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Recent Advances in Mycology and Plant Pathology

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The recent advances in Mycology and Plant Pathology are considered separately in view of the differences in their scope and development. The developments in these sciences from the beginning of this century have been considered.

Mycology: At the beginning of the century mycologists were busy collecting and naming the fungi in different countries. Taxonomic studies were concentrated upon and an enormous number of species of fungi has been described from all over the world. This number appears to be steadily increasing and may even outstrip the number of species of flowering plants in course of time. Alongside this development, the method of preservation and maintenance of the specimens also improved. In the beginning of the century the mycological specimens especially plant pathogens were mounted in the same manner as in the case of flowering plants. In many of the specimens so preserved the fungal sori or spores disappeared in course of time due to disturbances in handling specimens and they lost their value later. To avoid such damage, in many of the herbaria the type specimens are now kept in paper folders or covers and these are attached to the mounting boards. In addition permanent slides of the spores and diagrams of these bodies also are being maintained in some herbaria. With the advancement of the taxonomic studies the revision of the systems of classification was suggested by different schools. Phylogenetic systems of classification found favour in preference to the others in vogue.

Besides the collection of fungi, their isolation and study in pure cultures were taken up in earnest. The improvements in cultural technique developed by the bacteriologists were readily adapted by mycologists. Intensive activity on the study of the behaviour of fungi on culture media and the course of development of different types of reproductive bodies, followed. Emphasis was being laid on the phenomenon of sex in fungi. The sex organs readily distinguishable in several Phycomycetes were not clearly evident in the other groups. Harper demonstrated the existence of sex in Ascomycetes. The discovery of heterothallism in Mucoraceae by Blakeslee gave an impetus to investigations on similar lines in other fungi. The elucidation of the nuclear behaviour and the phenomena of

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mitosis and meiosis enabled the proper appreciation of sexuality in fungi also, especially in the Ascomycetes and Basidiomycetes. The classic work of Craigie on rusts showed the real function of pycnia in the *Uredinales*. Buller's remarkable investigations on diploidisation, Dodge's contributions to the knowledge of the behaviour and inheritance of characters in *Neurospora*, Lindergren's and Subramanian's work on yeasts have all added considerably to our knowledge of the cytology and genetics of higher fungi.

With the acquisition of more precise information of the development of different groups of fungi, attention was focussed on the probable lines of evolutionary progress in this group. The old idea of the Phycomycetes being the lowest of the fungi and the other groups having developed from them gave way to the more rational and modern view of the different classes of fungi having evolved from different groups of lower organisms. The systematists have also realised that fungi are living organisms exhibiting variations and influenced to a large extent by the environment and that consequently the rigidity of the species concept could not be adhered to (especially the type specimen concept) and a certain latitude is necessary in fixing the limits of the species.

With the improvement of the technique of isolation and culture of fungi, more and more attention began to be devoted to the study of the physiology of fungi. The readiness with which the organisms could be grown and the possibility of raising several generations of these organisms in a short period rendered them particularly suitable for these studies. Considerable information on the nutritional requirements of fungi, the enzymes produced by them, the influence of vitamins and other growth regulating substances on their growth and reproduction have accumulated. These physiological and bio-chemical studies have resulted in the development of various industrial processes, utilising these organisms. The fermentation industries utilising different species and strains of yeasts and moulds for different end products, the production of citric acid, gluconic acid, acetone and glycerol by fermentation processes, the manufacture of food yeasts and other yeasts as sources of vitamins, fats and protein and manufacture of diastase from *Aspergillus oryzae* are some of the recent developments. The progress of the studies on the nutrition of fungi have resulted in the use of different fungi for the detection of deficiencies of certain micro nutrients in the soil without any laborious chemical analysis (*Aspergillus niger* for zinc, copper and manganese).

During the world war II the most revolutionary development was the discovery of *Penicillin* and *Streptomycin*, bacteriostatic products from *Penicillium notatum*, and *Streptomyces griseus* by Fleming and Florey in England and Waksman in the U. S. A. respectively. This was followed by a feverish rush described as 'mycological rush' comparable to the 'gold rush', for antibiotics. Several hundreds of species of fungi were investigated. However the results were not commensurate with the amount of energy spent. Yet the studies have resulted in giving to the world a few more useful drugs like chloromycetin, aureomycin, terramycin etc. Any way these studies have shown that the ubiquitous moulds in the soil or those that damage our fruits and food stuffs may yield some products useful to man. The early use of these antibiotics was to treat the bacterially induced diseases of man. In more recent times search is being made for antibiotics having antifungal properties also so that they may prove useful in keeping down diseases of plants too. The days of the pure mycologist are numbered. Unless he equips himself with a basic knowledge of biochemistry he will find himself a back number in no time. The investigations on fungi and their activities carried out all over the world are so numerous and so varied that it will be a hard job to keep oneself in touch with all the literature. One may be able to concentrate on particular aspects of the subject alone.

Plant Pathology: In olden days a mycologist and a plant pathologist were understood as being synonymous and we still find in India and often in England also the two terms not clearly distinguished and a plant pathologist often designated a mycologist. A plant pathologist is a plant doctor. In the earlier years most of the known crop diseases were due to fungi and this led to the impression that a mycologist or a plant pathologist were different names with the same meaning. But it is well known at the present day that diseases of plants may be caused by fungi, bacteria, viruses, flowering parasites, deficiency of nutrients etc., and that a knowledge of fungi alone will not be sufficient for a plant pathologist.

Plant pathology as we know at the present day is of recent origin and is only about 60 years old. Diseases of crops caused by fungi had resulted in untold misery and huge financial losses in the last century. The blight of potato, mildews of grapes, rusts of wheat and the rust of coffee in Ceylon are a few of the well known examples. Though the causal organisms were known the measures for combating these diseases did not develop rapidly. The use of sulphur for combating mildew, the discovery of Bordeaux mixture in France for controlling grape-vine diseases and later the blight of potato and the effect of copper sulphate for seed treatment for the control of bunt of wheat were known. But these had not been widely adopted. The scepticism of the growers, the lack of suitable equipment and local prejudices stood in the way of widespread use of these methods. The impetus to the extended use of chemical fungicides was given by the American Department of Agriculture in the early decades of this century. The chain of agricultural and horticultural research stations established in that country has also contributed to a large volume of literature on plant diseases and their control, emanating from that country. The advances in the control of plant diseases proceeded in different directions viz., in the development of the chemical fungicides, in the breeding of crops with an eye for disease resistance and in the improvement of the equipment for the application of fungicides.

For a very long time the materials used for the control of fungal diseases consisted of compounds of sulphur, copper and mercury. The last group was mainly utilised for seed treatment as it was too poisonous, expensive and toxic for use on foliage. Copper fungicides were employed for the protection of most of the crops and sulphur for the control of the mildews and diseases of orchard crops. Though investigations were being carried out in Europe and America with compounds of various elements these three were the chief elements in use, mainly, on the consideration of cost. The great depression in the early thirties prevented any extension of the plant protection methods. The next development was in the use of organic mercurials synthesised in Germany. This aimed at the reduction of the mercury in the formulations considerably and thus brought down the cost of treatments. Further these could be used as dry seed dressing material which was easier to handle than the steeps or dips recommended earlier. The formulations of sulphur were modified to improve their efficacy. It was found that the smaller the particle size of sulphur used for dusting, the greater the efficacy of the fungicide. This knowledge led to the preparation of finer powders and the use of colloidal and wettable sulphurs. These preparations were good but more expensive.

Bordeaux mixture was the most widely used copper fungicide but its preparation was rather tedious. This stimulated the search for other compounds of copper with equivalent efficiency in controlling diseases. Copper oxychloride and cuprous oxide were used in different formulations with satisfactory results. The World War II demanded maximisation of food production in all the belligerent countries. Therefore more attention was paid to the control of diseases of all crops. The high prices of raw products which prevailed during and after the war and still continues, enabled the growers to use fungicides freely without being afraid of the expenditure. The urge for the use of fungicides on crop plants like apple and some varieties of grapes which are injured by bordeaux mixture resulted in the testing of various organic compounds besides the usual chemicals. A wide array of such products is now being placed in the market mostly by American chemical concerns like Du Pont, Rohm and Haas, Monsanto and others. These are derivatives of organic sulphur (dithiocarbamates), organic mercury (mertholates), quinone compounds (phygon, spergon) and others The new fungicides were good for specific purposes but did not serve as wide a range as Bordeaux mixture. But the ease with which they could be prepared and the absence of clogging of nozzles of the sprayers are responsible for making some of them popular.

Side by side with the development of the fungicides improvements in the spraying and dusting equipments were also introduced. The time-consuming operations with small sprayers and dusters are giving way to labour saving applications with mechanically more efficient dusters and sprayers either operated by hand or by power units. The design of the nozzles has also undergone considerable changes and we have now low volume sprayers, high volume sprayers, mist sprayers, swing fog machines, micron sprayers etc., all aiming at reducing the quantity of the fungicide used, wider range of application and quickness of action with no loss in efficiency or coverage of the crops. The principle of atomisation of the liquid by air blast is incorporated in some of these machines. The droplets vary in size from 80 to 100 microns or even smaller. These improvements have enabled the protection of large areas of field and plantation crops in a short time. On this account, one of the greatest difficulties experienced by planters in transporting water or liquids for the preparation of the mixtures in the difficult terrain of the plantations has been eliminated or brought to the minimum. Further, a round of treatment over the entire plantation can be completed in a limited time thus providing adequate and quick protection at critical periods. These operations are also being carried out economically so that expenditure on plant protection is reduced by the use of these modern equipments.

Another line of advance in the control of plant diseases is the evolution of disease resistant varieties and stains of various crop plants. Though it had been recognised in the last century that there were differences between varieties in regard to the damage caused by diseases, it was only after the rediscovery of Mendel's laws of inheritance at the dawn of this century that concerted attempts were initiated to breed resistant varieties. Biffen is to be given the credit of being the first to attempt at hybridisation between resistant and susceptible varieties of wheat to combat yellow rust. His attempts were crowned with success and the variety "Little Joss" was brought into being. Almost simultaneously attempts to overcome the scourge of black rust in Canada, the United States and Australia by breeding for resistance with or without the assistance of the Mendelian theory were initiated by numerous pathologists and breeders. Varying degrees of success were attained. Meanwhile the rusts also began to exhibit differences in their virulence in different tracts. Close study of this phenomenon revealed that new races of rusts exhibiting specialisation on particular varieties were being developed. Eriksson in Sweden and Stakman and his associates in the United States of America showed that *P. graminis* is made up of more than one race. Now over 200 races and biotypes of this rust alone are known each specific on certain varieties of wheat. Thus the race between the breeder and the pathogen came into full swing with success on either side at different periods. Besides the work carried out on wheat, breeding of all crops for resistance to diseases became a normal feature of many of the Agricultural Research Stations all over the world and a large number of resistant varieties in different crops, annuals and perennials have accumulated. However more often these successes have been short lived. In many cases new varieties or races of pathogens exhibiting higher virulence have developed in the meantime capable of infecting the resistant varieties. Thus the fight becomes eternal.

Besides fungi other parasitic organisms like bacteria, have now been known to cause crop diseases. E. F. Smith has the honour of being the pioneer in the study of plant pathogenic bacteria. A large volume of literature has accumulated in all the countries on various bacterial diseases affecting vegetables, fruits and other crops. The blackarm of cotton, the canker of citrus, the brown rot of potatoes and the black leg of tobacco are a few of the common bacterial diseases prevalent in our country. The control of these diseases is being attempted on the same lines as for diseases caused by fungi.

The most significant development during the period under review is the advance made in the study of virus diseases of plants. More attention came to be given to the virus diseases after the year 1920. The plant virus diseases appear to have spread alarmingly and to have become much more prevalent in the present day. Conflicting theories of the nature of viruses themselves were prevalent for a long time and there was much of wrangling as to whether the viruses were living organisms or only inanimate proteins. The intimate relationship between the viruses and their insect vectors in certain cases was worked out in detail. The dispersal of the viruses through specific insects in certain cases and by a set of insects in others without any specialisation was brought out by the researches carried out in different parts of the world. Pathologists, entomologists and biochemists worked in teams to discover the properties and nature of different viruses. Stanley was able to isolate the tobacco mosaic virus as a crystalline nucleo protein which induced the mosaic when injected back into the healthy tobacco plants. His discovery constituted an important event in the history of virus pathology and this was eagerly seized upon and diligently followed by a group of English workers Bawden, Piere and Bernal amongst others. But still, the controversy whether the viruses are living organisms or chemical entities goes on. There is a school which is of opinion that the viruses are presumably akin to genes. Numerous viruses were being discovered on the different crop plants and these differed from one another in their host range, specificity of insect vectors, physical properties etc. This necessitated their classification in some form or other.

The earlier workers classified the viruses of different plants according to the hosts and the symptoms caused on the hosts like 'Sugarcane mosaic virus'. 'Tobacco mosaic virus' etc. This was followed by the system of classifying the viruses affecting particular genera according to the genus of the host and giving numerals to the different viruses occurring on the same host as 'Solanum virus', I, II. 'Saccharum virus', I, II, etc. Holmes in the United States of America proposed a binomial system of nomenclature for the classification of viruses. This has as its basis the symptom picture produced on the hosts. All mosaic diseases came under the family *Marmoraceae*, and the virus causing mosaic of tobaco was designated

Marmor tabaci. This classification however has not found much support among the other virologists. At the sixth International Congress of Microbiology held in Rome in 1953 the question of the nomenclature of the viruses was considered. It was decided that the use of systems of classification for and the application of binomials to viruses as a whole are undesirable and should be discouraged. (Nature 172, 620. 1954). The discovery of the electron microscope enabled the confirmation of the particulate structure of viruses. This instrument is being put into greater use for furthering the knowledge of the properties of viruses. In spite of all the extent of information available on viruses, the control of virus diseases presents a difficult problem. More reliance is placed on the search for resistant varieties of crop plants. In this attempt more and more use of the wild ancestors of the different crop plants is being made. Vigorous attempts have been in progress in fighting the degeneration (virus) diseases of potato. Stress is laid on the production of disease free seed tubers and their multiplication in isolated areas to replace the seed material in infected localities. The west of Scotland is the source of seed for England and the northern state of Maine for the Southern states of U. S. These places have been chosen because they are often free from insect vectors which help to spread the disease. The tristeza or the quick decline of orange is also attributed to a virus and is threatening the cultivation of oranges in many parts of world. Intense research in the use of different root-stocks, use of nucellar seedlings and adoption of other special horticultural practices like inarching on different root-stocks is being carried out in different continents for overcoming this disease. The swollen shoot of *Cacao* has come into prominence in recent years. It can be confidently stated that almost every agricultural or horticultural crop is affected by one or more virus diseases. Though virus diseases were known from ancient days, (breaking of tulips) more definite information about the nature of the viruses, their transmission and methods of control has accumulated only in recent years. Furthermore the differentiation of the different viruses occurring on crops is being attempted by serological tests. It has been found that when certain plants are affected by a mild form of a virus it is able to resist the infection by more virulent forms. This knowledge has stimulated the trials at immunising perennial plants (fruits) by infecting them with the mild virus. It remains to be seen how far this will become a practical method. A certain amount of success has been achieved. Chemotherapy is being employed to inactivate viruses in perennial plants. By injection of 9-aminobenzene sulfonamide (0·05%) the virus of X-disease of peach is being inactivated. Thiouracil is reported to act as a viricide.

Following the studies on the physiology and nutrition of higher plants, the influence of various nutrient substances on the intensity of infection by pathoganic organisms were also studied. We know at present, that excess of nitrogen favours the onset of various diseases in several crops. Phosphates are known to keep down infection especially those affecting roots. Balanced application of N. P. & K. are necessary to keep down certain diseases (stemrot of rice). The role of micronutrients both on physiology of fungi and in the control of diseases caused by fungi is under extensive investigation. There are indications that zinc compounds in small doses keep down wilt diseases of cereals and others. Foliage sprays of urea and micronutrient substances are coming into vogue both as a method of supplying nutrition and for the control of certain diseases as root rot and die back of *Citrus*. The influence of manures on the incidence of virus diseases is also receiving greater attention in Europe and America. The attempts to control vascular diseases of plants through chemotheraphy has given success in some cases. The control of toxin-induced Dutch elm disease by the injection and use of 8 hydroxy-quinoline benzoate is a notable instance.

The development of the study of antibiotics produced by various microorganisms has resulted in attempts to utilise this phenomenon for the control of crop diseases. The earliest attempts were directed towards the encouragement of the growth of saprophytic moulds in the soil by the addition of humus or organic matter or green manures. These moulds either by competition or by antagonism helped to keep down the pathogenic organisms and thus reduced the incidence of diseases. The control of the scab of potato by green manuring is a notable example.

Further developments were in the direct use of the antibiotics produced by different fungi for combating crop diseases. However many of them were not fungistatic but only bacteriostatic. Actidione one of the products produced by *Streptomyces* has been reported to be efficient in the control of mildews of peas and beans. Griscofulvin is known to be absorbed by the roots and translocated to different parts of the plant rendering the latter immune from infection by specific pathogens. The antibiotic produced by *Bacillus subtilis* is also claimed to have a similar effect in preventing infection by *Alternaria solani*. These studies are however limited in extent and the adoption of the measures recommended is not within the reach of many of the cultivators at the present time. However they indicate the possibilities of utilising these products or the direction in which future research may look for suitable fungistatic antibiotics. It may not be possible to obtain such remarkable therapeautic results with these substances on plants as in the case of human beings and animals. At present there is wishful thinking for the development of systemic fungicides. The production of systemic insecticides for the control of pests has stimulated the desire and search for such fungicides which will, if discovered have a continued effect and will be very effective against root diseases or soil borne infection. There will not be any necessity for repeated applications of fungicides which increase the cost of plant protection. There is however one snag in this. The chemicals that are now applied remain on the surface of the plants and destroy the fungi or bacteria which may come into contact with the coated surface later or the chemical destroys the spores which are on the surface. A systemic fungicide must be able to kill the mycelium growing inside the tissues, without at the same time affecting the host cells. Since the host and the parasite belong to the same vegetable kingdom and not to different groups as in the case of insects and plants the chances of discovering an efficient systemic fungicide are not so readily attainable as in the case of insecticides.

To sum up, during this half century there has been considerable development in the knowledge of life histories of fungi, their cytology and physiology, the factors favouring their parasitism and the host parasite relationship. There has been considerable advance of the knowledge of the nature and transmission of virus diseases a new branch which has been developed only during this period. Remarkable progress is evident in the formulations of the fungicides and in the development of spraying and dusting equipments within the last decade due to the stimulus of World War II. If the same rate of progress is maintained the control of several devastating plant diseases will be rendered easy in the near future. However there are still certain groups of diseases which defy all our attempts to keep them in check as for instance soil borne diseases and root diseases. It is hoped that by the united efforts of the chemist, physiologist, pathologist and the engineer suitable methods of control will be evolved for checking these diseases at an early date.

So far the progress in plant pathology in the world has been considered. Coming to India, sustained interest in plant pathology as we know it today was taken up only after the appointment of Dr. Butler as the Imperial Mycologist at Pusa in first decade of this century. In the early years he was reconnoitering and collecting informatian on the incidence of various fungi and diseases of crops in the country. He has done remarkable pioneering work and his book 'Fungi and disease in plants' is a standing example of the quality and quantity of work done. Some attempts were made in the selection of rust resistant wheat also at Pusa. With the establishment of agricultural departments in the various States more attention was devoted to the study of diseases of crops in the provinces. Madras and Mysore have excellent records to their credit and several diseases affecting perennial crops like *Areca*, coconut, rubber palmyra and orange were investigated and control measures evolved. In combating rice diseases, Madras has taken the lead and by persistent efforts has given to the cultivator a number of useful strains which could withstand the dreaded blast disease. Mehta's contributions to the study of rusts of wheat in India should be taken note of. After the World War II, the role of plant diseases in reducing production has been recognised by the centre and the states and special plant protection organisations have been started to help the farmer in combating the diseases affecting his crops. All this progress is not enough to meet the problem. This branch of Agricultural Research should be expanded much more. One Pathologist situated in one Institute cannot do justice in the investigation of all the diseases of the multifarious crops grown in the State. In the case of human beings constituting one species, the number of hospitals and doctors attending to the well-being of the people are so many though the number may not be considered adequate for the population. But when the crops are many and each crop has several diseases affecting it and there is little chance of communication between the patient and the doctor regarding the nature of the trouble, the necessity for a number of pathologists to tackle the disease problems of each group of crops in different regions is obvious.

In these days of specialisation it is suggested that we must follow the lead of other countries where agricultural research has advanced considerably and have pathologists for each group of crops like cereals, fruits, vegetables and so on to enable intensive research to be carried out on the various diseases peculiar to each.