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SELECTED ARTICLE

Recent Advances in Control of Fungous Diseases of Plants.

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At the present time, when it is necessary to promote in every possible way the increase of agricultural production, and when the output of fundamental work has been substantially reduced, it is appropriate to consider a few of the directions in which advances have been made during the last very productive decade. This period has been by far the most productive, judged by volume, of all the history of plant pathology. In some quite new directions studies have been made and have resulted in useful knowledge, but in most cases the information which has lent itself readily to practical applications has been due to the reinvestigation of old fields which for some time have not received much attention. As very good examples of this we may quote the excellent work which has been done on such widely different subjects as plant hygiene, fungicides and nutrition in relation to disease.

Hygiene. By plant hygiene we refer to those steps which are taken to ensure that the diseased parts of plants are removed and destroyed or in some way rendered harmless to healthy crops. Some very valuable work of this sort has been done on the root rot disease of rubber in Malaya, caused by *Fomes lignosus* Kletzsch and *Ganoderma pseudoferreum* (Wakef.) Van O. et Bt. This fungus produces long creeping strands of tough resistant hyphae, which spread from diseased jungle stumps to the healthy rubber trees. It has been found that by removing completely the diseased stumps the spread of the fungus can be stopped. Another most valuable hygienic method, involving the use of chemicals, is now widely adopted in Europe and America for controlling the late blight disease of potatoes. The fungus, *Phytophthora infestans* de By., attacks first the leaves of the plants and from the rotten leaves passes down to the tubers. The fungus is however, a highly developed parasite which makes little growth in the soil, and consequently if the leaves are destroyed before the spores have had time to form in sufficient quantities, the tubers are not likely to become badly infected. To accomplish this when an epidemic seems about to set in plants are now sprayed with 5 per cent copper sulphate or 12½ per cent sulphuric acid solution, completely destroying the foliage. Of course this cannot be done in an immature crop without reducing the yield, and the stage of development at which it can be safely done has to be scientifically worked out for the condition under which the crop is being grown. An example of hygiene for the control of a disease in India is to be found in the gram blight disease caused by *Mycosphaerella rabiei* Kovachevsky. Here the clearing up and burning of all diseased tissues prevents the spread of the disease, but unfortunately it has not proved possible to get all cultivators in a district to carry out the work simultaneously, and consequently another method of control has had to be evolved.

Soil conditions and plant disease. The physical and nutrient condition of the soil have long been considered important factors in the development of disease. These factors received particular attention at the end of the last century, and led to the formation of a school of plant pathologists known as the 'Predispositionists'. Outstanding among the names were those of Paul Sorauer and Henry Marshall Ward. There was a lack of agreement among the investigators, and it was perhaps due to the tendency to generalize when drawing conclusions based on observation or experiment. One of the outstanding findings from recent work has been that it is possible to draw from a single experiment conclusions which can be of general application. By restricting the conclusions in their interpretation to the particular diseases on which the results were obtained, information of direct practical application has resulted. A few examples may be quoted.

It was a matter of common observation that most of the soil borne diseases of annual crops are intensified by frequent growth of one kind of crop on the same soil. This is very noticeable in the cereal crops which suffer heavy losses from foot- and root-rots carried in the soil. However, this is not always the case, and some soils become (sick) less quickly than others. There are also instances, as for example the *Pythium* disease of wheat, where disease is worse after a bare fallow than after a previous wheat crop. The different behaviour exhibited by different crops is due to the action of several factors. The soil condition may influence either the host or the parasite. Thus in the case of most of the root rot diseases of cereals the effect of soil conditions seems to be on the parasite, and any condition which favours the growth of the parasite favours also the development of the host. One of these conditions is continuous growth of the host which thus supplies over a long period of time conditions favourable for the fungus out of all proportion to the general level of soil microbiological activity. It has been shown that in the case of the *Pythium* disease of wheat the fungus is less susceptible to the harmful effects of other fungi which grow in great abundance in fallow soil, but on the other hand it is particularly responsive to the composition of the host plant. The disease does not operate severely in plants with a high phosphorus-nitrogen ratio which is found in frequently cropped soils. Subsequently it has been found that the disease can be controlled by a proper system of manuring with phosphates. A similar state of affairs exists in the *Pythium* root-rot of sugarcane in Hawaii.

A good deal is now known about the effect of physical conditions in the soil in relationship to the development of disease. The temperature most favouring the development of a number of diseases is known For example, the wilt disease of plants caused by species of *Fusarium* are severest at rather high temperatures. Wilt of cotton occurs with great severity when the temperature of the soil is about 28°C and with a soil moisture of 60 per cent of the water-holding capacity. The smut diseases of the common cereals occur at lower temperatures about 10° for common bunt, 10° to 20° for oat smut, and so on. Often it has been found that this optimal temperature is the same as that for the vegetative growth of the fungus, independently of the optimal temperature for growth of the host This rather rules out the popular idea that a plant grown at the ideal temperature is necessarily more resistant to disease. It also opens up a new field, namely the sowing of seed at the time least favourable for disease to develop An example can be found in the cotton crop in the Punjab, which suffers severe root rot if sown in the month of May but not if sown by the first week of April or towards the end of June. A common drawback in such a method is that the abnormal date of sowing has sometimes an adverse effect on yield. A similar effect can be brought about by growing the cotton crop intermixed with another crop such as *moth* (*Phaseolus aconitifolius*) which lowers the soil temperature. The extraordinarily beneficial effects of this method of control of cotton root-rot have to be seen to be believed.

There are, however, some cases in which the optimum for the disease is far lower than the optimum for the growth of the fungi in pure culture. It has been shown that this is because at lower temperatures certain fungi are much less susceptible than at higher temperatures to competition by other soil micro-organisms.

Resistant varieties. One of the first methods of obtaining resistant varieties was by increasing the progeny of isolated individuals which appeared healthy in fields in which most of the plants were heavily infected. It was tried with many crops and was sometimes successful but more often was a failure. The chief reason for the failures was that the plants which had all the appearance of being healthy were actually infected, but at a late stage or under such conditions that they did not succumb to the disease. This meant that the progeny grown were more often than not from parents that were not at all resistant, and the intentions of the plant selector were thwarted. It was possible to overcome this only when methods were found for guaranteeing heavy infection in a susceptible variety. This is one of the palces where fundamental research has played such a valuable part. By knowing the temperatures, humidities, soil conditions, etc. at which the fungi grow best and the disease develops most rapidly, it has become possible so to adjust conditions that heavy infection is certain provided the variety of the plant is a susceptible one. In this way very useful work is now being done in India as elsewhere in the breeding or selecting of resistant varieties of cereals to the rusts and smuts, of cotton and *arhar* to wilt, sugarcane to redrot, smut and mosaic, of potatoes to early and late blight and so on.

At the start there were many failures. Varieties which appeared to be highly resistant were found to break down with the passage of time or when the crop was grown in a new locality. One of the chief reasons for this was the fact that the fungi themselves exist in many physiologic forms, that is to say, races which were alike in appearance but attack quite different groups of varieties of hosts In recent years it has been realised that this is not a characteristic restricted to a few fungi, but is found in all the groups. That is not the end of the story. It is now known that by hybridization and by sudden inherited changes known as 'mutations' new physiologic forms of fungi with new ranges of hosts are constantly arising. It has even been shown, in the case of *Phytophthora infestans* de Bary, the cause of 'late blight' of potatoes, that such changes in the nature of a fungus may be brought about by growing it on a series of hosts, starting with susceptible ones and gradually working through the more and more resistant varieties until the fungus will eventually severely attack those which were previously considered to be immune. Such a state of affairs would be very discouraging, and few workers would care to try to secure resistant varieties were it not for the fact that the very existence of sharp differences in the behaviour of the different physiologic forms of the fungi on different groups of hosts indicates correspondingly sharp differences on the part of the hosts, and use can be made of the plant breeder's skill to unite in one plant the different types of resistance exhibited by a number of different parents. The establishment of a series of 'differential hosts' for recognizing the different physiologic forms is now a recognised routine with the plant pathologist. Breeding and selecting for resistance to disease is one of the most popular fields of endeavour of plant pathologists in India. Following are a few of the diseases for which Indian workers are breeding or selecting resistant varieties.

Crop.	*Disease.*
Wheat.	Stem rust (*Puccinia gramini* Pers.) Yellow rust (*Puccinia glumarum* (Schm) Erikss. et Henn.) Brown smut (*Urocystis Triticina* Erikss.) Flag smut (*Urocystis Tritici* Koern.) Loose smut (*Ustilago Triciti* (Pers.) Jens.)
Barley.	Smut (*Ustilago Hordei* (Pers) Legerheim)
Oats.	Smut (*Ustilago Kolleri* Wille)

Paddy.	Leaf spot (*Piricularia Oryzae* Cavara)
Cotton.	Wilt (*Fusarium vasinfectum* Atk.) Root-rot (*Macrophomina Phaseoli* (Maubl) Ashby.)
Pigeon-peas.	Wilt (*Fusarium udum* Butler)
Sann-hemp.	Wilt (*Fusarium udum* Butler var Crotalariae (Kulkarni) Padwick)
Gram.	Wilt (*Fusarium orthoceras* App et Woll. var. *Ciceri* Padwick) Foot-rot (*Operculella Padwickii* Kheswalla). Blight (*Mycosphaerella rabiei* Kovachevsky.)
Potatoes.	Late blight (*Phytophthora infestans* de Bary) Early blight (*Alternaria Solani* (Ell. et Mart.) Jones et Gr.)
Sugarcane.	Red-rot (*Collatotrichum falcatum* Went). Smut (*Ustilago scitaminea* Sydow) Wilt (*Cephalosporium Sacchari* Butler).

Fungicides. The sprays used as fungicides have undergone little change in recent years. Little really new has been found, and the improvements have been chiefly in the direction of manufacture. This has been partly due to our greater knowledge of colloids. A number of proprietory copper and sulphur colloidal sprays are now available which have only to be diluted with water to be ready for use. They are naturally convenient and have proved popular among small growers who have not the skill or the materials necessary to do their own preparation. Really new materials for spraying have been few. There have been, however, marked improvements in spreaders used, and good proprietory compounds are now on the market.

An important development has been the tendency to replace the use of sprays by dusts. Cupric and cuprous oxides have particularly come to the fore. This development has been due in a considerable measure to commercial interests, but the extent to which they are capturing the market in various parts of the world and are being put to a wide range of uses is a clear indication that their effectiveness is of a high order.

In the seed dressings there have been three distinct lines of development. The first of these is in the replacement of wet dressings by dusts. Immersion in a solution of copper sulphate has practically gone out of use, and even formalin solution has dropped in popularity in western countries, though still in favour in India. Immersion in solutions of organic mercury compounds came into vogue in the early twenties, to be followed shortly by dusts consisting of small quantities of the active substance mixed with talc or some other inert substance. Among the favourites were the chlorides, hydroxides and nitrates of the paraffin series. Generally speaking the more volatile compounds were the most effective as seed dressings. Now it has been found that the phosphates of these compounds are particularly potent fungicides. The switch over to these better mercurials and the treatment of seed with them on a big scale marks a distinct advance in the control of seedborne diseases. The third development, and in some ways the most interesting, is the production of a non-mercurial seed dressing of sufficient merit to become a competitor of the mercurials. This is a compound produced by Imperial Chemical Industries Ltd., in England, and known as Nomersan having tetramethyl-thiuram-dissulphide as the active constituent. It has proved so effective a seed dressing that the whole of the flax crop in Ireland has been treated with it to prevent seedling blight. The compound is non-poisonous to animals in any quantities in which it is ever likely to be consumed, and it therefore seems as if it might spread in countries where poisonous substances are disliked.

Need for continued research. The few instances of recent advance which have been quoted are not intended to give a full picture of the research which is going on. To do so would take volumes. They are merely intended to indicate a few of the many directions in which considerable advances have been made. The refinements of research technique in recent years have been notable but there is still room for improvement and for the wider adoption of better methods. Furthermore, the advance of other sciences brings new problems. When the plant breeder produces new varieties with a combination of good commercial characters, they are often susceptible to diseases. When a variety is introduced which is resistant, it sometimes happens that the fungus population changes so as to give rise to a form, perhaps previously existent only in small numbers, but now the predominating type, which can play a havoc with the new host in a quite unexpected way. Again, the growing tendency to specialization in agriculture involves soil conditions which may be favourable to the growth of fungi, or may make the hosts unusually susceptible to infection. The proper use of fungicides can only be made if they are tested under the conditions in which they are intended to be used. There is in fact no end to research in sight for the plant pathologist. (*Indian Farming* Vol. 3, No. 9 September 1942).

ABSTRACT

Toxic effects of sodium pentachlorphenate and other chemicals on water hyacinth. A. A. Hirsch. *Bot Gas.* **103**: (1942) 620. Preliminary experiments were carried out on the eradication of water hyacinth by treating it with two recently introduced chemicals: sodium pentachlorphenate, an industrial algaecide and fungicide marketed as Santobrite by the Monsanto Chemical Company of St. Louis, Missouri, and Beneclor 3, achlorinated hydrocarbon manufactured by the Chloroben Corporation, Jersey City, New Jersey. Although some damage was inflicted by beneclor 3, its toxicity was insufficient to be of much use. In the case of santobrite even the initial dose caused yellowing of stalks and withering of leaves. Thirty five parts per million seemed to arrest growth and complete necrosis was obtainable with a concentration of 80 parts per million.

The physiological action of santobrite suggests two field procedures for combating the problem of water hyacinth: (1) A light application, somewhat more than 5 parts per million, for retarding growth in areas where complete removal is not essential or in zones where the aquatic life is to be preserved. (2) complete elimination by a dosage approximating 80 parts per million.

M. M. K. M.

EXTRACTS

Synthetic plant hormones. New synthetic growth-promoting substances, or plant hormones, many times more powerful than those now in use experimentally and by greenhouse men, have been prepared at the Boyce Thompson Institute for Plant Research. Yonkers, N. Y., by Dr. P. W. Zimmerman and Dr. A. E. Hitchcock. Applied to plants in the form of vapour, spray, emulsion, lanolin paste, or added to the soil, they induce profound changes in growth, and they can also induce the formation of seedless fruits from unpollinated flowers at points on the stem a foot or more from the place of application. Treated plants are so changed that sometimes they look like different species. The new hormones are prepared from various milk organic acids, which have no effect on plants in their ordinary state, by the addition of atom-groups containing chlorine, iodine or bromine, either singly or in combination. One very effective compound of this sort is known as dichlor phenoxyacetic acid. It has been found to be fully 300 times more effective in producing plant changes than indolebutyric acid, one of the synthetic plant hormones now widely used. Solutions as weak as 10 to 25 parts (by weight) in a million parts of water have been