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Professor K.S. Thind: The Humane Scientist

T. N. Lakhanpal
Department of Biosciences, Himachal Pradesh University, Shimla
Corresponding author Email: tezlakhanpal@rediffmail.com
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ABSTRACT

In this manuscript besides recollecting my life long memories of association with my revered teacher Late Professor K.S.Thind, I have tried to give a glimpse of my work on myxomycetes, morels , agarics and boletes, the three areas of research in which I was introduced by this great man. Along with key to the Indian species of *Hemitrichia,* a new species *H. thindii* in honour of late Professor K. S. Thind has also been described.

Keywords : Slime moulds , plasmodia, capillitium, morels, agarics, boletes

REMINISCENCE FROM A STUDENT

Congratulations and heartfelt appreciation to the Mycological Society of India and the Editorial Committee of KAVAKA for honoring the founder fathers and legendary figures of Mycology in India by bringing out special issues on them. The second issue in this series pertains to Prof. K.S. Thind, Botany Department of Punjab University, Chandigarh who pursued and furthered the cause of mycology in India for more than three decades. This brings honour not only to them but also to those who thought of this mission.

It is actually the practice not mere precepts which influence society and the welfare of society rests on three cardinal principles: 'Love for God, Fear of Sin and Morality in Society'. These supreme maxims serve as the foundations of a good educational set up and a teacher is the medium and the role model to promote these. “The teacher offers, the student receives, teacher is like a tank, student like the tap, and pure water in the tank gives pure water in the taps”. Prof. K. S. Thind, was such a teacher and researcher who practiced the three vedic injunctions but never advertised his achievements. 'Mycologists are poor propagandists' so quotes Professor Constantine John Alexopoulos in his book 'Introductory Mycology'. Prof. Thind was a poor propagandist but he was the greatest proponent and propagator of Mycology in India.

It was somewhere in 1961 or 1962 that Professor Thind addressed the biology students at Government College Hoshiarpur, where I was a student. That brief interaction perhaps had an impact on me and made me inclined to study fungi at Botany Department at Chandigarh.

Prof. Thind has been a man of few words; his words were meaningful and he was immersed fully in the ocean of fungi. He was unassuming, work was his worship, simplicity was the hallmark of his persona and he possessed the “Hands of Janaka, Heart of Buddha and the Head of Shankaracharya”. To his students he was a true friend, philosopher and guide.

After graduating from Punjab University, Lahore and receiving PhD from the University of Wisconsin, he joined his Alma Mater, Botany Department of Punjab University under the patronage of Prof. S.R Kashyap, Prof. P.N Mehra and Prof. R.S Chopra, the world renowned teachers and researchers in Botany. Beginning his career as Lecturer, then Reader, Professor, then Senior Professor and ultimately retired as Head of the Department of Botany. However, these positions were overshadowed by his magnanimous and simple personality. He pioneered the research in different groups of fungi in North India. His association with luminaries like G.W. Martin and C.J. Alexopoulos, Iowa State University, USA and the University of Texas, USA attracted him to *Myxomycetes* and the associations with R.P Korf, to *Discomycetes* and with EJH Corner to *Clavaraciaceae*, in the early nineteen fifties. *Clavariaceae* was first to be monographed by him in 1962. He initiated explorations simultaneously, of myxomycetes, *Xylariaceae*, Operculate and Inoperculate *Discomycetes* and all the families of the traditional *Polyporales* (*Aphyllophorales*) and *Gasteromycetes*. These groups of fungi remained very close to his bosom. Shrewdness, cleverness and diplomacy were nowhere near him. Prof. Thind was a gentle and straight forward individual interested in putting Indian Mycology on World map and that he could largely achieve by exploring mycoflora from Kashmir to Arunachal Pradesh; only Indian Mycologist to undertake so intensive and extensive field work in the difficult terrain of the Himalaya. He would invariably join the students during fungal forays in the months of July-August, when the rainy season was at its peak. He was a strict disciplinarian and non-compromising on casual and disrespectful behavior. Even among the students and classmates he always desired them to address each other with respect. He had fixed up 11 AM and 3 PM as tea time and would sit for tea with all the research students in the mycology laboratory. This provided everyone opportunity to discuss problems related to research and seek solutions instantaneously. He would sit on the microscope for hours examining the preparations and checking the descriptions, illustrations and comparing the notes. He would begin with big letters and then cover every nook and corner of the page, with frequent interjections with the word “however”. It was a sight to see his face glow at the discovery of a new species or new records. He would repeatedly examine the specimens to arrive at a final conclusion. He would like to be disturbed least when finalising species descriptions and would avoid calls even from his family members, such was his commitment to work.

When I decided to join him for Master's degree, he categorically told me that learn systematics at Masters level and then you would have a base to venture into any other aspect of fungi, and I realise now how true and sincere was his advice. He permitted me to choose any one of the groups his lab was engaged in. When I selected myxomycetes, he jokingly said "work on slime moulds and also on jelly fungi and be the 'Martin of India', because Prof GW Martin was at that time an International authority on these two groups at the University of Iowa, USA. I could not work on jelly fungi but this group of fungi is extremely interesting in understanding the evolution of fungi; as these possess characteristics which provide evolutionary link to other groups of fungi. So far the jelly fungi have remained a neglected group in India.

At that point of time, there were around five students working with him on different groups of fungi. To mention a few of them: Dr. G.S Rawla, Officer Incharge, S.S. Saini, K.S Waraitch, H.S. Garcha, H.S Khara, S.S. Rattan, S.S Dhillon working for their PhD and three of us; myself, H.S Chahal, D.S Sidhu for M.Sc. Hons., dissertation. Meera Madan who joined him as a teacher fellow with us for M.Sc. Hons was allotted a lab problem on nutrition of fungi, being a girl student. Others to join him later for Ph.D. were J.S. Dargan, G.S. Dhingra, R.S. Dhanda, R.M. Sharda, S.C. Kaushal, M.P. Sharma, B.M. Sharma and R. Sharma. It was customary and compulsory that the entire group leaves Chandigarh with bag and baggage to the Himalayas. The trip would begin by mid June and will be completed by mid September or end of September, depending upon the rains. During our forays, we covered the Himalayan ranges from Shimla, Narkanda, Baghi, Khadrala, Taklech, Daranghati, Bahli, Sungri, Sarahan, Rampur, Ani, Kullu upto Rohtang pass, camping at various places, collecting specimens and taking field notes and working them out for gross features in the temporary labs established at the places of stay. There were daily forays to nearby forests, the communication links were poor and so were the road transportation facilities. The roads were being laid out and the Narkanda Rampur road was just being started. It was in 1965 and most of the places were without roads. The forests were almost undisturbed and many a times we could spot wild life. In 1965, the war broke out between India and Pakistan. It was rumoured that Pakistan is dropping paratroopers in different locations. We were camping at Banjar in Kullu district. We moved out to the forest as usual around 8 AM. Since we would be looking for specimens on soil, grasslands, rotten logs, etc, we would always be in the thicket of the forest and would rarely walk on the paths or roads. We heard voices of people and thought they must be village folk, visiting the forest for fodder and wood. But soon we found them making a circle around us, armed with sticks and *lathis*. They thought we were all paratroopers from Pakistan. No explanation could pacify them and ultimately, they took us to the Pradhan of village Panchayat and the Police Station. It was with great difficulty that we could persuade and convince them that we all were students from Punjab University, Chandigarh and then only they let us go. But these forays were great training grounds and these taught us community living, sharing and caring and management of time, money and energy and compassion. These excursions also placed us day in and day out in the lap of Mother Nature and in the serenity of environment. Much has changed now for detriment in all those areas with regard to environment.

The road from Bhuntar to Manikaran was laid out only upto Kasol. We stayed at Kasol for almost 10 days. Manikaran at that time was a very small place with the temple and hot water springs everywhere. In place of the Gurudwara, there was only a newly constructed hall with two rooms and the person looking after it had a son and daughter. He would serve free tea and all meals with a smile. When anyone arrived he would simply enquire "*Kinia murthia Ne*" (how many faces). There was arrangement for night stay too. From Manikaran at a distance of 12 Km was Pulga, almost at 7000 ft and further 14 kms ahead was Kheer Ganga with lush birch forests. Then, all these distances were to be covered on foot, but the forest around Pulga proved to be a gold mine for all groups of fungi and infact Narkanda, Pulga and Hidimba temple surroundings in Manali were rich in fungal diversity and one could walk through natural fungal gardens specially during the months of August September.

When I joined Prof. Thind and opted for myxomycetes for Master's dissertation, around 10 students had worked on myxomycetes for their M.Sc. dissertation prior to me. By that time Prof. Thind received an invitation from I.C.A.R., New Delhi to write a monograph on Indian Myxomycetes. He therefore wanted to examine and authenticate all the earlier specimens before finally including them for monographic treatment. He desired that I work out all the specimens collected by earlier workers so that he could examine and authenticate them. I was required to prepare slides of all these specimens, consolidate the technical details of each species and Prof. Thind then would check and finalise the description and discussion for each species for final inclusion. This provided me a rare opportunity to reexamine and work on nearly 1500 collections of myxomycetes from the entire Himalayan range. This was a unique practical experience and a big opportunity to get trained in the taxonomy of this group. This proved very useful and handy when I pursued the same group for my Ph.D. with Prof. K.G. Mukerji in Delhi University on different aspects of myxomycetes. Dr. Thind was unhappy that I shifted to Delhi leaving the Junior Research Fellowships at Chandigarh. But I would invariably see him at Chandigarh on my way to Delhi or to Shimla and I continued this till his last days. Many a times he compelled me to stay with him, not allowing me to travel by night buses, especially during the rainy season. Such great was his concern.

MYXOMYCETES-THE ANIMAL PLANTS

With regard to biodiversity work in nature it can be stated that nature exhibits unparallel diversity, which is unified in the same manner in the white light as seven colours. Out of the approximate 1.5 million recognized living forms, the fungi are presently represented by only about 25-30 thousand species. There are bound to be many more and future explorations are likely to prove this true.

Plants are colourful but fungi are said to be colourless, a name they have earned because of the lack of chlorophyll. But the role they play in nature, products that they yield for human welfare and the damages they cause are surprisingly large and therefore fungi are actually very 'colorful' as organisms. I shall deliberate here briefly on two groups of fungi: the myxomycetes and the morels, which were very close to Prof.

Thind. But a lot of water has flown through Ganges ever since and now the myxomycetes are no longer considered plants and they are fungi only in the broader sense. But that is besides the point because if we see the people who are working on them the world over, only botanists are among the mycologists, who are investigating them so by this corollary they are very much fungi. Here a quote from Keller and Everhart (2010) will make it clearer, "Despite formal classification as *Amoebozoa*, *Myxomycetes* will continue to be studied by mycologists, and classification of species is likely to continue as such. The International Code of Botanical Nomenclature due to the practicality of retaining the system and difficulty in transitioning to another nomenclatural system".

Myxomycete plasmodia and fructifications are very colourful and have attracted painters, amateurs and professionals alike. Paintings depicting myxomycetes fruiting bodies appeared in full colour in the National Geographic Magazine long back (Crowder, 1926). To quote Alexopoulos (1962) "The fructifications of *Stemonitis,* one of the myxomycetous organism attained dubious fame at Chicago World's fair in 1933, when placed on exhibit at the "Believe it or Not" pavilion over the caption "Hair growing on wood Believe it or not". Students of mycology did not".

The myxomycetes or the acellular slime moulds are organisms which resemble both plants and animals and have been rightly called "Animal Plants". They resemble plants in the manner of reproduction and animals in the characteristics of their assimilative phase. The assimilative phase comprises of a free living acellular mobile mass of protoplasm, the plasmodium. The plasmodium results from the fusion of compatible swarm cells or myxoamoebae or myxoamoebae and swarm cells, the fusion resulting into the zygote whose nuclei divide synchronously forming the plasmodium. Swarm cells or amoebae emerge from the germinating spores and the spores are contained in the fruiting bodies. The plasmodia also fall into three main types: Protoplasmodia, Aphanoplasmodia or, Phenaroplasmodia (Alexopoulos, 1960). A protoplasmodium is very small, inconspicuous, and visible only under the microscope and is homogenous even at maturity. It lacks veins and also rhythmical reversible streaming of the protoplasm. Aphanoplasmodium resembles a protoplasmodium initially, but soon elongates, branches and becomes a network of very fine transparent strands. The veins are not differentiated in gelified ectoplasm and fluid endoplasm but may show rhythmical streaming of the cytoplasm. A Phaneroplasmodium is visible to the naked eye right from the beginning is differentiated into veins, is robust and shows typical rhythmic reversible streaming of the cytoplasm. The plasmodial types are good taxonomic characters. The fruiting bodies are either plasmodiocarps, aethalia or sporangia. The Plasmodiocarps are usually continuous, branched or netted structures or discontinuous simple or branched discrete but elongated units. The aethalia are usually large, cushion shaped fructifications covered by a thick cortex and normally represents an aggregation of sporangia with walls adherent or lost, not recognizable individually. Sporangia are spherical usually with or without a stalk but covered by a wall called peridium and enclosing within spores and or capillitium. Fruiting body types and their constituents are important diagnostic features in the identification of species.

The individual sporangia generally have a characteristic shape, size, colour, and may be sessile or stalked or stipitate. The fruiting bodies are very brightly coloured and hence very beautiful, they may rest on hypothallus, bear a stalk, posses a columella or pseudocolumella, a covering called peridium and usually a fair network of non cellular threads interwoven or not, forming capillitium which is usually hygroscopic in nature and helps in spore dispersal. The spores fill the sporangium and are dispersed by rupture of the wall or may have some specific mechanism for dehiscence. The spores are predominantly globose with very few exceptions and exhibit a wide range of colours from hyaline, brown, violet, pink, orange, black to red. The studies on wall composition reveal around 81% galactosamina, which is strictly different from the wall of fungi, Protozoa and cellular slime moulds (Mc Cormick *et al.*, 1970).

The reduction division occurs during the differentiation of spores and hence spores are haploid and so are the swarm cells. The swarm cells are potentially anteriorly biflagellate, one flagellum being larger and other shorter (Alexopoulos and Mims, 1979; Ross, 1958; Aldrich, 1968). Both homothallic and heterothallic forms have been reported in myxomycetes and pioneering investigations on this aspect have been made by Collins, 1963 onwards. Heterothallism is bipolar type with multiple alleles at the mating type locus (Collins, 1963; Dee, 1966; Henny and Henny, 1968).

The compatible myxoamoebae or swarm cells fuse in pairs, form zygote and restore diploid condition. The zygote undergoes karyokinesis without cytokinesis, transforming the zygote into multinucleate acellular mobile mass called plasmodium. The nuclear divisions are synchronous and intranuclear. The plasmodim is holozoic as well as saprobic in nutrition and spreads itself in the form of veins; veins fuse and form larger veins ultimately producing a beautiful network. The endoplasm in the veins exhibits to and fro rhythmical reversible streaming of cytoplasm due to the interactions of a contractile protein myxomyosin measuring 4000-5000 Å long and with a molecular weight of six million and ATP (Kamiya, 1959). Ultra structural studies by Ts'O *et al.*(1956 a,b;1957a,b) demonstrate the presence of myxomyosin, actin and ATP in the plasmodium of *P. polycephalum*. The reaction of these substances appears to be similar to that of ectomyosin- ATP system in the muscle. It was also demonstrated in *P. polycephalum* that protoplasmic streaming is caused by hydraulic pressure flow mechanism generated by the contractions of the protoplasm, as the contraction is due to the assembly of actin containing cytoplasmic fibrils in the cytoplasm (Hinssen, 1981). It is the degree of polymerisation of actin which determines the differentiation into gel ectoplasm and fluid endoplasm this is in turn found to be regulated by a polymerization inhibiting protein (actin modulating protein) (Martin, *et al*., 1981).

The rhythmical reversible streaming of cytoplasm of plasmodium is a very fascinating phenomenon to observe under a binocular microscope. The protoplasm first moves in one direction for 60-90 seconds at a high velocity, then halts for 10-15 seconds and then flows in the reverse direction for a similar period, to reverse itself again and again.

The Plasmodia are hyaline to brightly coloured presenting different hues of yellow red, orange, etc. The colour of the plasmodium is reported to the affected by pH and temperature and also the food ingested. The yellow pigments have been reported to have properties of anthracenes, flavonoides, pteridines, polypeptiodes or polymers, some plasmodia possess carotenoides and xanthophylls (Czeezuga, 1980). Pigments perhaps act as photoreceptors and play some role in sporulation. The presence of enzymes, vitamins and steroids,organic substances and antibiotics has also been reported in several species. The process of sporulation occurs at night and temperature, moisture, light, available food, plasmodial size and pH influence sporulation and lot of biochemical changes occur during the process of sporulation. A shift in oxidases apparently takes place (Daniel and Rusch, 1962 a, b)

The sporophore development is of two types:subhypothallic (non stemonitid) and Epiphypothallic (Stemonitid). In the former the plasmodium settles at several places, develops hemispherical slimy mounds, the slimy layer forms the hypothallus. After the hypothallus is laid the mounds rise above into pillars and then transform into fruiting bodies. There is continuous membrane connecting the hypothallus, stalk and sporangium (Ross,1973; Blackwell,1974). In the stemonitid type of sporophore development, the plasmodium first deposits a hypothallus on the lower surface of the plasmodium, above the hypothallus the mounds start rising, the stalk elongates carrying the mounds at the top which finally moulds into fructifications. The internal deposition of the stalk material continues and a fructification characteristic of a species is formed. There is no membrane connecting the sporangium and hypothallus (Mims, 1973; Ross, 1973).

The pioneering work on myxomycetes of India was done by Mrs. A. Drake in the pre independence days. The real interest in the group was initiated by K. S. Thind around 1952 in North India and Agnihothrudu in South India almost around the same time. Thind's work culminated with the monographic treatment “Myxomycetes of India” in 1977 describing and illustrating 182 species. His monograph included 19 new species and 2 new varieties. Agnihothrudu and associates described 78 species from South India and 56 species from N.E. India, including two new species. In a subsequent monographic treatment Lakhanpal and Mukerji (1981) described 43 genera and 292 species of myxomycetes. Now there is a need for revision of these works as the number of myxomycetes has swelled to 350 in 48 genera and this includes more than 50 new species and many new records, especially of the corticolous myxomycetes (Lakhanpal and Chopra, 1997). There is also a need to show the light of the day to the monumental PhD work on N.E. Himalayas including the Royal Kingdom of Bhutan done by two worthy students of Dr. Thind, S.S. Dhillon and Rajesh Sharma. There are still many un-worked out collections of slime moulds in the Herbarium of Botany Department, Panjab University Chandigarh, which along with undescribed material of other groups constitutes a rare germplasm collection from N.E. region of the country. A loss of these collections will be a great national loss in this era of biodiversity concerns.

The broad outline followed herein for systematics of myxomycetes is that of Martin and Alexopoulos (1969); Ross (1973); Martin *et al.*(1981); Ing and Nannenga-Bremekamp (1967) and Lakhanpal and Mukerji (1981). Traditionally, three subclasses, *Ceratiomyxomycetidae*, *Myxogastromycetidae* and *Stemonitomycetidae* are recognized in myxomycetes. The same is being followed herein. Currently the myxomycetes are classified as Myxogastrids in the subclass Amoebazoa and in the first rank Eumycetozoa (Adl *et al.*, 2005). This follows the International Code of Zoological Nomenclature and the proposed classification of protists by the International Society of Protistologists (Adl *et al.*, 2005).

ECONOMIC IMPORTANCE

The economic importance of myxomycetes has been a debated issue and there is not much that can be stated on this aspect except that they are an integral component of the ecosystem. Little doubt that they are fascinating organisms with a peculiar lifestyle which transcends the human made barriers of falling in line with classification systems and defying the limits set forth by all these systems which pigeonhole organisms into designated categories.

Myxomycetes in recent times have proved to be good model organisms in research and source of novel compounds with biological activity. Many species have been investigated and their role in aging, cancer research and the production of novel compounds with biological activity stands authenticated. The pioneering work was by Daniel and Rusch (1962a, b) and their associates in the US. The synchronous miotic divisions in the plasmodium are controlled whereas in the cancerous cells these are uncontrolled or unregulated. Experiments by Cummins and Rusch (1968) and Rusch (1970) showed that mitotic synchrony is not triggered inside the nucleus but the stimulator accumulates in the cytoplasm and is transferred to the nucleus shortly before mitosis. The most remarkable example of myxomycetes enabling cancer treatment is with non-toxic, non-immunogenic and biodegradeable nanoconjugate drug delivery system called Polycefin (Ljubimova *et al.*, 2008). More than 100 secondary metabolites in the category of lipids, fatty acids, amides and derivatives, alkaloids, aminoacids and peptides, napthoquinone pigments, aromatic compounds, carbohydrate compounds and terpenoid compounds have been isolated from myxomycetes (Dembitsky *et al.*, 2005). Most secondary metabolites isolated from the plasmodia and fruiting bodies of myxomycetes are directly responsible for pigmentation and there are a number of compounds that have shown some promising biological activity (Steglich, 1989; Keller and Everhart, 2010). For example Arcyriacyanin A isolated from *Arcyria nutans* shows inhibiting activity against a number of human cancer cell lines, inhibits protein kinase C and inhibits protein tyrosine kinase (Steglich, 1989; Hibono and Choshi, 2002). Similarly, Arcyriaflavin A isolated from *A. denudata* and *Lygola epidendrum* shows moderate antibiotic activity against fungi and bacteria (Steglich,1989; Frode *et al.*,1994;

Hosoya *et al.*,2005). Likewise Cribrarione A isolated from *Cibraria purpurea* shows antimicrobial activity against *Bacillus subtilis*, Kehokorins A-C, from *Trichia favoginea* var. *persimilis* is reported to be cytotoxic to human epithelial carcinoma and tubeferal A and B from the fruiting body of *Tubifera dimorphotheca* which inhibits human epidermoid carcinoma cells. Phase II and III clinical trials of semisynthetic staurosporine isolated from *Lygola epidendrum* have shown promise as a drug in slowing neurological degenerative effects of Parkinsons disease (Butler, 2005).

There are reported around 350 slime mould species from India, but there is hardly any investigation other than systematics. Maybe someone attends to the other aspects and exploits them for novel compounds.

The lack of cell wall in the plasmodium and massive amount of pure protoplasm makes slime moulds ideal tools for experimental studies on mitotic cycle, morphogenesis, physiology and biochemistry and also may provide answers to many fundamental questions.

MYCO-FLORISTIC ESTIMATION OF HIMALAYAN MYXOMYCETES

The variety of vegetation, topography, aspects and altitudes confer on Himalayan region a boon for harboring maximum biodiversity. The myxomycetes biodiversity is no exception (**Table 1**). Though the group has attracted less attention from individuals. The most productive period for myxomycetes systematic has been that beginning with 1970's. The monographic treatment of myxomycetes appeared in 1997 (Thind, 1977) which dealt with slime mold collections made by the group at Chandigarh till 1972 and those by others till 1968. This was followed by another monographic treatment of the group in 1981 (Lakhanpal and Mukerji, 1981). An immediate follow up was the summarization of "Contributions of Indian Myxomycetes during the decade 1970-1980 (Lakhanpal, 1983), which encompassed all the details of different aspects of slime mold biology, updating the entire research work as the group. Highlights of this subsequent decade were contribution to this group in the form of three doctoral theses (Bakode, 1989; Sharma, 1986; Chopra, 1984). Indira (1966) was first one to obtain a doctoral degree on different aspects of myxomycetes, followed by Lakhanpal (1975), Dhillon (1976) and Ranade (1978). Ranade *et al*., (2012) have prepared an up-to-date checklist of myxomycetes of India. An expanded checklist giving floristics of Himalayan myxomycetes follows.

Table 1. Status of *Myxomycetes* systematics in India

	Thind (1977)				Lakanpal and Mukerji (1981)				Lakhanpal and Chopra (Till Date)			
	G	S	V	F	G	S	V	F	G	S	V	F
Ceratiomyxomycetidae *Ceratiomyxales* ***Ceratiomyxaceae***	1	2	1	-	1	2	1	-	1	2	1	-
Myxogastromycetidae												
Liceales												
Liceaceae	1	1	-	-	1	14	-	-	1	28	1	-
Reticulariaceae	4	9	1	-	4	13	-	-	4	13	-	-
Cribrariaceae	3	13	1	-	3	20	-	-	3	22	-	-
Echinosteliales												
Clastodermataceae	1	1	-	-	2	3	-	-	2	3	-	-
Echinosteliaceae	-	-	-	-	1	3	-	-	1	9	-	-
Trichiales												
Dianemaceae	1	1	-	-	2	2	-	-	2	2	-	-
Trichiaceae	7	29	-	-	7	44	-	-	9	40	1	-
Physarales												
Physaraceae	7	56	-	-	7	77	1	1	9	85	1	1
Didymiaceae	4	36	-	-	5	67	-	-	5	70	-	-
Stemonitomycetidae												
Stemonitales												
Stemonitaceae	7	35	-	-	9	47	1	-	11	56	2	-
Total	367	183	2	1	43	292	3	1	48	339	6	1

G= Genera S= Species V= Varieties F= Forms

In the subclass *Ceratiomyxomycetidae*, one family and one order and one genus *Ceratiomyxa* is recognized. It is represented by two species and two varieties from India. The two species, *C. fruticulosa* (Mull.) Macbr., and *C. sphaerosperma* Boedijin have been recorded from the Himalayas.

Licea, the monotypic genus in *Liceaceae* and *Liceales* of *Myxogastromycetidae*, is represented now by 23 species, majority of which have been isolated from moist chamber cultures of bark (Lakhanpal and Chopra, 1997). Prior to this only 11 species were known, three from Eastern Himalayas and rest from N.W. Himalaya. Thind and Dhillon (1967) were first to record the maiden species in the genus from India, *L. erecta*. In addition, *L. biforis* Morgan and *L. variabilis* Schrad., were reported from nature in Eastern Himalaya where only L. *minima* Fries was collected in nature from N.W. Himalaya (Lakhanpal *et al*., 1990).

In the family *Enteridaceae* (*Reticulariaceae*) the four representative genera are: *Tubifera*, *Enteridium*, *Lycogala* and *Dictydiaethalium*. In the genus *Tubifera*, two species have been recorded both from N.W. and eastern Himalaya. Out of the three species known, *T. papillata* appears to be endemic whereas *T. ferruginosa* and *T. microsperma* are widely distributed. Nann. Bremekamp and Loerakker (1981) erected a new species *T. dimorphotheca* for *T. microsperma*, to be a look alike which possessed characteristic clusters of small globose to subglobose sporangia, covering the raised stalk like hypothallus. Many of the N.E. Himalayan collections earlier placed in *T. microsperma* were found to be like *T. dimorphotheca* designated so and described (Thind *et al.*, 1991). The genus *Enteridium* is represented by three species, *E. splendens* and *E. jurana* from Eastern Himalayas and *E. lycoperdon* from both parts of Himalaya. The genus *Lycogala* is represented by five species; four are reported in both Himalayan regions whereas *L. flavofuscum* is so far represented only in N.W. Himalaya. *Dictydiaethalium plumbea* is cosmopolitan and represented in both parts of Himalaya.

In the family *Cribariaceae* of the *Liceales*, three worldwide genera *Cribararia*, *Dictydium* and *Lindbladia* are reported from India. They have minute fructifications, usually microscopic and are a good material for making appearance in moist chamber cultures though some can be discerned with naked eye as well. Out of the eighteen species recorded, six occur in Eastern Himalaya. i.e., *C. argillacea*, *C. intricala*, *C. languescens*, *C. macrocarpa*, *C. splendens* and *C. tenella*. The genus *Dictylium* is represented by *D. cancellatum* and *D. mirabile* whereas *Lindbladia* by *L. tubulina* from N.W. Himalaya.

In the *Echinosteliales*, the family *Echinosteliaceae* is with monotypic genus *Echinostelium* and has minute almost microscopic fruiting bodies and was like *Licea*, considered rare before isolation of many species by moist chamber culture. Total number of species now stands at ten which at one point of time was just one. Most of the species have been recorded from N.W. Himalaya, not because they do not occur in Eastern Himalaya but because no moist chamber cultures have been raised from Eastern Himalayan region and in nature they are hardly visible to the naked eye (Nann. Bremekamp *et al*, 1991). Same holds good for genus *Barbeyella* in the family *Clastodermataceae* and one has to be content with just one species *B. minutisima*. In the genus *Clastoderma*, *C. debaryanum* is an old guard and has been reported both from Eastern and Western Himalaya whereas *C. dictyosporum* is a new entrant to the list of myxomycetes. But more intensive culturing of different substrates, especially bark of different trees is desired along with a keen observational eye.

The family *Dianemaceae* in the *Trichiales* continues to be represented by *Calomyxa metallica* and *Dianema nivale* from both the country and N.W. Himalayan regions, not from Eastern Himalayan region. It seems that they are missed in nature because the time of collections and their appearance in nature may vary. Hence, mass scale raising of moist chamber cultures is warranted. This will also enable understanding their ecological behavior, substrate preferences and fruiting phenology, which have not been possible in natural populations where the niches are selective and the controlling parameters loose.

In the family *Trichiaceae*, only eight genera are represented in India out of the twelve. In genus *Arcyria*, out of the 20 species recorded, 19 have been reported from Himalayan region, 10 have also been recorded from Eastern Himalayas but not exclusively only with overlaps. One of the rare species, *A. nigella* Emoto has been obtained in moist chamber, suggesting an overall shift and supplementation of myxomycetes with moist chamber technique. The genus *Cornuvia*, is represented by *C. serpula* alone whereas the genus *Hemitrichia* by eight species, four from the Eastern Himalayas as well. Two new species *H. ellae* sp. nov., and *H. thindii* sp. Nov*., have been isolated in moist chambers again stressing the importance of moist chamber technique, if we want to expand the distribution domain of slime-molds. *Metatrichia vesparium* and *Oligonema flavidum* are still in the same state of representation. *M. vesparium* is recorded from both the Eastern and Western Himalayan regions whereas *O. flavidum* is known only from the Eastern Himalayas. The genus *Perichaena* is represented by still the same five species, four being natural collections and one moist chamber isolate. But the other species also appear frequently in the moist chambers. The genus *Trichia* is represented by 13 species from India and the Himalayan region. Out of these four species, namely *T. crateriforme, T. lustescens, T. subfusca* and *T. subretisporum* are known only from NW Himalayas. These four species have been isolated in moist chambers (Lakhanpal and Chopra, 1997).

Three families in *Physarales* are: *Elaeomyxaceae*, *Physaraceae*, and *Didymiaceae*, however, *Elaeomyxaceae* is still unknown from the Himalayas. Out of nine genera in the family *Physaraceae*, *Protophysarum*, is not recorded from India whereas *Badhamiopsis ainoe* (Yam.) Brooks and Keller has been now isolated in a moist chamber culture in H.P. The genus *Badhmia* is now represented by nine species from the Himalayan region. Lakhanpal and Chopra (1997) described *B. evada* sp nov. and a new var. of *B. gracilis*. Out of these *B. evada* sp. nov., *B. iowensis* Macbr., *B. nitens* Berk., and *B. panacea* (Fries) Rost., have been isolated in moist chamber. The genus *Wilkommlangea* Cienkowskia still remains to be represented by *W. reticulata*, a single species as are *Leocarpus fragilis* (Dicks) Rost., and *Erionema aureum* Penzing. The first one is represented from Eastern Himalayas and second one from both N. W. and Eastern Himalayas. All these are collected from nature. Here again it appears that moist chamber culture would be fruitful in yielding new records and new species.

In genus *Fuligo* the two species *F. cinerea* and *F. septica* are represented both in N.W. Himalaya and Eastern Himalayas. The genus *Craterium* is represented by seven species in the Himalayan region. The genus *Physarum*, the largest in the family *Phyraceae*, is represented by 50 species, out of which Lakhanpal and Chopra (1997) described three new taxa, *P. complexum* sp. nov., *P. tubulatum* sp. nov., and *P. leucophaeum* var *columellatum* var. nov., from Himachal Pradesh and Sharma (1986) described four new records from the Eastern Himalaya, eg. *P. Penetrata* Rex., *P. straminipes* Lister, *P. viride* var. *hinnuleum* Lister. The species obtained by moist chamber culture from N. W. Himalaya regions are *P. bivalve* Pers, *P. crateiforme* Petch, *P. echinosporum* Lister, *P. javanicum* Racib., *P. superbum* Hangelst., *P. compressum* Alb. and Schw., *P. rigidium* Lister, and *Physarum* sp. Dhillon and Nann.- Brem. The genus *Physarella* is represented by *P. oblonga* (Berk.and Curt) Morgan only from N. W. and Eastern Himalayas.

Martin *et al*. (1981) recognized 6 genera in the family *Didymiaceae*. Kowalski added a new genus *Squamuloderma*, *Lepidodermopsis* Honn. was also raised to generic rank. *Trabrooksia* was added by Keller so that with these three genera the generic number in *Didymiaceae* is nine. The genus *Wilczekia* Meylan till recently considered a valid genus is now transferred to *Diderma*. The genus *Diachea* is represented by 4 species in the Himalayas. These are *D. bulbillosa*, *D. leucopodia.*, *D. megalospora* and *D. splendens.* In The Genus *Diderma*, 21 species are represented in Himalaya out of a total of 29 species. Lakhanpal and Chopra (1997) recorded *D. platycarpum* var. *berkeleyii* Nann.- Brem. for the first time from India, and also described two new species, *D. intermedium* sp. nov. and *D. yamamati* sp. nov. Sharma (1986) recorded *D. effusum* var. *pachydictyon* Naan. Brem. and *D. subfloriformis* F. Cand.et Nann.- Brem. for the first time from India. He also proposed two new species in the genus yet to be named from among these *D. intermedium, D. platycarpum* var. *berkeleyii, D. yamamati, D. simplex* have been isolated by moist chamber technique.

**Hemitrichia thindii* sp. nov., is being described here for the first time in honour of Late Prof. K.S. Thind.

Out of the thirty two species in the genus *Didymium*, 21 are known from Himalayan Region. Sharma (1986) has proposed three new species in the genus from the Eastern Himalayas. Out of these *D. clavus* and *D. saturnus* have been obtained in the moist chambers. The genus *Lepidoderma* remains to be represented by the same species, *L. leonia* and *L. martini, Physarina echinospora* remains unchanged. In the subclass *Stemonitomycetidae* order *Stemonitales* has two families. The families *Schenellaceae* is monotypic with genus *Schenella*, not yet recorded from India and the family *Stemonitaceae* has 10 genera. The two new genera erected by lng and Nann.-Brem. (1967) and one by Nann. Brem. *et al*. (1984) are recognised herein.

The genus *Amaurochaete* awaits discovery and *Colloderma, Diacheopsis* and *Brefeldia* are known by one species each. *Enerthenema papillatum* (Pers.) Rost. has been recently recorded in N.W. Himalaya in a moist chamber culture and in nature from Eastern Himalayas. The genus *Comatricha* represented by 13 species, has 9 species recorded from the Himalayan region. Lakhanpal and Chopra (1997) recorded for the first time, *C. rigidireta* Nann.- Brem., *C. ellae* Hark. and *C. acanthodes* Alexop. and two new species, *C. laxifilia* sp. nov., and *C. confusa* sp. nov. Sharma also described *C. acanthodes* and *C. elegans* (Racib.) Lister, for the first time from India (Eastern Himalayas). He also proposed a new species, *Comatricha* sp. nov. Some of these, namely *C. anastomosa, C. confusa, C. ellae, C. regiderata, C. tenerrima* and *C. nodulifera* have been obtained in moist chambers.

In the genus *Lamproderma* out of the nine species eight are known from the Himalayas. Sharma recorded *L. echinatum* (Berk.) Rost. and *Lamproderma* sp. nov. from the Eastern Himalayas. The genus *Macbrideola* has three species recorded from the Himalyan region . Lakhanpal and Chopra (1997) also reported *M. decapillata* H.C. Gilbert and *M. bremekempii* sp. *nov*. . These as well as the remaining species in *Macbrideola* , *M. cornea, M. indica*, and *M. robusta*, all have been obtained in moist chamber cultures.

In the genus *Stemonitis* out of the 16 species; 14 are recorded from the Himalayan ranges. Lakhanpal and Chopra (1997) have isolated a new species *S. enerthenemoides* sp. nov. Sharma recorded *S. aequalis* (Peck) Massee var. *microspora* Nann.-Brem., and Yamamato, *S. microsperma* lng; *S.hyperopta* Meylan and *S. webberi* Rex for the first time from India. Nannenga- Bremekamp *et al*. (1984), described a new species *S. rhizoidipes* from Eastern Himalayas. Species in *Stemonites* which have been isolated in moist chambers are *S. enerthenemoides,. S. farrensis, S. inconspicua, S. nigerscens, S. smithi, S. herbatica, S. uvifera* var. *microcarpa*. The genus *Symphytocarpus* lng and Nann.-Brem., remains to be represented by *S. herbaticus* from N. W. Himalayas alone. The genus *Stemonaria* also remains to be represented by *S. reticulospora* Nann.-Brem., Sharma and Yamamato, from Eastern Himalayas.

Though many new genera have been created to include border line species with passage of time and in practice one has to fall back on the concepts propounded by Martin *et al*. (1981).

Herein is being described a new species in the genus *Hemitrichia* in the family *Trichiaceae* of the order *Trichiales*. This family is represented by 10 genera all over the globe and 8 of these are recorded from India. These are: *Hemitrichia, Trichia, Metatrichia, Perichaena, Oligonema, Arcyria, Arcyodes* and *Arcyria*. In the genus *Hemitrichia*, six species are reported from India. The new species *H. thindii* being described is the seventh species and it has been isolated from the bark of *Pinus wallichiana* in moist chamber culture. The placement and the relationship of the species has been indicated in the key to the Indian species of *Hemitrichia* given below:

Key to Indian species of *Hemitrichia*

1. Fructifications sessile sporangiate or plasmodiocarpous.... 2

2. Fructifications netted and reticulate plasmodiocarp, Spores reticulate………………………….. ***H. serpula.***

2´. Fructifications primarily sporangiate, spores nor reticulate ……………………………………………... 3

3. Fructifications primarily sporangiate varying to plasmodiocarps, spores 10-14 µm in diameter,minutely roughened……………………………..…… ***H. karstenii.***

3´. Fructifications sporangiate, iridescent, spores 9-10 um coarsely warted, warts up to 1 µm long and may be arranged in lines ……..................…….… ***H. thindii.***

1´. Fructifications sporangiate, primarily stalked.............. 4

4. Spores 9-13µm wide, warted; sporangia subsessile or stalked, yellowish- brown or black............ ***H. leotrichia.***

4´. Spores smaller, verrucose or reticulate; sporangia stalked, if sub-sessile or so, then heaped 5

5. Sporangia heaped, copper coloured; spore mass and capillitium wriggling out of the peridium on dehiscence; spores 6-7µm in diameter, minutely verrucose.......... .... ***H. imperialis.***

5´. Sporangia neither heaped nor copper coloured olivaceous yellow; spores more than the 7 µm in diameter, mostly reticulate 6

6. Sporangia densely clustered broadly clavate or pyriform, stalk 0.8 mm in length, gradually merging into hr calyculus; capillitium minutely roughened; spores 7-9 µm in diameter, coarsely reticulate .... ***H.clavata.***

6´. Sporangia scattered or gregarious, globose or turbinate; stalk mostly longer and demarcated from the sporangium; capillitium smooth; spores 6-7.5µm spinulose reticulate .... ***H. calyculata***.

The detailed illustrated account of the new species being described is given below :

***Hemitrichia thindii* Lakhanpal and Chopra, sp.nov.**

Mycobank number : MB 817380

(Fig.1)

Diagnosis: Sporangia always scattered, astipitate, never orange coloured, spores 9-10 µm wide, coarsely warted or spinulose with spines being 0.5 -1µm in height, reticulum not formed; capillitium threads with very few, free clavate ends having angular swellings at the nodes.

Etymology: Named after renowned Indian mycologist Late Prof. Kartar Singh Thind (K. S. Thind) for his significant contributions in the field of mycology.

Holotype*:* Shimla, on bark of *Pinus wallichiana* in a moist chamber, (HPUB) RKC/TNL 302 (21.04.1980), H.P.U.Shimla.

Fructification sporangiate, sessile, sporangia scattered, globose to semi-globose 0.4 to 0.8 mm in diameter, light to medium yellowish brown, iridescent; peridium single apparently thin and delicate, at times appears wrinkled, in mounts yellow, scantily filled with debris and granular matter; dehiscence by irregular rupture at the apical portion, basal portion persisting as a small irregular cup; capillitium grayish brown, yellow in mounts, consisting of smooth branched, anastomosed elators, 3-3.5 mm in diameter, marked with 3-4 compact spirals, free ends few and slightly inflated, threads swollen angularly at the point of branching, measuring 3-5 µm, spirals usually present in the clavate free ends, may be absent at times; spore-mass grayish brown, bright yellow under transmitted light, globose, 9-10 µm in diameter, coarsely warted, warts prominent and up to 1 µm long, with a tendency to get arranged in lines in polar view, spores may be slightly lighter on one side; hypothallus yellowish brown, membranous or forming a constriction at the sporangial base and sporangia appearing sub-stipulate.

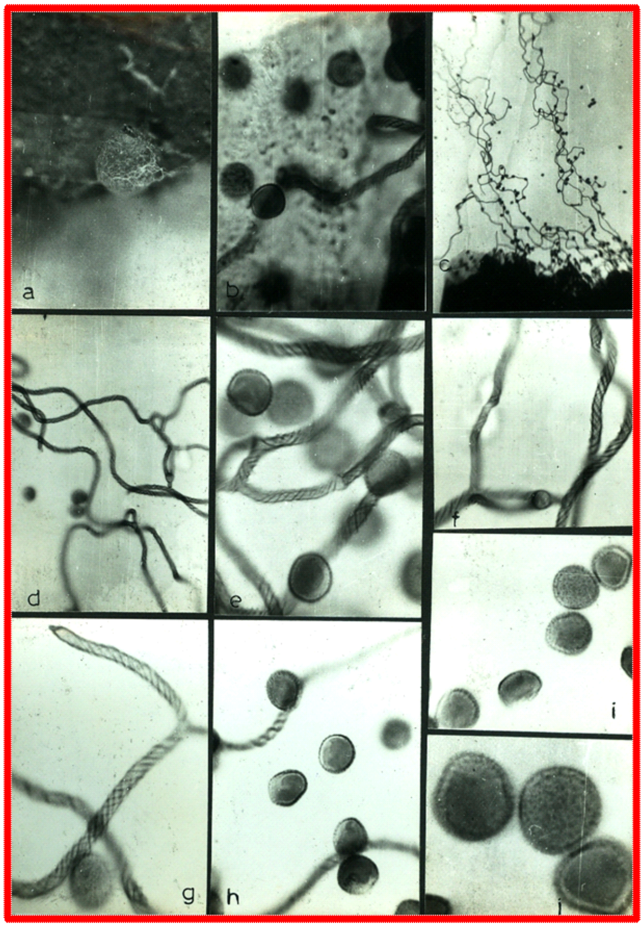

Fig. 1 (a-j). *Hemitrichia thindii* sp. nov.

a. Sessile scattered fructifications, X 40.
b. Mount showing wrinkled peridium scantly filled with granular debris, X 900
c. Mount showing branched and anastomosed capillitial threads forming an intricate network, X 100.
d. Branched capillitium bearing 3-4 compact spiral bands, X 300.
e. Capillitial threads bearing 3-4 compact spiral bands with angular nodes, X 1100.
f. Capillitial thread with compact spirals, X 700.
g. Capillitial threads with compact spirals and clavate free ends, X 1100.
h-j. Coarsely and prominently warted spores, X 700, X 1000, X 2200.

Habitat: Bark of *Pinus wallichiana* at 3-6 meters height.

Collection Examined: Shimla, on bark of *Pinus wallichiana* in a moist chamber, (HPUB) RKC/TNL 302 (21.04.1980). [Holotype].

Discussion: Following Martin and Alexopoulos (1969) the population is keyed to *Hemitrichia abietina* (Wigland) G. Lister. However, it differs from that species in many important features. Its sporangia are always scattered, never orange coloured, without a stipe, the spores are 9-10 µm wide always i.e., slightly smaller and never possesses reticulum but are coarsely warted or spinulose with spines being 0.5 -1µm long. The capillitium threads have very few free ends which are slightly clavate but not swollen or inflated. They however, do possess angular swellings at the nodes. The species is also different from new species of *Hemitrichia* published after 1969 (Neubert and Nann.-Brem. 1976; 1977; Flatau and Nann.-Brem. 1980; Nann.-Brem. and Loerakker, 1981 and Nann.-Brem. and Frentrop, 1981). Because of these differences, this population is treated as a new species of *Hemitrichia*, *H. thindii* in the honour of Professor Kartar Singh Thind.

BIOLOGY OF INDIAN MUSHROOMS

Another group of fungi which interested Dr. Thind was the biology of morels. One of his esteemed student Dr. L.R.Batra, who made an international mark in research in *Discomycetes* and served USDA for a long time. He pioneered exploration of Indian morels in early sixties and was first to collect and consider the developmental stages (Batra and Batra, 1963) in the taxonomical treatment. They produced a compendium on '**Indian Discomycetes'** where in they reported five species in the genus *Morchella* from India. Similar reports were made by Sohi *et al*. (1965) from Himachal Pradesh and Kaul (1981) from Jammu and Kashmir. Another student of Prof. Thind, K.S. Waraitch who worked on Operculate Discomycetes for his Ph.D., in 1976 reported all the six traditional species of *Morchella* from H.P. and J&K. Four of these were collected by him and two by others.

I was fascinated by morels and wished to continue Prof. Thind's work and in 1979, exploration of morels of Himachal Pradesh was begun and the exploration has been continued till 2005. The work formed the material for two Ph.D. thesis (Dr. Onkar Shad and Monika Rana) and four M. Phil dissertations, ultimately culminating with a monograph as "**Biology of Indian Morels**" (Lakhanpal *et al.*, 2010). The main features of the work include the systematic treatment of morels at morphological, anatomical and molecular level. Besides work on their ecological aspects, physiological aspects, nutritive and nutraceutical components, rhizomorphosphere studies, ethnomycolological and sociological aspects, mycorrhizal association, cytology of ascus development and culinary aspects was also undertaken so as to understand their complete biology. The purpose of investigating all these aspects was to achieve some breakthrough in artificial cultivation, which eluded us as usual. Nevertheless, the material compiled will definitely serve a useful purpose as opined by Prof. Thind as he was one of the examiners' for Onkar Shad's thesis.

Our group could collect all the six species of morels from Himachal Himalayas. We found that *M. tibetica* a new species of *Morchella* described by Zang (1987) was also represented in our collection. Not only, this, there was also a new species, which was described as *M. simlensis* Lakhanpal and Shad. The validity of all species has been authenticated through molecular characterization. Thus, we were happy that we could carry the work forward initiated by Prof. Thind at Chandigarh.

When I joined the Department of Biosciences of H.P. University, Shimla in1976, Prof. Thind advised me to initiate work on order *Agaricales*, which he said he has not been able to investigate. I took his command and initiated exploration of of *Agaricales*. It was decided not to collect all mushrooms which come up but to start family wise survey and it was started with family *Boletaceae* in 1976. Besides pioneering work on various aspects of agarics of North West Himalayas including systematics, ethnomycology, sociobiology, conservation, nutritional and nutraceutical evaluation and establishment of mycorrhiza, etc. was also undertaken.

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