TROPICAL MYCOLOGY : FUTURE NEEDS AND DEVELOPMENT

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THE study of the taxonomy, biology and distribution of tropical fungi and the application of the knowledge gained from such study for human welfare is the concern of tropical mycology. Fungi are neither plants nor animals and are considered to belong to a kingdom of their own. Though they lack the green pigment chlorophyll and must therefore, depend for their sustenance on living plants, animals or other organisms, or the dead remains of these, this deficiency is more than compensated by their ability to produce a fantastic variety of enzyme systems capable of breaking down an equally fantastic variety of substrates. Little wonder then that they occur in all kinds of habitats and on all kinds of substrates. About 60,000 species of fungi have been named or recognised, but new species and genera are still being described from all parts of the world, especially from the tropics. Despite the admittedly extraordinary diversity of form, structure and habitats of tropical fungi, tropical fungus floras have been mapped unevenly, inadequately and irregularly both in space and time. Vast tracts in the tropical belts, and diverse habitats and substrates in them, remain completely unexplored.

The fungi are a major component of tropical ecosystems throughout the world. They are involved in innumerable interactions with plants, animals and man, ranging from saprophytism to parasitism and symbiosis. Not much is known about these interactions as they occur in the tropical situation. But we do know that these interactions may sometimes be harmful and sometimes beneficial. Knowledge about the taxonomy and biology of tropical fungi has immediate relevance to the control of harmful interactions and the harnessing of useful fungal activities for human welfare. The main aim of this paper is to highlight some of these interactions and outline the directions in which tropical mycology should develop in relation to our needs.

Consider, for example, the problems posed by fungi causing superficial or deep-seated infections (mycoses) in man and animals in the tropics. Some of these obviously have a very wide distribution in the tropics and are a serious threat to human and animal health. Unfortunately, both veterinary and medical mycology have attracted very few students in India and in the tropics generally. The etiology and distribution of many tropical mycoses are not understood at all and naturally there are no methods of control either. Although superficial infections which are so obvious may not remain unnoticed, other cases in which fungi may be involved as, for example, ocular infections or infections of the nervous system may invariably remain unnoticed and undiagnosed for want of the kind of expertise that is required. The recent discovery of *Blastomyces dermatitidis*, the fungus causing blasto-mycosis, in bats in India (hitherto known only from the New World and Africa) by Dr. H. S. Randhawa and his colleagues at the Patel Chest Research Institute in Delhi underlines the need for similar studies. The study of the occurrence, distribution, etiology and control of mycoses of man and animals needs to be taken up urgently as, for example, Rhinosporidiosis which has baffled students for a long time and the true nature of the organism involved is itself still controversial.

On the other hand, a fungus may sometimes help in the solution of a public

health problem, for example malaria. Despite the spectacular success of DDT in the control of mosquitoes and thus of malaria in the tropics during the last war, continued use of DDT has led to the development of resistance to the insecticide in the target insects and malaria now shows up again in the tropics. The discovery of two species of fungal parasites (*Coelomomyces—C. anophelisica, C. indiana*) of mosquito larvae in India by M. O. T. Iyengar more than 50 years ago was followed by the discovery of many more species, all parasitic on larvae of various species of mosquitoes which are vectors of malaria from many parts of the tropics. Pioneering work in this field has been done over a period of many years by Prof. John N. Couch of the University of North Carolina at Chapel Hill. Prof. Couch has the most comprehensive collection of these fungi and their vectors and he has been working almost single-handed on a monograph of this important group of fungi. Later work by Prof. Whisler of the University of Washington at Seattle revealed the interesting fact that one of these fungal parasites completes its life cycle partly on mosquito larvae and partly on a Copepod, both of which occur in the aquatic habitat. While a great deal of taxonomic work on these fungi has been accomplished by Prof. Couch, there is the urgent need to critically study the biology of these fungi in the natural environment in which they occur, for example, in the paddy fields of Southern India. Such studies are likely to lead to a method of biological control of the vectors and any success in this area would be of far-reaching significance in the control of malaria.

The problem of nutrition is closely linked with public health. One major problem in which fungi are involved concerns post-harvest damage to grains, fruits, vegetables and animal feed resulting in enormous losses and a positive depletion of much that is produced. This situation is an anticlimax to our other achievements in agriculture which led to the green revolution. Also, many moulds attacking grains and feeds produce toxins (mycotoxins), many of which are a serious hazard to the health of man, of livestock, poultry, etc. There are records of mycotoxicoses going back to over a hundred years or so, but knowledge of their cause is more recent. Moreover, it is in the tropics that these problems loom large; the high humidity coupled with high air temperatures of the humid tropics are ideal for the development of moulds and their toxins. Mycotoxins and mycotoxicoses are, in fact, a major hazard to public health in the tropics and only a knowledge of these can provide possible methods of control. Methods need to be developed for the quick identification and even assay of at least the more common and potent of these toxins. The alleged use of mycotoxins in warfare is a warning against complacency and must in fact provoke not only criticism of the unethical issues involved, but a positive effort to step up research on methods of combating the effects of such toxins. Fortunately, there is an awareness of the importance of studying mycotoxins in India, but it is necessary that studies should be aimed at obtaining practical solutions to problems.

Apart from toxins produced by moulds there are highly potent toxins produced by mushrooms which are poisonous. Our knowledge of tropical mushrooms is meagre. The mushroom *Amanita phalloides* is deadly poisonous even in small doses. Various toxins such as the Phallotoxins and Amatoxins have been isolated from this mushroom species. The mode of action of these toxins has been elucidated. However, a great deal of further work is necessary in this area.

Notwithstanding the success of the green revolution, biodeterioration of products of the green revolution continue to pose a serious problem. Innumerable common moulds are involved in such biodeterioration of essential items of food and feed in the tropics. Biodeterioration by fungi is

universal and affects not merely food and feed but numerous other raw materials and products such as wood, pulp, paper, textiles, leather, rubber, paints, plastics, and innumerable items of common use. The importance of such biodeterioration came to be recognized particularly during the last world war. As a result, considerable research was initiated, especially by the defence and other establishments in many countries. The discovery of the kerosene fungus *(Amorphotheca resinae)* and its widespread occurrence in kerosene fuel has now become a global problem causing considerable damage by way of choking of fuel systems in jet aircraft. The extent of damage or loss from biodeterioration is incalculable and is reflected in the publication of the *International Biodeterioration Bulletin* and its corollary, the *International Biodeterioration Titles*, both published by the International Biodeterioration Centre in the United Kingdom. It is necessary to evolve methods of controlling biodeterioration. Critical studies of methods of storage of grains and feed and controlling the development of moulds in storage are needed.

It is also necessary that unconventional methods of production are investigated. The possibility of turning agricultural, industrial and other wastes into some kind of biomass that can be used directly or indirectly as food or as feed has not only been mentioned but is being attempted. The fungi have the unique ability to break down complex substrates such as lignin, cellulose, chitin, keratin, etc. and in bringing about various transformations. In fact, the fungi play a very important role in the decomposition of organic matter in nature without which much of the recycling of basic materials on which life depends would not be possible. It is equally possible to rely on these abilities of the fungi to bring about transformations of various kinds. For example, a great deal of work has been done, particularly in the United States and in Japan, on the possible use of fungi in the conversion of cellulose. However, it is in the tropics that one needs to search for moulds with an enormous potential for various transformations one is interested in. The tropics is nature's store-house for these magnificent moulds and, needless to say, culture collections of these fungi need to be built up in different countries of the tropics including India. This, of course, implies the need for trained and competent fungal taxonomists, whatever may be the problem in which the fungi are involved.

Equally important is the need to study tropical mushrooms with particular reference to their edibility and culinary properties. Again, this is a very much neglected area of study. We do not know our mushrooms. The most widely cultivated edible mushroom is the common *Agaricus bisporus* but several others, particularly species of *Volvariella* and *Pleurotus* are cultivated extensively in some countries in the East. The use of mushrooms as food is apparently quite common among primitive tribes in various parts of India and other tropical countries, although mushrooms as a widely used item of food are not popular among these people generally. Ethnomycology concerns the study of mushrooms and other fungi used by ethnic groups as food or drugs or otherwise and it is essential that we collect all available information before the tribes become extinct and the information becomes unavailable.

A major threat to man's future on this planet is the continuing deterioration in the quality of the environment. The continued denudation of forests for short term benefits of wood and fuel, has not only led to an erosion of the sustaining qualities of the soil but also to far-reaching and adverse changes in climate. Similarly, the spectacular and successful use of pesticides, fungicides and weedicides for the control of pests, fungi and weeds, has led to a dangerous accumulation of many of these substances in our

ecosystems. Equally significant and dangerous is the problem of pollution due to industrial wastes and effluents. The first of these problems calls for afforestation on a massive scale. A major factor contributing to success in afforestation programmes is the occurrence of fungus-root (mycorrhiza) associations which are widespread but yet may often be very specific in that, only a particular kind of fungus may be associated with a particular species of trees. Fungus-root associations are of mutual benefit to the fungus and the tree concerned. A great deal of work has been carried out on mycorrhizal associations in the temperate regions, but little has been done in the tropics. Studies on mycorrhiza have immense potential in afforestation programmes throughout the world.

The problem of pollution of our environment by pesticides and other toxic chemicals and by industrial wastes and effluents needs to be tackled by using microbe power. The biodegradation of a number of commonly used insecticides, fungicides, nematicides and other biocides by various species of soil fungi *e.g. Penicillium*, *Trichoderma*, many of which are common in soils has been demonstrated. However, further studies are needed in the application of these findings in promoting desirable biodegradative activities using these moulds. Similarly, there is the possibility of using fungi in the biodegradation of industrial effluents. This subject has received very little attention. Studies of the mycoflora of various industrial wastes and effluents such as have been initiated in this Centre are necessary to isolate and identify fungi which may have potential use in the degradation of effluents. The growth of various industries such as those related to petrochemicals, pharmaceuticals, paper, plastics, rubber, etc. in the foreseeable future, especially in India, calls for special attention to research in the microbiology of treatment of effluents from various industries. The study of mycofloras of industrial wastes and effluents has special relevance in this context.

When one considers the direct use of fungi in various industrial processes and fermentations, one immediately notes that there are very few chemical industries in which fungi are not used directly or indirectly. Antibiotics (*e.g.* penicillin, cephalosporin, griseofulvin), various organic acids, a variety of enzymes such as diastase, amylase, protease, etc. are well known examples. Much of the work in this field has largely been done in the West. Professor Raistrick of the London School of Hygiene and Tropical Medicine pioneered the study of mould metabolites. A vast literature on fungal metabolites exists, thanks to studies carried out by organic and biochemists. However, the search for fungi for potential use in various industries is endless and must continue. As already noted, the tropics are a very rich source of potentially useful fungi many of which probably have not even been recognised, described or named. There is little doubt that continued exploration and systematic study of fungi in the tropics would bring to light many species which may have potential use in biotechnology.

Considerable work has been carried out with a view to evolving better strains of moulds *e.g.* strains giving higher yields of penicillin or better strains of yeast (*Saccharomyces cerevisiae*) for use in the brewing industry. The development of new strains has been achieved by mutation and breeding. The demonstration of protoplast fusion in different species of fungi, further facilitates the possibility of obtaining suitable hybrid strains for use in the industries. While these methods must continue to be used, it is equally important to tap nature's own vast assemblage of potentially useful species and strains.

Let us consider another area of tropical mycology which is of considerable interest. This relates to the interesting group of fungi

that infect insects, and often referred to as entomogenous fungi. The fungi which attack insects are a highly specialised group and practical importance naturally attaches to some of these fungi which attack insect pests of our crops. Admittedly, biological control of insect pests may not be easy, but yet it is a challenging problem well worth study. Somewhat on the same line of thinking, one might consider using fungi for the control of weeds, some of which like the water-hyacinth and *Parthenium hysterophorous* pose a serious problem.

Notwithstanding the general paucity of serious research in the tropics in many of the areas mentioned above, one notes with satisfaction the fact that relatively much more work has been carried out on plant disease due to fungi in the tropics. The tropics are the source of the bulk of the tropical agricultural and forest products for the rest of the world and it is not surprising that in many parts of the tropics which have been under political domination of western countries a great deal of work has been initiated on fungi and plant diseases. In fact, this is one area of applied mycology which has received the greatest attention in the tropics. The emphasis in such studies has naturally been on the effects of disease on crops. Considerable work has been done not only on the etiology of many of these diseases but also on the problems of disease resistance and also on virulence and variability of pathogens. However, the effects of various varieties and species of hosts on growth and multiplication of pathogens or fungi in the parasitic phase have received little attention in the past. Future studies must focus attention on the effect of host plants not only on multiplication but also on the genetics of pathogens.

The development of tropical mycology is therefore a vital component of any plan for the development and welfare of the peoples not only in the tropics but throughout the world because the future of man must depend on international cooperation and collaboration. This fact was taken note of at the second International Mycological Congress held at Tampa, Florida, in the United States 5 years ago. The Congress adopted a resolution recommending support for the development of mycology in the tropics, particularly in developing countries where support may not be available or may be inadequate. More recently, the International Union of Biological Sciences, not only accepted this resolution at its General Assembly held in Helsinki in 1979 but further recommended that the establishment of an Institute for Tropical Mycology be considered.

The development of tropical mycology can be achieved only by the development of research in the taxonomy and biology of fungi and the application of the knowledge gained to control the activities of fungi which are harmful and to harness activities which are useful for human welfare. The most pressing need is to have competent taxonomists who can identify the innumerable fungi that are everywhere and involved in many activities of concern to us. Admittedly, this cannot be achieved without suitable provision for training mycologists. Teaching of mycology in the tropics is unfortunately largely based on European texts and European examples and this is an anomaly which must be done away with. Tropical fungi must be studied by us in the tropics so that we become completely self reliant. Our teaching of mycology will then become really meaningful and lead to training of competent mycologists who can study the problems posed by fungi in the tropics on their own.