although sulphur and sulphides of potassium have been in common practical use for a very long time, we are still in almost entire ignorance as to their action on the fungus. In the case of Bordeaux mixture, discovered about 1875, it was not until 1907 when Mr. Spencer Pickering carried out his researches,* that its chemistry was elucidated. Bordeaux mixture is the best and the most widely-used of all fungicides, yet its exact fungicidal action is still a matter of dispute. According to what may be termed the *chemical* explanation, put forward by Mr. Spencer Pickering, it is due to copper sulphate liberated from insoluble

* *S. U. Pickering;* The chemistry of Bordeaux mixture (Woburn Experimental Fruit Farm, Eighth Report (1908).

basic sulphates of copper by atmospheric carbon dioxide; according to the *biological* explanation, advanced by Swingle, Clark, Schander and others, and supported by the important recently-published work of Messrs. Barker and Gimingham,† the fungus itself acts on the insoluble copper compound in such a way as to poison itself. Many important practical points in the treatment of plant diseases stand to be affected by any advance in our scientific knowledge on the present subject.

If the biological explanation of the fungicidal action of Bordeaux mixture is correct, then we have scientific grounds for emphasising the importance of two practical points in the making and application of Bordeaux mixture. Messrs. Barker and Gimingham believe that the fungus acts on the insoluble copper compound only when there is actual contact between the fungus and the particles of the insoluble copper compound. Therefore in making Bordeaux mixture, that practical method should be followed by which the copper precipitate is obtained in as finely divided a state as possible; and, secondly, it follows that Bordeaux mixture should be applied in as finely divided a spray as possible, so as to deposit very minute drops uniformly over the surface of the sprayed part.

Another very important problem concerns the nature of the injuries which occasionally occur on plants after they have been sprayed. A form of injury known as "Bordeaux injury," which follows the use of Bordeaux mixture on some varieties of fruit-trees, is often so severe that it has lead to the abandonment of the use of this valuable fungicide on the varieties in question. In connection with this problem—which is continually being brought to his notice by the practical grower—the economic mycologist has to study many non-mycological matters such as the different degrees of susceptibility to this injury shown by the various "varieties" of cultivated plants; the effect of different meteorological conditions on foliage and fruit before and after spraying;—and so forth. Experiments carried out at Wye College during the past season have shown that under certain weather conditions gooseberry bushes are almost completely defoliated when sprayed with a certain lime-sulphur spray, which under other weather conditions is harmless to them. Further, susceptibility to injury from this spray varies very greatly according to the variety of gooseberry. It has also been shown* that a particular variety of apple which is very susceptible to "Bordeaux injury" may be safely sprayed with a lime-sulphur spray.

† *B. T. P. Barker* and *C. T. Gimingham;* The fungicidal action of Bordeaux mixture (Journ. Agric. Science, vol. 4 (1911)); *C. T. Gimingham;* The action of carbon dioxide on Bordeaux mixtures (l.c.).

* Journ. S. E. Agric. Coll., vol. 19 (1910).

Also, such practical points as the following must be considered to lie within the field of work of the economic mycologist; the selection of different types of spraying machines and nozzles for use with different sprays and for different crops; and the testing of the comparative efficiency and cost of hand-, petrol-, compressed air- and steam-power for spraying. He should be acquainted, too, with the most economical use of labour in the work of spraying, and also of the best systems from his special point of view of the planting up, and subsequent management, of the orchard and plantation. In parts of Kent the practice of spraying has already become so firmly established that the most progressive fruit-growers are now laying out from the start their fruit plantations in such a way that spraying can be most efficiently and economically carried out.

The second method of combating fungous diseases is by injecting into the plant, or by making its roots take up, some substance which absorbed into the tissues will confer immunity against the disease. This method must be regarded at present more as a theoretical way of dealing with diseases of plants than a practical one. In certain directions, however, some success has been reported. Marchal, in 1902, stated* that lettuces are made resistant to the attacks of the lettuce mildew *(Bremia Lactucae)*—a disease which often causes heavy losses to this crop when raised on the French system of gardening—when seedlings are grown in a nutrient solution to which copper sulphate has been added in the proportion of 3 or 4 parts to 10.000 parts of water. Massee soon afterwards stated† that cucumbers grown in soil watered with a solution of copper sulphate become "immunised" against the "spot" disease *(Cercospora Melonis).* Mr. A. D. Hall carried out experiments‡ to test the latter statement, and these showed that it is very questionable if such a result can be obtained. I may refer here to my own experiments § which showed very definitely that seedlings of cereals cannot be made resistant to mildew *(Erysiphe Graminis)* by making them absorb copper. Seedlings of wheat, barley and oat were grown in a series of cultures, and various amounts of copper sulphate added to the nutrient solution; in every case—even in those where the seedling plants had taken up so much copper that its leaves were stunted in growth and of an abnormal, dark green colour—infection resulted on the leaves of the treated plants as readily as on those of the untreated "control" plants. Cases have been recorded of success following the in-

* *E. Marchal;* De l'immunisation de la Laitue contre le Meunier (Comptes Rendus, 135 (1902))

† *G. Massee;* in Journ. Roy. Hort. Soc., vol. 28 (1903).

‡ *A. D. Hall;* in Journ. Board Agric., vol. 12 (1905).

§ *E. S. Salmon;* in Annal. myc. vol. 2 (1904).

jection of iron sulphate into the stems of plum-trees affected with "Silver-leaf," but these do not rest on scientific testimony.

The third method—that of obtaining plants resistant to disease by selection or by breeding—is one which is now attracting more and more scientific attention. For dealing with certain classes of diseases—such as the Rusts *(Uredineae)* or the class known as "soil diseases"' *(Fusarium-*" wilts,' *Oospora-* and *Synchytrium-* "scabs," &c.)—this method offers the only solution. Important practical results have already been obtained in this field of work. One of the earliest successes was obtained in the United States, in connection with the "wilt-" disease of cotton *(Fusarium niveum).* Dr. Orton, one of the mycologists on the scientific staff of the United States Department of Agriculture, found that in fields of cotton which were badly diseased one or two plants here and there resisted the disease and came to maturity. Seed was collected from these plants, and sown on land very subject to the disease; seed was collected from those seedlings which again proved resistant, and the operation repeated. At the end of four years plants were obtained of good cropping powers, with good quality of fibre, and with marked powers of resistance to disease. The seed of such plants was distributed by the Department of Agriculture to cotton-growers, and it was then found by general experience that these seedlings survived and produced a good crop in soils where the ordinary strains of cotton were a complete failure. In this case the practical grower quickly realised the importance of selecting for disease-resistance, and is still carrying on the work. In another case, also in the United States, "cross-"breeding between cultivated varieties of the Melon and a wild species of non-edible Citron has been successfully employed. By this means a good, edible Melon has been obtained which is resistant to a most destructive *Fusarium*-disease, very similar to the wilt-disease of cotton. In England, through the patient work of Prof. Biffen at Cambridge, wheats of high quality and immune to "rust" *(Puccinia glumarum)* have recently been produced. In this work a "rust-" resistant strain of wheat of low quality was "crossed" with one of high quality but very susceptible to "rust." The resulting "hybrid" plants all proved to be very susceptible to the disease, but these plants when self-fertilised gave seed which produced many plants immune to this "rust." Further, Prof. Biffen in his work has established the most important fact* that this susceptibility or resistance to disease behaves as a unit character, its inheritance following the now well-known Mendel's "law." In later work by Dr. Salaman, similar results have been obtained† with "hybrids" of

* *R. H. Biffen;* in Journ. Agric. Sci., vol. 2. (1907).
† *R. N. Salaman;* in Journ. of Genetics, vol. 1 (1910).

the potato as regards their resistance to the potato "blight" *(Phytophthora infestans)*. It is impossible to over-estimate the economic importance of the *data* which have recently been obtained as to the inheritance of disease resistance.

All facts noted in the field that bear on the subject of disease-resistance should be carefully stored by the economic mycologist. Among the "varieties" of nearly all our cultivated plants some stand out as possessing powers of resistance to disease, or show at least what has been lately termed in America "disease endurance." Certain very suggestive facts in this connection may be noted among our cultivated varieties of apples. The "canker" disease *(Nectria ditissima)* has practically stamped out the commercial cultivation of a number of excellent English apples, e.g., the "Wellington"; and has made that magnificent apple Cox's Orange Pippin unprofitable from the commercial point of view. Now one very strong-growing variety of apple, "Bramley's Seedling" by name, proves very resistant to "canker." If badly cankered trees are cut and "top-grafted" with Bramley's Seedling grafts, the "constitutional" powers possessed by this variety enable the tree to "grow out" of the disease, so to speak—any "cankers" in the stem or branches of the stock die away or heal over; while if grafts of weaker growing varieties are used on exactly similar stocks, the trees will quickly succumb to "canker"—the disease frequently causing the graft to die where it has been inserted in the stock, or through starvation caused by the "cankers" increasing on the stem or branches of the stock. By "cross-" breeding with this end in view there could very possibly be produced new varieties of apples having the highest quality and good cropping powers combined with resistance to "canker."

In the work of raising disease-resistant varieties results can only be obtained by trained scientific workers carrying out experiments of many years' duration. We require in this country many more workers in this important field of research; it is much to be hoped that at the John Innes Horticultural Research Station, recently established at Merton, Surrey, under Prof. Bateson, the breeding of disease-resistant plants will be undertaken on an extensive scale.

Finally, I would call attention to the important problem of the education of public opinion to the economic importance of combating fungous diseases. In a book recently published in the United States, by Stevens and Hall, entitled "Diseases of Economic Plants," these sentences occur: "Much can be done towards the eradication of fungous pests by the creation of a more enlightened public sentiment regarding them. . . To create a much-needed, enlightened, aggressive public opinion is part of the duty of plant pathology." This side of the subject should certainly not be neglected in this country; the need for enlightening public opinion is considerably greater at present in England than in the United States.

The creation at our Board of Agriculture of a properly equipped Horticultural Department is a reform long overdue. There are many directions in which such a Horticultural Department could move. There is no reason why our Government should not organise great Fruit Shows as those of other countries do. At such shows important educational exhibits could be arranged and authoritative scientific advice given with regard to plant diseases. Let me give one instance where the spread of scientific information is needed urgently. At the present time the most progressive commercial apple-growers in England and Ireland are just beginning to market their best apples in non-returnable boxes, graded and packed in the most approved American and Colonial methods. These up-to-date methods are only possible where the apples have been grown free from the "scab" fungus. The presence of "scab," in an average season, on a large proportion of English apples is the chief reason which at present tends to make the bulk of our crop of apples inferior to that of the leading fruit-growing countries. The fact that in an average season apple trees require to be sprayed to keep off the "scab" fungus is one which requires to be driven home. With an energetic State Horticultural Department the present partial wastage year after year of the English apple crop due to the ravages of "scab," "canker," and "brown rot," could be enormously diminished or even stopped.

Further, illustrated articles on the common fungous diseases, with the methods of prevention, should be sent to journals widely read by the public, together with statistics, readably presented, showing the heavy annual losses due to the destruction or deterioration of cultivated plants caused by parasitic fungi. This method of popularising technical knowledge is widely used in America and in our Colonies. In connection with the cultivation of land in "small holdings," which is now being advocated, it should be pointed out that the intense cultivation of most crops demands for commercial success a sound knowledge of the best methods of combating plant-diseases. In Ireland the farmers are assisted by the State to purchase potato-sprayers and materials for making sprays; in connection with any scheme in this country for the creation of Credit Banks for the assistance of "small holders," provision should certainly be made for assisting them with loans for the purchase of spraying machinery and necessaries. Also, some information on the subject of plant diseases might be given in the rural school.

There are many other ways in which the economic importance of the present subject can be brought home to the grower and public generally, and none of these should be neglected by the State. To protect our crops against epidemics of disease caused by fungi and insects further compulsory measures will be required, and it must not be forgotten that for legislation to have its full beneficial effect it always requires to be sustained by an educated public opinion.

NOTE SUR LE PSEUDOPHACIDIUM SMITHIANUM.

Par Emile Boudier.

Lorsqu 'en 1908 je fis paraître dans le Bulletin de la Société mycologique d'Angleterre, ma notice sur le petit Discomycète découvert par Miss Lorrain Smith, et que m'avait communiqué mon bon ami Mr. Carleton Rea, je croyais avoir eu en mains des échantillons, nombreux cependant, ayant atteint leur complète évolution. Il n'en était rien d'après ce que j'ai pu reconnaître en Août de cette année, sur de très nombreux spécimens que notre Collègue Mr. Crossland a eu la bonté de m'envoyer à deux reprises différentes. L'examen de ces nouveaux exemplaires m'a permis de constater, comme l'avait déjà reconnu notre savant Collègue lui-même, que les spores de cette espèce n'étaient pas seulement continues et incolores ou peu colorées, mais qu' avec l'âge, non seulement elles acquéraient une coloration intense, poussée même à parfaite maturité, jusqu' au noir-olivâtre mais présentaient alors une cloison médiane bien visible seulement à cette époque, puisque ces spores ayant même la couleur olive foncé n'en montrent souvent pas. De plus je ferai remarquer que les paraphyses que j'avais vues primitivement simples ou seulement divisées dès la base, présentent souvent comme l'a vu aussi Mr. Crossland, des ramifications dans leur parties supérieures. Ces diverses constatations ont nécessairement dû modifier mon opinion sur le genre dans lequel cette espèce doit être rangée, et bien que quelques uns des caractères ne concordent pas suffisamment, je crois devois la faire rentrer dans le genre *Phaeangella* de Saccardo. Cette rectification nécessaire, est une preuve de plus en faveur de l'opinion que j'ai émise bien des fois, du peu de certitude qu' offre, chez les Discomycètes, l'interprétation du cloisonnement des spores. Ces organes ne présentant très souvent de cloisons dans leur intérieur que dans leur extrème évolution, peuvent amener à faire rentrer les espèces dans des genres différents, comme peut la faire aussi leur coloration tardive.