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A Perspective of Mycological Research & Teaching in India[1]

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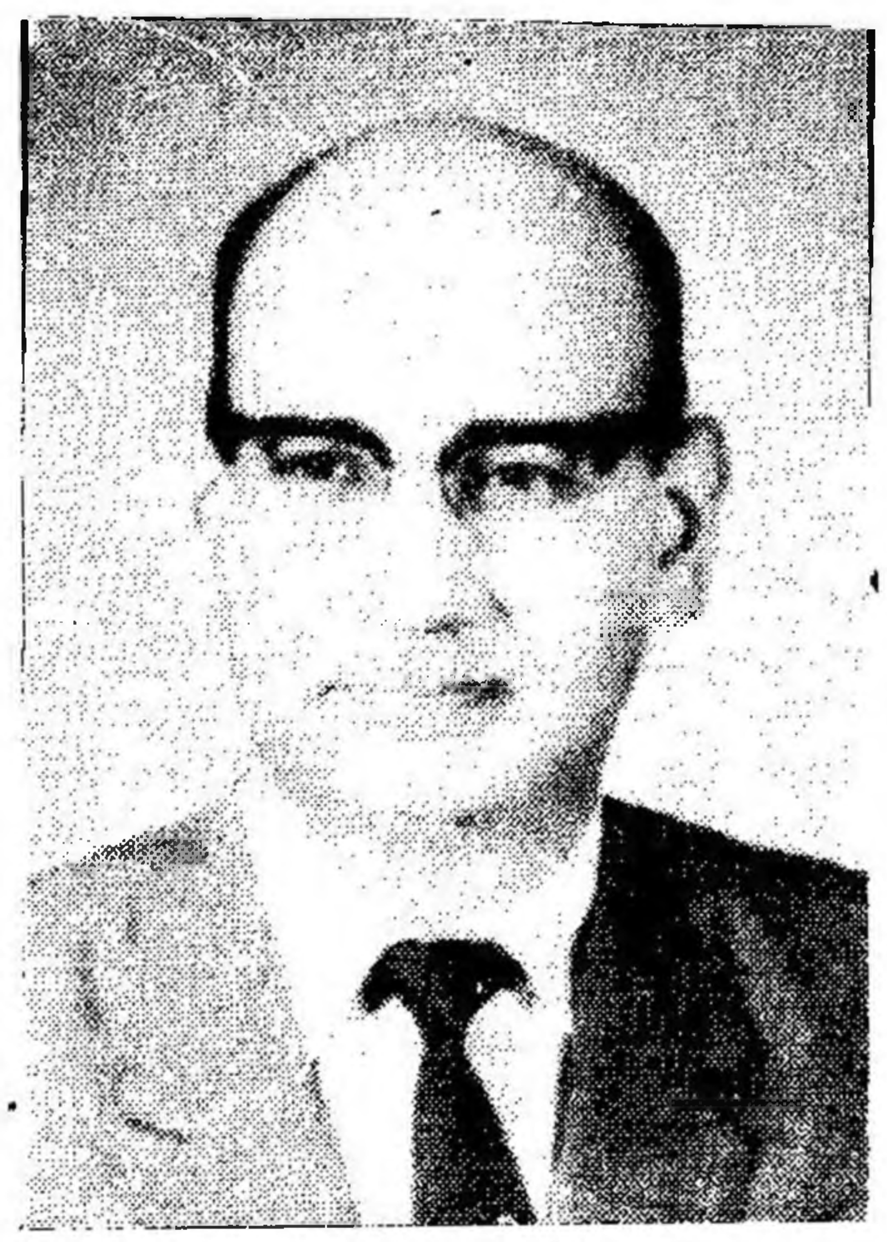
I am indeed deeply grateful to the Indian Botanical Society for the honour it has done me by presenting this coveted Birbal Sahni Medal instituted in honour of the greatest among the great botanists of our country. Besides being an eminent paleobotanist he was equally a great teacher, a gratifying exception to a generalisation that good researchers seldom make good teachers and vice-versa. An eloquent testimony to this fact is the endowment for this medal itself as it is the result of the lasting impression Professor Sahni left on one of his students who was destined to be the present Professor T.S.Sadasivan, one who is respected not only among mycologists and plant pathologists but also among the botanists as a whole. Few of us, however, might be aware that Professor Sahni was very much interested in mycology or more precisely paleomycology, as well. During the course of his presidential address to the 27th meeting of the Indian Science Congress in 1940, held at this very university, he recorded two fossil fungi for the first time in India. One with spherical closed bodies of a dark colour *Perisporiacitis varians* Sahni & Rao (1943) and the other with flask-shaped perithecia resembling the present genus *Sordaria* which was named *Palaeosordaria lagena* Sahni & Rao (1943). They were subsequently published in 1943 (Sahni & Rao, 1943) and still figure in the latest edition of Ainsworth's and Bisby's Dictionary of fungi (1983).



In choosing a topic for a privileged talk for this occasion I had one prime consideration in mind; that it should be one in which botanists in general may feel interested even though I may have to divert from my present field of interest.

Mycology is one of the oldest disciplines of Botany which has not only survived in the presence of many new attractive disciplines but has progressively increased in its glamour. Maximum teaching of mycology is still being imparted in the Botany departments of this country. In fact, this department at Madras has been known for its contributions in mycology and also its application to plant diseases. It is here in 1929, while delivering his presidential address to the Botany Section of the Indian Science Congress, Dr.K.C.Mehta declared for the first time that wheat rusts in India perhaps survive in the hills through the summer. Here we also had one of the most largely attended international symposia on taxonomy of fungi in 1973. Is it not then befitting that a mycologist, and for that matter mycology itself is being accorded a recognition at this Centre ?

While dealing with fungi we have to bear in mind some of the outstanding peculiarities inherent to this group of organisms; their absorp-

[1] irbal Sahni Award lecture delivered at Madras, December, 1986.

tive mode of nutrition as against either photosynthetic or ingestive of all other multicellular organisms, extraordinary flexibility of somatic couplings resulting into astonishing diversity of form and developmental patterns and capacity to invade and survive in nearly every environmental condition on earth, as well as a number of cytological peculiarities: chromosomes of most fungi (except Oomycetes) lacking or having only small quantities of the histone proteins that are characteristic of the chromosomes of all other eukaryotes, mitotic division intranuclear, dikaryotic vegetative phase (in higher fungi) and its prolonged survival, and natural occurrence of heterokaryosis and parasexual cycle.

Besides their above noted peculiarities, they are one of such groups of organisms whose status among the living organisms is not free from controversy even today. Their continued acceptance as plants has been described even an "yet another example of the inertia of orthodoxy and conservatism" (Ainsworth, 1976). These are the reasons why fungi have attracted the attention of naturalists since the dawn of history and are still attracting morphologists, taxonomists, cytologists, geneticists, biochemists, ecologists, industrialists and biotechnologists.

For a title with such a wide coverage as the present one, it is necessary to choose what to omit from the great array of areas in which mycology is playing its significant role. I have consequently selected certain topics of greater interest to me from the following three major areas of mycological research; a. Mycological surveys, b. Mycology in Biotechnology, c. Mycology of special ecological niches. At the end, a brief discussion of the present and future of mycological teaching in India will follow. The thrust as a whole will not be on a review of the literature on the different aspects chosen by me, because I have already done so on separate occasions elsewhere, but to first introduce the topic and then to point out some of the contributions of our own, and what more is still to be desired.

MYCOLOGICAL SURVEYS - Surveys of fungi in any country are essential, as different geographical locations harbour different flora and not only the pathogens of all region have to be identified for they may pose a danger for other regions, but also the saprotrophs be accurately determined as they may prove to be useful for practical application in industry or as biological tools. Mycological surveys are still more important in India because of the existence of a wide variety of physiographic features in this country.

Fungi have been known to us since time immemorial. They are mentioned in our Vedas which date back to 1200 B.C. or so. However, hardly 100 species of fungi were known in India till 1850, and that too, mostly of higher fleshy fungi collected by expeditionists visiting India for a purpose other than mycological explorations. The present number of species reported as per Sarbhoy *et al.*'s list of fungi published in 1981 is 13,555. This figure, even if we take it for granted to be correct, is far from encouraging in view of the long period, a century and a half, of activity of our mycologists. We should rather expect a much higher figure in view of 64,200 species known from the world (Hawksworth, *et al.*, 1983). With over 15,000 species of phanerogamic plants, we have the largest number for any single country in the world. Several hundred of these are endemic to India. Based on surveys made in areas with sufficient number of mycologists it has been observed that parasitic fungi total approximately equal to or as high as five time the number of hosts (Bisby & Ainsworth, 1943) and the number may be much more when we take into consideration the animal hosts as well (Ainsworth, 1968).

As compared to world figures of different groups of fungi, we have still a long way to go. A number of taxonomic groups have not even been touched because of the difficulty in studying them or because little is known about the practical importance of such organisms. In general macrofungi have received more attention than the microfungi for the apparent ease in collecting them. The great potential of the mycological flora in our country is apparent from the fact that, in whatever group there has been intensive activity, a substantial addition to the flora of that group has been made. From my own experience with the order Mucorales, I can say with confidence, that if our activities are stepped up, the results will be still more rewarding. From a mere 40 species, belonging to 12 known genera of the order Mucorales, the number had escalated to over 135 species belonging to 26 genera in a short span of 5 years (1961-1966). Such additions to the number of species have not been a mere increase in number but have also added significantly to our understanding of the respective group in which our mycologists have worked.

PROBLEMS OF A TAXONOMIST - Fungi are inherently a variable group of organisms with a few aspects of fungal morphology that are stable. Fungal taxonomy has even baffled seasoned taxonomists not because it is in its infancy but because of the lack of information of the behaviour and attributes of certain fungi under altered environmental conditions. There are a number of difficult groups of fungi in which there is a dire need for additional taxonomically reliable criteria which can conveniently be ascertained, not only by an expert taxonomist but also by one who is interested mainly in their potentiality. Even in such groups earlier taxonomists have done a commendable job. I had an opportunity in 1956-57 of examining all the *Aspergillus* and *Penicillium* species monographed by Raper & Fennell (1965) and Raper, *et al.* (1949) respectively, in the same laboratory in which they were prepared. I can say on the basis of my personal experience that the major characters on which emphasis has been laid in the two monographs have largely remained stable all these years. However, efforts to find additional criteria to separate more closely related species, especially the ones with different important biochemical potentialities should continue. For example, in the case of the genus *Penicillium*, recent efforts to straighten its difficult taxonomy are laudable. The use of API ZYM testing system for rapid screening of enzyme activities (Bridge & Hawksworth, 1984) and cell wall composition (Gomez-Miranda *et al.*, 1984; Leal *et al.*, 1984) appear to be promising. Incidentally it may be mentioned that the cell wall of *Penicillium allahabadense*, Mehrotra and Kumar reported over 25 years ago by us has more galactose than the other 7 species tested by Leal *et al.*, (1984) in Spain. This adequately justifies a concerted search even for such intensively explored genera as *Aspergillus* and *Penicillium* .

WHAT IS NOW NEEDED TO STIMULATE OUR TAXONOMIC EXPLORATIONS OF THE FUNGAL FLORA?

Undoubtedly there is great scope in India for discovering newer fungi, not only with interesting morphological features but also with newer biochemical potentialities though there is a tendency among taxonomists to shift to more glamorous fields in mycology/for which funds are available, and this is true not only for India but even for advanced countries of the world. Some efforts have to be made to encourage this useful and rewarding activity of mycologists. Few of the ideas put forward by me earlier (Mehrotra, 1977, 1983a) are being briefly reiterated here as they are pertinent and relevant even today and may go a long way in boosting taxonomic explorations in India.

A more intensive survey of the fungi of India, in all possible ecological niches and on the basis of botanical regions, keeping in view the type of vegetation, is worth undertaking. A thorough knowledge of the ecology of both hosts and parasites is essential for a reliable taxonomy of parasites as has been emphasized for rusts by Savile (1979).

Efforts ought to be made to conserve the mycoflora. There is enough talk on the conservation of our biological resources. An inventory of the flowering plants (2,000 species out of 15,000 species) has also been made. But nothing has been done in this direction either nationally or internationally to identify species which are on the verge of extinction due to indiscriminate collections and man-made environmental hazards. A day may come when we may be left with little to explore especially with respect to such higher fungi which since posterity have been attracting the curiosity of man.

An uptodate list of fungi by a group of competent mycologists specializing in different major groups, prepared after ascertaining the validity of the new taxa, is of great value.

Culture collections and herbaria be established in the country as in U.K., U.S.A., and The Netherlands, with specialists in different taxonomic groups of fungi. National identification service centres are a must for speedy identification of cultures of our mycology and plant pathology workers, many of whom still are depending on foreign culture collections even for not too difficult isolates. The best course for our country seems to be to afford facilities for identification services for different fungal groups under the charge of persons who have already distinguished themselves with those groups. This will be economical as well as more efficient than establishing a single Centre.

A multi-disciplinary integrated approach towards solution of problems of identification in groups where species circumscription is uncertain.

Attempts be made to determine the affinities of mycoflora of India with those of other lands, just as has been done with the flowering plant flora.

Finally, may I plead for the preservation of taxonomic laboratories. Such laboratories are not established overnight; they gradually come up generally by a single man's effort who leads a team of workers and with his/her retirement the laboratory should not be allowed to perish as happens often!

MYCOLOGY IN BIOTECHNOLOGY - The foundation of the present day manufacture of useful chemicals was laid by mycologists - the French mycologist van Tiegham in 1867, who gave the process for gallic acid, and the German mycologist Wehmsr in 1891 and 1893 by discovering the manufacturing processes for oxalic and citric acids, respectively. Undoubtedly mycologists still can make significant contribution to biotechnology. Our culture collections, according to Hawksworth (1985), are a valuable resource to biotechnology and related fields. I had once pleaded at the International Conference on Culture Collection held at Tokyo in 1968 (Mehrotra, 1970) for the establishment of a culture collection of industrial cultures for the promotion of industries internationally but it seems this will be translated into a reality only when the fermentation industrialists cooperate.

A number of well-established biotechnological applications of fungi are known. Out of these, the production of citric acid and fats from moulds, in which my group has been particularly interested will be briefly discussed here.

FUNGAL PRODUCTION OF ORGANIC ACIDS - Most of the citric acid being industrially produced in the world is by fermentation of molasses by a high yielding strain of *Aspergillus niger*. The technology developed for this manufacture has even helped in the subsequent industrial production of antibiotics. Six of the high yielding strains were selected out of hundreds of isolations from nature on a selective medium for the determination of the optimum nutritional (Mehrotra & Singh, 1972a, Singh & Mehrotra, 1972a, 1972b) and environmental (Mehrotra & Singh, 1972b) requirements for citric acid production. An evaluation of Indian strains of *A. terreus* for itaconic acid production was also made by us and the requirements of fermentation for this acid were determined (Mehrotra & Tandon. 1970a; 1970b and Tandon and Mehrotra 1970).

In India we have yet to set up our own citric acid industry. Attempts in the past with foreign collaboration have failed. Divekar *et al.* (1971) at the Regional Research Laboratory reported the recovery of 75-78% in shaken flasks and 72-75% in laboratory fermenters by using sugarcane juice with a little pretreatment. Citric acid requires a control over a number of factors and experience of both the fermentation and recovery stages is needed. Important considerations in fermentation are adequate methods for reduction of the levels of ions, especially copper and zinc, which are needed in minute quantities, and iron and manganese which have to be efficiently removed from the broth. More recently, yeasts (*Candida* and *Saccharomycopsis* spp.) are being tested for citric acid production from natural oils, fatty acids, glycerol, etganol, and n-paraffin (Furukawa & Kaneyuki, 1975, Ikeho *et al.*, 1975).

FATS AND OILS - An adequate supply of fats and oils is essential for all countries. Though plant seeds are the principal sources and animal fats and fish oil are additional sources, yet there is a perpetual shortage of fats and oils leading to high prices. There is therefore, enough scope for subsidiary sources to meet the food and/or industrial requirements for these. Among fungi, yeasts *Rhodotorula* and *Lipomyces* spp. are considered favourable for fat production (60% of the cell dry weight). Some of the filamentous fungi have also been tested for their potentiality for fat production. In a survey conducted in our laboratory, 96 species of moulds belonging to 14 genera were screened for fat production. Seven of the species of the genus *Mucor* and one of *Phycomyces* yielded fat above 40 percent and 19 species produced 30-40 percent (all of the order Mucorales) and the rest below 30 percent (Mehrotra & Nand, 1970a). The hydrogen-ion concentration of the substrate suitable for fat production was 6.5 for some species and 8.5 for others (Nand & Mehrotra, 1970) and for some, a temperature of 20°C and for others 25°C was suitable for fat production (Mehrotra & Nand, 1970b). Fats from moulds in general are said to have more commercial value than from yeasts because of their higher content of polyunsaturated fatty acids (Whitworth & Ratledge, 1974). Much more work in India is needed for establishing a commercially feasible proposition for manufacturing fats and oils from moulds but it will be well worth the toil in view of the high cost of fats and oils in the country even for industrial use.

MYCOLOGY OF SPECIAL ECOLOGICAL NICHES - Fungi are well known to colonize a large variety of ecological niches and some of them have even adapted themselves to peculiar and unusual habitats. I have chosen three such categories of fungi out of the ones I had been interested in, i.e. the thermophilic fungi, the grain storage fungi, and the mushrooms.

THE THERMOPHILIC FUNGI - Thermophilic fungi constitute a small but significant segment of the fungal world. They are characterised by the extreme tolerance to temperature as they grow optimally between 40° to 50°C (maximum 60° to 62°C) and their minimum is 20°C. This capacity to tolerate high temperature by thermophilic fungi is astonishing in view of the fact that proteins coagulate between 55° to 60°C, a dog can survive for 5 h at 55°C and a man only for 6 minutes at 53°C (at R.H. 70%).

Not only their capacity to grow at high temperatures but also their incapacity to grow below 20°C is intriguing in view of the fact that many fungi do grow below this temperature. Hardly 50 species or so belonging to 20 genera are so far known to be thermophilic out of over 64,000 species of fungi. The ones which tolerate high temperatures but can grow below 20°C are generally categorized as thermotolerant. Interest in such fungi has generated only in the recent past and two or three good reviews are available.. Recently I have reviewed it (Mehrotra, 1985) during the Jeersanidhi Award of the Indian Phytopathological Society. A brief discussion is mandatory to project the importance of these fungi.

Taxonomically the thermophilic fungi are being studied by a number of workers. To the list of such fungi, a new genus *Thermomucor* has been reported from India by Subramaniam *et al.*, (1977). A number of thermophilic and thermotolerant fungi have been reported (Mehrotra & Basu, 1976; Mehrotra *et al.*, 1979; Srivastava *et al.*, 1981; Mehrotra & Basu, 1980). However, a more concerted search involving a variety of thermal habitats in India is very much desired.

Thermophilic fungi have a number of roles to play as biodeteriorants, biodegredants, in industrial fermentations, and as biological tools. As biodeteriorants they can cause spontaneous self-heating or ignition of stacked organic matter, damage to stored grains and disease in warm-blooded animals. Recently it has been reported that the toxin produced by a thermophilic *Thermoascus crustaceus* possibly acts as a co-factor in the aetiology of AIDS disease (Eichner & Mullbacher, 1984; Sell *et al.*, 1983). As biodegradants, they play a role in mushroom compost, chocolate and tobacco processing, upgrading of natural rubber from Guayule, bioconversion of agriculture, municipal, household and industrial wastes, biodegradation of ground newsprint to crude protein and upgrading of fodders to better feed. They are potentially useful organisms in industrial production of antimicrobial substances and enzymes.

Though themselves enigmatic thermophilic fungi offer promise for revealing the riddles of nature, such as evolution of eukaryotic life on earth and of late to throw light on the physiology of sexual morphogenesis. It is this latter aspect which I shall elaborate briefly as it has interested us lately.

There is no doubt that sexual reproduction in Mucorales is an appealing field of research for developmental biologists, biochemists, and students of secondary metabolism (Ende, 1978). Considerable effort has been made to explain the physiology connected with sexual morphogenesis in this order. The species that has been repeatedly employed for this purpose is *Mucor mucedo* Brefeld, a heterothallic species in which zygophores are distinct from vegetative hyphae - a distinct advantage in observation of the intiation of the sexual process. In recent years, evidence has been presented that trisporic acid(s) are involved in sexual morphogenesis in the Mucorales but as yet we know very little about the primary interaction between the mating types which initiate sexual activity. The inducer has been suggested to be an unknown volatile substance, a non-volatile substance, or a possible proteinaceous transforming principle.

As compared to heterothallic species, the physiological changes accompanied with initiation of sexual activity in homothallic species of Mucorales are still more enigmatic as little is known about them. Taking advantage of the fact that in a homothallic and thermophillic species, *M. miehei*, the sexual activity stops at higher ambient temperature (50°C) though vegetative growth continues, studies were conducted to investigate the physiological disability of the fungus at high temperatures. It was observed that at low temperatures (35°C or so) at which sexual reproduction occurs, the metabolic reactions within the fungus are such that they result into endogenous production of certain amino acids which are absent in the mycelium at higher ambient temperatures. Two of three amino acids i.e. aspartic acid and phenylalanine, if supplied singly and extraneously to the fungus at 50°C initiated sexuality even at that temperature and ultimately perfect zygospores were produced (Mehrotra & Mehrotra, 1980). Short spells of 5 h or so of low temperature incubation alternating with high temperature eliminated the extraneous supply of amino acids. We therefore concluded that the initiation of the sexual process in thermophilic species of *Mucor* is controlled by gene(s) which is repressed at high ambient temperatures and is derepressed at low temperatures. It is this gene(s), which is responsible for the production of the appropriate precursor, an amino acid(s), or the final product essential for the initiation of the sexual process. The speculation of the earlier workers (Ende & Stegwee, 1971) that in heterothallic species *M. mucedo* a continuous elaboration of a proteinaceous transforming principle may be involved may be true in view of this definite evidence of self produced amino acids in initiation of sexual activity in a homothallic member of the same order of fungi.

MYCOLOGY OF GRAIN IN STORAGE - Storage of grains is a must for any country whether deficient in food grains or in excess, not only because their harvesting is seasonal and their consumption is throughout the year, but also to cope up with the natural calamities and abnormal circumstances.

The high moisture content (ca. 53% in wheat) and the nutrient status of the grain in the field before harvest harbours a different flora than that in storage. Of the "field fungi" *Alternaria alternata* and *Cladosporium cladosporioides* are the most common (Mehrotra & Dwevedi, 1980). In storage, the grains deteriorate due to physiological causes and biological agents. Here they are in a different microenvironment than that in the field. Among the physical factors are temperature, relative humidity and CO_2 and O_2 content of the microenvironment. A relative humidity above 65% is not safe for grain storage. CO_2 content differs with the period of storage as it increases with respiration of the grains. Oxygen content of the microenvironment controls the microflora and insect flora as both depend on it for their survival and multiplication. Temperature of the environment controls the biotic factors e.g. insects are not found below 15°C, no mites below 5°C and no fungi below 0°C.

Of the microorganisms that invade the stored grains, fungi are the most important because they posses the greatest seed infecting capability. Further, the practice of storage of undried cereal grains in temperate countries (Hyde, 1965) has increased the importance of fungi over insects as under high moisture conditions fungi are the chief agents of deterioration. Besides, their potential to produce mycotoxins has greatly added to their importance, an aspect which we shall discuss later.

Two of the factors, moisture and temperature of the grains are most important in grain storage. Most stored products absorb water from the atmosphere until a state of equilibrium is reached. The moisture content or equilibrium relative humidity (erh) or water activity (Aw) is by far the most important factor in grain storage. Different kinds of grain may have different "critical moisture" at which they can get heavily infected, (23% bengal gram, 16% rice, 10% ground nut; Majumber *et al.*, 1965). The degree of infestation differs among grain-producing countries (Wallace & Sinha, 1975). For example, in a survey conducted by us from 1969-1974, it was found that the microflora associated with the imported wheat was less than in indigenous wheat (Mehrotra, 1976; Mehrotra & Basu, 1976; Mehrotra & Kunwar, 1980). Moisture above 13%

(Aw 0.7) is unsafe for storage and under such conditions fungi flourish. Generally 14-18% moisture in grains is congenial for supporting the growth of Aspergilli, mostly osmophillic of the *A. glaucus* group, 16-26% moisture is needed for Penicillia, *Absidia, Mucor, Rhizopus, Chaetomium*, and *Scopulariopsis*.

The temperature of the grain lot is one significant factor in the evolution of the mycoflora. Although growth of storage fungi can occur between 0°-36°C, optimum infection occurs around 27°C.

The general health of the grain is also a factor effecting deterioration. An unbroken seed coat is the best protection against all biotic factors. Careful handling and balanced drying always helps.

The infection of grain by storage fungi may differ in different cases. It may be intraembrial, extraembrial, systemic, local or organ-specific. The site of infection may be just the seed coat only, as in pea, pepper,squash, or embryo as in cereal grains. Commonly the storage fungi first grow within and on the inner layer of the seed coat probably because these tissues are frequently low in polyphenolic compounds. During a survey made by us, we found that subepidermal mycelium of *A. flavus, A. fumigatus*, or *A. niger* was present in 12-100% of the wheat grain samples examined (Mehrotra & Dwevedi, 1977).

INTERACTION OF FUNGI WITH INSECTS IN STORAGE

Infestation of grains with fungi is directly proportional to the level of insect infestation. Insects not only act as consumers but also add moisture and heat to the storage bin during the course of their activity therein. Certain fungi support full growth and development of the insects, some reduce the growth rate or reproductive capacity of insects chiefly if the fungus is a toxin producer (Wallace, 1973). Recently under an ICAR sponsored project, we observed that a substantial number of spores are carried on the surface of insects and a large number of spores are mechanically carried along with food in their alimentary canals. The spores present within the alimentary canals of the dissected insects were counted under a microscope and later isolations were made. The infestation of insects with fungi externally as well as internally was directly proportional to the fungal infestation of grain lot. Such a spore load of fungal spores serves as an inoculum for other areas in the grain lot. Besides, the respiration of insects adds moisture and warmth to the grain (Majumder, 1974). The insects have their own preferences for fungi. Given a choice of several fungi, the female foreign grain beetle viposits on *P citrinium* and *A amstelodami* (Bulla *et al.*, 1978). Mehrotra & Pandey (1985) found that given the choice between a common field fungus and a storage fungus, the insects *Tribolium castaneum, Rhizopertha dominica* and *Sitophilus oryzae* prefer the former *(Drechslera, Fusarium, Alternaria, Cladosporium* and *Cuvularia)*, and within storage fungi they can distinguish between common non-toxin producers as *A sojae. A. fumigatus. A. tamarii, A. niger* and *A. terreus*, from the well-known toxin producers, *Trichoderma viride, A. flavus* and *A. parasiticus*. The typical volatile secondary metabolites from fungal infested grains attract or dispel the storage insects, which possess an enigmatic capacity to code the sensory information relevant to them.

MYCOTOXIN CONTAMINATION OF STORED GRAINS BY STORAGE FUNGI -

The economic loss due to mould infestation of grains is not only due to decrease in their quality but also due to mortality in human and animal consumers of grains containing toxic metabolites produced by the moulds during their growth. Mycotoxicoses due to consumption of mould infested grains is known for over 5000 years but they have come into prominence during the last 25 years or so.

Of all the mycotoxins, the aflatoxins are by far the most potent carcinogenic compounds known to man. Contamination of aflatoxins occurs mostly in stored grains and in some crops, such as maize, cotton, groundnut and sorghum; it may occur in the field itself. Only two closely related species of *Aspergillus*, i.e, *A. flavus* and *A. parasiticus* are known to produce aflatoxins, some strains of the former and all strains of the latter species are potential producers of these toxins. During a survey from 1973-76 it was found that *A. flavus* was more frequent on cereal grains in India than *A. parasiticus* (Mehrotra, 1983b).

THE FUTURE - The mycotoxins, especially the most common and important, the aflatoxins, have received the attention of a number of mycologists and biochemists in India. Several papers deal with the fungi associated (superficially and/or intimately) with cereal grains, spices, dry fruits, and other commodities. A number of projects have been completed and some are in the process of completion. But an overall picture of the mycotoxin problem vis-a-vis the country is far from sight. Also, neither the consumers nor the live-stock farmers have developed that awareness towards the dangers involved in the consumption of such contaminated food-and feed-stuffs. Although some effort has been made to develop cheaper and convenient methods to decontaminate aflatoxin contaminated commodities, yet no wide-scale application of such methods is being resorted to. Therefore, some suggestions for canalizing research, extension and education on mycotoxins are desirable.

A co-ordinated programme for the whole country has to be chalked out and centres established for different regions. Dietary components of different communities in India differ and, therefore, aflatoxin intake of the populace in different regions of the country has to be carefully determined. It is likely that while certain food stuffs being consumed by a particular community are normally mycotoxin contaminated but the supplements to their diets are such (as spices-different in quantity and quality) that they are decontaminating such food in the human system. For example, addition of cinnamon (about 1%) in raisin bread decreases mold growth and even smaller concentrations prevent production of aflatoxin (Bullerman, 1974). Further, the diverse practices of cookimg such as roasting in different parts of India should also be taken into consideration in determining the actual mycotoxin intake of the consumers.

Most of the workers on mycotoxins have isolated fungi from food and feed stuffs and found them to produce one or more mycotoxins but few attempts have been made to isolate the toxin from the grains.

Employment of methods of control, whatever are already known and the newer ones, has not been made on a large scale in India. Provision of decontamination facilities with known methods should be made at godowns and mandies. Biochemical investigations leading to the discovery of new chemicals and plant products for decontamination and also to denature mycotoxins, once they have entered the human or animal system, be encouraged.

COPROPHILOUS & LEAF LITTER FUNGI - THE MUSHROOMS - Of the coprophilous and leaf-litter fungi, the mushrooms have attracted the attention of man since posterity and there are numerous references to them in ancient scriptures of India and many other countries. Payak (1984) reported mushroom paintings at Bagh Caves at Dhar District of M.P. which date back to the second half of the 5th Century A.D. The fruiting bodies of larger fungi abound in the pine wood forests (265-460kg/hectare), less so in oak and beach wood (13-95kg/hectare) and least in grassland (1-10 kg/hectare). Some of these mushrooms have received the attentioon of man and are cultivated the world over (*Agaricus* 75%, *Lentinus edodes* 14%, *Volvariella* 4%, others including *Pleurotus* 7%). In India, roughly 1,000-1,500 tonnes of mushrooms are produced annually but this figure is far too little for a predominantly vegetarian population in a country of 680 million.

A lot has been said about mushrooms, probably there are more books on mushrooms than on any other group of fungi. Still no discourse of fungi as a whole can be complete without them. The utility of the mushrooms has to be judged from a variety of considerations. They are a rich source of palatable protein (60% of the total nitrogen) and of vitamins (B,C,D, niacin) but their digestibility is only 60-70% because of the non protein nitrogen in chitinous cell walls. They are more important for their flavour and condiment value. They are believed to have medical effects such as antitumor, antibiotic, antifungal, antiviral and hypolipidemic activity. Other considerations for the popularity of mushroom cultivation are that the cost of protein obtained is less than by conventional agricultural practices and the unit area utilised for farming on the basis of protein yield is much less for the mushrooms than for other sources. The annual yield for dry protein per hectare is 78 kg for beef, cattle and conventional agriculture, for fish 675 kg. per hectare and for *A. bisporus* 65,000 kg. per hectare. Also, mushroom cultivation results into recycling of agricultural waste,the spent compost can also be used as fertiliser, and opens new avenues of employment. The method of cultivation of button mushroom (*A. bisporus*) is now well-established and we can predict the yield with precision. It is the result of combined efforts of amateur enthusiasts, mycologists, bacteriologists and biochemists. Major problem of mushroom cultivation is that the cost of protein production is many times more than by conventional agricultural practices and therefore efforts are being made to utilise waste materials. Keeping this objective in mind, *Pleurotus* species have been cultivated on a number of waste materials instead of the traditional beech trunks and logs of deciduous trees. Some of these are sterilized saw dust, rice bran, paddy straw, maize meal, crushed corn cobs, cotton waste and more recently, our formula of using waste tea leaves and waste paper (Mehrotra *et al.*, 1982). Because of the antifungal activity of *Pleurotus* spp. the common saprophytes do not interfere in their cultivation.

Mushrooms have posed ethno-mycological problems and reflect on the culture prevailing during a historical era in the span of a country's history. The attractive and delicious *Amanita caesarea* was used to kill the Roman Emperor, Claudius Caesar by his wife Agrippina, taking advantage of the fact that the Emperor was most greedy of this mushroom. At the time of attaining Nirvana, Gautam Buddha is said to have partaken a mushroom at a village near Kusinara (Kasia in Bihar and near to Gorakhpur). This meal was called sukaramaddava which Wasson (1982) thinks to be a hallucinogenic fungus *Stropharia cubensis*. A similar view had been expressed by Yamamoto (1984) at the last International Mycological Congress at Tokyo. The Soma, mentioned in Rig Veda is believed to be another hallucinogenic species *Amanita muscaria* (Fr. ex l.) Quel. popularly known as Fly Agaric. After a quarter of century of study involving translations of our ancient Vedic texts, fables and folklore as well as actual visits to the site convinced Wasson (1969), that the Soma was the hallucinogenic mushroom *Amanita muscarea*.

Though this effort has to be commended, to many of us, Soma is a sacred invigorating drink compared with a mushroom with hallucinogenic properties. In the light of information from 'Sushrut' (ancient Ayurvedic book) and Veda our most respected scriptures, it is rather difficult to accept Wasson's contention:

The plant Som Lata was known to the Vedic saints. It is difinite that it was a creeper which produced a leaf on every day of the full moon. One leaf would fall off daily during the dark fortnight (Krishna pakcha) till on the day of amavasya the creeper was completely denuded. The juice called 'Som Ras' was supposed to give tranquility of mind to those who drank it so as to be able not only to hear the preachings of the saints but also to translate them in their lives for the benefit of the human race. It gave physical health resplendence, aura to the external form, a capability to control the senses and ensured a long life full of blessings.

Also the finding that the great Gautam Buddha chose to eat a hallucinogenic fungus for his last moment is beyond comprehension. It is the heuristic need that Indians with the zeal of Wasson and a greater acquaintance with the philosophy of life prevailing in ancient India should take up ethno-mycological problems like that of Soma then only a true and concrete picture may emerge.

MYCOLOGICAL EDUCATION IN INDIA AND ITS FUTURE - While research extends the domain of a discipline of Science, teaching imparts it a new dimension. Almost all mycological congresses have a section on teaching but nothing happens subsequently. A biased trend towards research than on education and training prevails almost globally. While our research laboratories are being equipped with more and more sophisticated instruments there seems to be no improvement in teaching laboratories.

Though many attractive citadels have been built since mycology emerged as an important discipline yet in the eyes of students and educationists it has remained more or less a foundation science. Our syllabii still lay emphasis on observation of structure and little on experimentation. There is no doubt that mycology can as well inspire an ingeneous and inventive student as any other field of endeavour if the emphasis in teaching shifts from structure to function as fungi are dynamic functioning organisms.(Mehrotra, 1983c)

A course in mycology may have the following broad sections:

A. Morphology and Taxonomy of Fungi. B. Mycology in Biotechnology. C. Mycology of Mycotic Infections. D. Fungal Ecology. E. Fungi as Fundamental Biological Tools. F. Symbiotic and Antagonistic Interactions between Fungi and other Organisms.

It is true for mycological education as for education in general that it should provide a link between its academic relevance and emerging employment opportunities including self-employment. Mycologists can be gainfully employed in plant pathology institutes, biochemical laboratories, in a number of fermentation industries, in marketing and storage concerns, in veterinary hospitals, in quarantines and seed corporations. Only our teaching syllabii and methods of teaching have to improve to suit the needs of the above institutions.

EPILOGUE

It is indeed a treat to speak for organisms which have fascinated me now for nearly forty years. Though the diverse topics covered have made the talk heterogeneous, they all centred around fungi. Since the title could cover a wide area I had to be selective and partisan. In this process if I have accorded less emphasis to any field of activity or any work, you have my apologies.

Thank you.

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