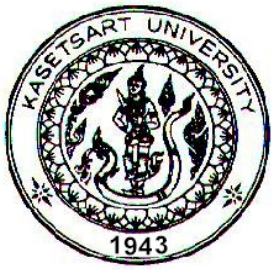

THESIS

ASSEMBLAGES OF MYXOMYCETES
ASSOCIATED WITH AGRICULTURAL GROUND AND FOREST FLOOR LITTER
IN NORTHERN THAILAND

TRAN THI MY HANH

GRADUATE SCHOOL, KASETSART UNIVERSITY
2006

THESIS APPROVAL

GRADUATE SCHOOL, KASETSART UNIVERSITY

Master of Science (Tropical Agriculture)

DEGREE

Tropical Agriculture — **FIELD**

Interdisciplinary Graduate Program — **PROGRAM**

TITLE: Assemblages of Myxomycetes Associated with Forest Floor and Agricultural Ground Litter in Northern Thailand

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THESIS

ASSEMBLAGES OF MYXOMYCETES
ASSOCIATED WITH FOREST FLOOR AND AGRICULTURAL GROUND LITTER
IN NORTHERN THAILAND

TRAN THI MY HANH

A Thesis Submitted in Partial Fulfillment of
the Requirements for the Degree of
Master of Science (Tropical Agriculture)
Graduate School, Kasetsart University
2006

ISBN 974 – 16 – 2614 - 2

Tran Thi My Hanh 2006: Assemblages of Myxomycetes Associated with Forest Floor and Agricultural Ground Litter in Northern Thailand. Master of Science (Tropical Agriculture), Major Filed: Tropical Agriculture, Interdisciplinary Graduate Program. Thesis Advisor: Associate Professor Orarat Mongkolporn, Ph.D. 98 pages.
ISBN 974-16-2614-2

The ecological distribution and seasonal patterns of occurrence of myxomycetes associated with forest floor and agricultural ground litter were investigated in six study sites in northern Thailand from October 2004 to October 2005. Specimens developing under natural field conditions and specimens obtained via moist chamber cultures were determined. Eighty-five species of myxomycetes representing 20 genera were ideintifed; 48 species were recorded during the dry season and 59 species were recorded during the wet season. Although species totals were only slightly different for the two seasons, distinct differences were noted for numbers of positive moist chamber cultures; numbers of both moist chamber and field collections, and (especially) species composition when data obtained for the two seasons were compared. The assemblage of myxomycetes recorded for the wet season was more diverse (S/G value = 3.28) than in the dry season (S/G value = 4.36).

The fruiting phenology and substrate relationships of myxomycetes in five 100 m^2 study plots in mid-elevation forests of northern Thailand were investigated during the same period. Sixty-two myxomycete species representing 18 genera were identified. Few fruitings occurred during the dry season (which extends from November through May), but fruitings were prominent in the wet season, especially during June and July. Numbers of species recorded for these two months were 45 and 33, respectively. Forest floor litter derived from two trees (*Dipterocarpus* sp and *Macaranga denticulate*) represented an especially favorable substrate for myxomycetes.

In total, 100 species of myxomycetes representing 22 genera were identified. Seventy-eight of these are new records for northern Thailand, *Licea erecta* var. *erectoides* being known from only a few other localities worldwide. The assemblages of myxomycetes associated with litter in northern Thailand are quite high in term of species richness, but less in term of total biodiversity in comparison with other tropics and especially temperate areas. A combination of methodologies should be utilised when assessing myxomycete diversity.

Student's signature Thesis Advisor's signature 26 July 06

ACKNOWLEDGEMENTS

I would like to send very special thanks to my parents, sisters and brothers, who not only teach me what love is, but also generate the passion about study in me and make me as good as I could be. I wish I could find out an accurate word to express enough how much you are meant to m y life.

My gratitude extends to Dr. Steven L. Stephenson who first introduced me to the wonderful world of myxomycetes. Without whose help, encouragement and support, my study would have never been possible.

I am grateful to Dr. Kevin. D. Hyde for giving me the chance to carry out the project with such the great myxomycete expert, for being extremely patient and forgiving with the hard beginning and ending of my study.

Thanks to Dr. Orarat Mongkolporn for the general advices and kindly helps, and Dr. Ratiya Pongpisutta for providing the knowledge on mycology.

I am grateful to my former supervisor, Dr. Hang. T. Mai for the encouragements and for having such unfaltering faith in the ability to study of her "stubborn student".

Jacques Fournier gained my respect and appreciation for his great passion for mycology and for the sharing the invaluable experiences on fieldwork.

Thanks to Dr. Edward Grand for the laboratory assistance and Dr. Atchariya Prabaripai for help with data analysis.

Aung Swe, Alvin Tang and Hu Hongli really made the literature review chapter of my thesis completed by patiently helping me collect the references on myxomycetes of China and Thailand. Thank you all a lot for that.

Special thanks to my special friend, Mar Tin, who ''secretly prays'' for me everyday. I will try not to make many mistakes in the future, Mar Tin.

I am grateful to Nut, the manager of MRC, for paying attention to our living and studying in MRC

I must thank Huyen T. T. Le, Iman Hidayat, Lam M. Duong, Popo Than, Zhao Ruilin and my lovely roommate, Ohnmar Myo. Your presences, kindness and sense of humors make the life in the rain forest become enjoyable.

Other thanks go to my intimate friends, who patiently listened to my uncountable complaints, cheered me up and filled ''my neglectful head'' with much information on "the life outside the laboratory".

Tran Thi My Hanh

July, 2006

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ASEMBLAGES OF MYXOMYCETES ASSOCIATED WITH FOREST FLOOR AND AGRICULTUAL LITTER IN NORTHERN THAILAND

INTRODUCTION

The myxomycetes (plasmodial slime molds) are a group of primitive phagotrophic eukaryotes, commonly associated with decaying plant material in terrestrial ecosystems (Stephenson and Stempen, 1994). The life cycle of a myxomycete includes two morphologically distinct trophic stages, one consisting of uninucleate amoebae (with or without flagella), and the other consisting of a distinctive multinucleate structure, the plasmodium (Martin *et al.*, 1983). Under favorable condition, the plasmodium will give rise to fruiting bodies containing spores. The spores complete the life cycle by germinating to produce the amoeboid cells (Stephenson, 1993)

Because of the presence of spores, myxomycetes were thought to be fungi and thus placed into the Kingdom Mycota (Martin, 1949). However, because of the lack of a mycelium (the diagnostic characteristic of true fungi) and absence of a rigid cell wall in the amoeboid and the plasmodium, plus ingestion of food by mean of phagocytosis, they cannot be considered fungi. More recently, myxomycetes have been identified as a class in the Phylum Myxostelida that belongs to Kingdom Protozoa (Kendrick, 2000).

Although myxomycetes have no direct economic value, they play very important roles in the ecosystem and in some aspects of human life. Myxomycetes possess the mobile, giant cell with multi – nuclei existing independently, and especially non-enclosed by a cell wall (Alexopoulos *et al*., 1996). Myxomycetes have been used as an effectively experimental organism in many cytological, molecular, biochemical, and biophysical laboratories to investigate fundamental biological problems such as cell differentiation (e.g. cancer-cell development), cell movement, nuclear division (Braun and Behrens, 1969; Ashworth and Dee; Block *et al.*, 1995)

and the interaction of cell with its environment (Monnat *et al*., 1999). Recently, extraction of the bioactive chemicals from some species of myxomycetes has received attention, and these have produced some certainly prospective results. An anti–inflammatory substance, which can affect mucous membranes, has been isolated from fruiting bodies of *Lycogala epidendrum* and can be used as external application (Ying, 1987). Two unusual new triacylglycerols, two new diacylglycerols, and lycogalic acid dimethylesterns were also harvested from *Lycogala epidendrum* (Buchanan *et al*., 1996).

Slime molds consume bacteria and the other minute organisms, but they also provide favourable substrates and shelters for various species of fungi and insects (Stephenson and Stempen, 1994). Young aethalia of *Enteridium lycoperdon*, and plasmodium of *Fuligo septica* have been used as a human food source in the state of Veracruz, Mexico (Villarreal, 1983).

Plasmodia of some myxomycetes, such as *Fuligo septica* and *Physarum cinereum* are very large, colonising ornamental plants, and lawns, rendering them unsightly, even though they are harmless organisms (Subrahmanyam**,** 2001). Plasmodia and fruiting bodies of some myxomycetes are very beautiful and intriguing such that myxomycetes have become "irresistible models" for photographers, and people encountering them (Stephenson and Stempen, 1994)

Myxomycetes are commonly associated with decaying plant material throughout the world, even under severe conditions like deserts, or alpine areas, or the margin of melting snow (Stephenson 2003a; Moreno *et al*., 2001). However, their distribution is not random. It seems that myxomycetes mostly sporulate at certain periods in the year, and certain myxomycete species tend to be associated with certain substrates (Martin *et al.,* 1983; Stephenson and Stempen, 1994). There is no complete explanation for this phenomenon, but some physical and biotic factors such as humidity, temperature, light density, pH of substrate, and the availability of bacteria, fungi, and insects are supposedly involved (Stephenson, 2003b)

With such the important roles of myxomycetes in human life and in the ecosystem, studying myxomycete biodiversity to discover assemblages of myxomycetes at different habitats, to analyze the relationship of myxomycetes with the ecosystems in which they occur, to provide more new species for the concerned sciences, and to lend myxomycete diversity data to measure and monitor biodiversity for sustainable utilization and conservation has been carried out as an emphasized task of myxomycologists (Hyde and Hawksworth, 1997)

There have been several studies on the ecology and taxonomy of myxomycetes in various parts of the world. Most have involved temperate regions, including Austria (Singer *et al*., 2001), New Zealand (Stephenson, 2001), Northeastern America (Stephenson *et al*., 1993), and Turkey (Sesli and Denchev, 2005). There have some in tropical regions, including Costa Rica (Schnittler *et al.,* 2000), Mexico (Lado *et al*., 2003) and Puerto Rico (Novozhilov *et al*., 2001). However, the tropics as a whole have received relatively less attention. Especially, except for some brief notes on the myxomycetes of Thailand (e.g., Reynolds and Alexopoulos, 1971**;** Siwasin and Ing, 1982). We are not aware of any previous study in Southeast Asia.

Agricultural areas represent one type of ecological situation that has been largely neglected in temperate regions of the world, and we are also not aware of any previous study that has considered the myxomycetes diversity associated with agricultural system anywhere in the tropics.

Due to the lack of knowledge of myxomycetes throughout Asia in general and Thailand, the country is thought to support one of the highest levels of biodiversity resource richness in the world (Smitinand, 1994), northern Thailand was selected to investigate myxomycete assemblages associated with agricultural and forest floor litter. The results from the project will provide baseline knowledge for studies of myxomycetes in other Asian countries.

The objectives of this study are to

1. Analyze patterns of species composition and diversity of the assemblages of myxomycetes associated with forest floor and agricultural ground litter

2. Compare myxomycete distribution and diversity between natural and agricultural habitats.

3. Investigate whether seasonality and agricultural activity affect myxomycete occurrence.

4. Determine a suitable method for monitoring myxomycetes in the field through direct observation in a selected forest over an entire year

LITERATURE REVIEW

Myxomycete classification status

Sharing characteristics with both fungi (reproduction by producing spores) and amoeboid protozoans (the myxamoeba produced in the assimilative stage of myxomycete life cycle is a uninucleate, haploid cell that has no cell wall and obtains nutrition by mean of phagocytosis), a conflict in the classification of myxomycetes has been maintained for a long period of time. As the result, in the past myxomycetes were studied by not only zoologists but also by botanists and mycologists (Martin *et al*., 1983)

According to Alexopoulos (1962), Myxomycetes belong to the phylum Myxomycotina, Division Mycota, and Kingdom Plantae. Ainsworth and Bisby (1971) divided phylum Myxomycota into 4 classes including Myxomycetes, Acrasiomycetes, Hydromyxomycetes, and Plasmodiophoromycetes and those belong to Kingdom Fungi.

Recently, along with Dictyostelids (or cellular slime molds), and Protostelids (protostelid slime molds), Myxomycetes have been placed into the phylum Eumycetozoa, which belongs to Kingdom Protozoa (Kendrick, 2000)

Taxonomic classification

The class Myxomycetes includes 6 orders, 12 families, 40 genera, and about 900 identified species (Lado, 2001). The unique taxonomy including identification and nomenclature of myxomycetes is well defined (Hernández-Crespo and Lado, 2005). Genus names and characteristics of each order are displayed in the Table 1

Table 1. Taxonomic classification of myxomycetes (Lado, 2001; Stephenson, 2001)

Subclass	Order	Family	Genus
Ceratiomyxomycetidae	**Ceratiomyxales**	**Ceratiomyxaceae**	*Ceratiomyxa*
Myxogastromycetidae	**Echinosteliales**	**Clastodermataceae**	*Barbeyella*
			Clastoderma
		Echinostelicea	*Echinostelium*
	Liceales	**Cribrariaceae**	*Cribraria*
			Dictydium
		Liaceaceae	*Enteridium*
			Licea
			Dictydiaethalium
		Reticulariaceae	*Lycogala*
			Reticularia
			Tubiferia.
		Didymiaceae	*Diachea*
			Diderma,
			Didymium
			Lepidoderma
			Mucilago
			Physarina
	Physarales	**Physaraceae**	*Badhamia*
			Badhamiopsis
			Craterium
			Erionema
			Fuligo
			Leocarpus
			Physarella
			Physarum
			Protophysarum
			Willkommlangea
	Stemonitales	**Stemonitidacea**	*Brefeldia*
			Collaria
			Colloderma
			Comatricha
			Diacheopsis
			Enerthenema
			Lamproderma

Table 1. (Cont'd)

Subclass	Order	Family	Genus
			Macbrideola
			Paradiacheopsis
	Stemonitales (Cont'd)	**Stemonitidacea** (Cont'd)	*Stemonitis*
			Stemonitopsis
			Symphytocarpus
		Arcyriacea	*Arcyria*
			Cornuvia
		Dianemataceae	*Calomyxa*
Myxogastromycetidae (Cont'd)			*Dianema*
			Arcyodes, *Arcyriatella*
	Trichiales		*Calonema*
			Hemitrichia
			Metatrichia
		Trichiaceae	*Minakatella*
			Perichaena
			Prototrichia
			Oligonema
			Trichia

Order Ceratiomyxales

There is only a single family Ceratiomyxaceae with just one genus *Ceratiomyxa* in this order. The members of this order are distinct from the other myxomycetes with white column-like fruiting body existing individually, or the hydra-like fruiting body sharing the common base and anatomizing at the upper part. It is the only case for the myxomycetes in which the spores are externally born on fruiting bodies instead of inside. (Stephenson and Stempen, 1994; Stephenson, 2003)

Order Echinosteliales

This order includes two families, Clastodermataceae with two genera *Barbeyella* and *Clastoderma* and Echinosteliaceae with only one genus *Echinostelium*. The diagnostic characteristics of this order are the very minute fruiting bodies (< 0.5 mm tall) (Stephenson and Stempen, 1994), true capillitium often present and fruiting body is sporangium form.

Order Stemonitales

This order contains only a single family Stemonitidaceae with fifteen genera *Brefeldia*, *Collaria*, *Colloderma*, *Comatricha*, *Diacheopsis*, *Enerthenema*, *Lamproderma*, *Macbrideola*, *Paradiacheopsis*, *Stemonitis*, *Stemonitopsis*, *Symphytocarpus*. Spore mass often has dark color. Fruiting bodies are mostly sporangium form. The capillitium consists of a network of smooth dark thread – like structures. Columellae are well developed in some species (Lado, 2001; Stephenson, 2001)

Order Liceales

There are three families in this order: Cribrariaceae including two genera *Cribraria* and *Dictydium* along with the Liaceaceae, also containing two genera *Enteridium* and *Licea*, and Reticulariaceae with four genera *Dictydiaethalium*, *Lycogala*, *Reticularia*, and *Tubiferia* (Stephenson, 2001)

The members of this order have four types of fruiting bodies, but are quite easy to recognize with the absence of true capillitium, a pseudocapillitium sometimes present and spore mass color is always light. Columella is never present (Alexopoulos *et al.*, 1996)

Order Trichiales

This order contains three families: Arcyriaceae with two genera *Arcyria* and *Cornuvia*, Dianemataceae also with two genera *Calomyxa* and *Dianema*, and the largest family of myxomycetes, Trichiaceae with 10 genera *Arcyodes*, *Arcyriatella*, *Calonema*, *Hemitrichia Metatrichia*, *Minakatella*, *Perichaena*, *Prototrichia Oligonema* and *Trichia* (Stephenson, 2001)

Members of this order are pretty easy to differentiate from the other myxomycetes because of the lack of a columella, spores often with bright color; capillitium is thread – like, ornamented or smooth (Stephenson and Stempen, 1994)

Order Physarales

The distinguishing characteristic of the Physarales is the presence of lime (calcium carbonate) in some parts of the fruiting bodies, either in stalk, peridium or capillitium. The plasmodium is of the phaneroplasmodium type, and spore mass is dark in color (Ashworth and Dee, 1975)

This order contains two families Physaraceae and Didymiaceae. Both of them are large and various, but members of Physaraceae with capillitium always encrusted with lime (granular form). While in those of the Didymiaceae the capillitium is limeless, lime (crystalline or granular form) present in peridium or stalk (Martin *et al*., 1983)

Family Didymiaceae including six genera *Diachea*, *Diderma*, *Didymium*, *Lepidoderma*, *Mucilago* (Stephenson, 2003)

Family Physaraceae contains ten genera *Badhamia*, *Craterium*, *Erionema*, *Fuligo*, *Leocarpus, Physarella*, and *Physarum.* Among of them, *Physarum* is the largest genus in the myxomycetes, including over 150 species (Lado, 2001)

Myxomycete lifecycle

Spores, spore dispersal, spore germination, myxamoebae and swarm cells

Spores are microscopic reproductive structures produced in or on the fruiting bodies of myxomycetes during the reproductive stage of these organisms (Ashworth and Dee, 1975)

Spores often occur separately or sometimes in cluster (e.g. *Dianema corticatum*). Sizes of spores are quite small, ranging from 4 - 20µm. Surface of spores can be fairly smooth to ornament. Spore ornamentation ranges from punctuate to distinctly warted, spiny, or reticulate (Stephenson, 2003)

Spore color in mass is categorized into two groups either dark (found in the order Stemoriales and Physarales) or light or brightly (found in all the other orders) (Stephenson and Stempen, 1994)

Little information is known about the structure of the myxomycete spore wall. In one of the most detailed studies on *Physarum polycephalum*, McCormick *et al*., (1970) reported that the spore wall of this myxomycete was composed mainly of a galactosamine polymer (81%) and melanin (15.4%) (Alexopoulos, 1992)

Mature myxomycete spores typically contain a single haploid nucleus; each spore also contains mitochondria, ribosomes, entoplasmic reticulum, golgi bodies, and often a large autophagic vacuole. The principal storage products in myxomycete spores are lipids and glycogen (Ashworth and Dee, 1975)

Spore dispersal

Spore of myxomycetes are generally liberated from fruiting bodies by a various means including wind, water, and activities of animals, especially arthropods (Stephenson and Stempen, 1994)

However, with their small size (4-20μm), spores are easily picked up by air, and air dispersal may be the most common and effective one for myxomycetes. Since the fruiting bodies (supposedly, all types of fruiting bodies) are ready to release spores, firstly the peridium (if still persisting) splits up (which may be regular or irregular) so that the spore mass will be exposed to outside, and then soon after that spores will be dried out (Alexopoulos, 1996)

The capillitium is responsible for releasing spores and the retention of spores in the fruiting body. If wind is available, and the other factors are favorable with the assistance of capillitium, the spores will be dispersed, carried away to new substrata. If dispersal conditions such as wind, temperature are not favorable, capillitium will retain spores so spore dispersal will be carried out gradually for over a long period of time that probably helps the left spores meet a better condition latter (Stephenson, 1993; Alexopoulos *et al.,* 1996)

Spore germination

When suitable external conditions (e.g. temperature, water, pH and humidity) exist, some internal factors supposedly internal pressure or enzymes associated with cell wall will stimulate spore germination. In most cases, the spore cell walls will crack to release a single uninucleate myxamoeba; however, in some species the myxamoeba is liberated through a small hole dissolved in the spore wall (Ashworth and Dee, 1975; Alexopoulos *et al.,* 1996)

The myxamoeba moves by amoeboid motion, feeds on bacteria, yeast cells, and other minute organisms by mean of phagocytosis, and reproduces asexually by mitosis and cytokinesis (Stephenson and Stempen, 1994; Stephenson, 2003a)

The existence of the myxamoeba stage depends on the surrounding. If food is abundant and the environmental conditions are favorable, it can last for a long period of time, reproduce repeatedly, and give rise to a large population of cells. And

oppositely if the condition is harsh myxamoeba will convert into the other structures (Alexopoulos *et al.,* 1996)

When free water is available, myxamoeba can convert into a swarm cell that has the same behaviors as the myxamoeba. Each swarm cell has two flagella, one is long and visible, and the other is very short, and mostly not visible (Ashworth and Dee, 1975; Stephenson, 1993)

During periods of unfavorable conditions, the myxamoeba or swarm cell protoplast becomes round up and forms a protective wall around itself (the resistant microcyst stage) protecting it from the environment. When the favorable condition comes back, myxamoeba or swarm cell will emerges from each microcyst. (Marie *et al.,* 1981; Alexopoulos *et al*., 1996)

Formation of Zygotes and Plasmodia

When a critical number of myxamoebae or swarms are formed**,** sexual reproduction in which myxamoeba and swarm cell function as gametes will take place**.** For heterothallic strains, in order for fusion to occur, it is required for gametes to be derived from different myxamoeba or swarm population and of a different mating type or strain (designated as A1 and A2) (Alexopoulos, 19963; Alexopoulos *et al*., 1996)

Since, two compatible mating strains meet each other, syngamy will occur and then a zygote (2N) will be formed. The zygote grows by undergoing synchronous mitotic division repeatedly to form multinucleate structure, called plasmodium (Alexopoulos, 1996)

The plasmodium is a single multinucleate cell with no cell wall, including many sets diploid nuclei and organelles like those of typical eukaryotic cells in protoplast. Plasmodium is also a trophic stage that can migrate from place to place and consume food by phagocytosis. Plasmodium of the same strain can mix with each

other without nuclear fusion to in crease the size. However, plasmodium of different species never fuses (de Bay, 1887). The growth of plasmodium is mainly companied by series of simultaneously mitotic division of nuclei within the cytoplasm. When the condition is unfavorable, plasmodium will form an outer layer and become dormant structure called a sclerotium. The Sclerotium is composed of a number of smaller multinucleate cells – macrocysts, each macrocyst will give rise to a new plasmodium when environment returns favorable (Stephenson, 1993, 2001)

Plamodia of myxomycetes are various in color, ranging from colorless, to white, grey, black, yellow, orange and red. Among those, the white and yellow colors are the most common (Martin *et al*., 1983)

However, based on the differences in the appearance and the movement, plasmodia are mainly divided into three types (Alexopoulos 1969; Martin *et al*., 1983)

The smallest type is protoplasmodium, characteristic of *Echinosteliales* and many species of *Licea*. This plasmodium is more or less homogeneous, forms no vein, streaming irregular, and only observed under microscope (Martin *et al*., 1983)

The aphanoplasmodium is the characteristic of *Stemonitales*. Such a plasmodium resembles to protoplasmodium at the early stage, and then soon forms a network of veins. The protoplasm is homogenous rather then granular. The veins are not differentiated into jellified and fluid regions, and streaming is rapid and rhythmic (Alexopoulos *et al.*, 1996)

The phaneroplasmodium, *Physarales* is characterized by this type of plasmodium. At the early time, the phaneroplasmodium is similar to protoplasmodium, but very soon after that, it becomes more massive. The protoplasm is granular. The gellified and fluid regions are distinguishable, and the streaming is also rhythmic (Alexopoulos *et al*., 1996)

Formation of fruiting bodies

The exhaustion of food and a suitable light intensity are thought to be the external factors stimulate formation of sporangia (Ashworth and Dee, 1975)

When sporangium formation starts, the plasmodium becomes more concentrated and forms a thick sheet called the hypothallus. The protoplasm of the plasmodium converts into many discrete nodules. Each nodule is a primitive fruiting body. As the nodule elongates, the basal portion becomes more and more constricted to form the stalk and the upper portion from which the sporangia will be derived continues expand. During the formation of fruiting body, the protoplasm is continuously pushed upward. When the protoplasm completely moves to the sporangium position, the shape of sprotheca will be formed and by this time the stalk is devoid of protoplasm (Wong, 2001)

Within the sporangium, the formations of spores are also carried out. Firstly, new - formed cell walls enclose the diploid nuclei, and then the nucleus inside each cell wall will undergoes meiosis to produce four 1N nuclei. Three of these will degenerate, and only one still exists. As the result, spore with haploid structure is formed.

The capillitium derives from coalescence of vacuoles, which contain various materials from the protoplasm, especially, that compose a lot of calcium carbonate in Physarales members (Alexopoulos *et al*., 1996; Wong, 2001)

Mentioned above is the formation of a sporangium with no comlumella. There is a small difference from that of a stipitate sporangium, a sporangium with well-developed columella derived from the stalk or stipe. For this species, stalk will continues to develop within the sporangium, and then the extension of the stalk forming the columella (Wong, 2001)

Fruiting body and types of fruiting body of myxomycetes

Fruiting body (also named as fructification, sporocarp or sporophore) Is the spore – producing appearing during the reproductive stage in the myxomycete life cycle (Stephenson, 2003)

Fruiting bodies of Myxomycetes are divided into 4 generally distinguishable forms

1 Sporangium (pl. sporangia)
2 An aetharium (pl aetharia)
3 Pseudoaetharium (pl.pseudoaethatia)
4 Plasmodiocarp (pl. plasmodiocarps)

The sporangium is the most common type of fruiting body. Sporangia are derived from separate portions of the same plasmodium; therefore they usually occur in groups. For example sporangium *Arcyria cinerea* (Alexopoulos *et al*., 1996)

An aethalium is a relatively large cushion shape, sessile structure, formed from all or a major potion of the plasmodium. Some examples of myxomycetes with aetharioid sporophores are various species of Lycogala, Mucilaco and Fuligo. *Fuligo septica* produces the largest sporophores of any myxomycetes (Stephenson, 2003 b)

The pseudoaethalium (Gr. Pseudo = false + aethalium), which is quite uncommon, is composed of sporangia closely aggregated together. Pseudoaetharia are usually sessile, although a few examples are stalked. *Dictydi athaerium* is characterized by a pseudoaetharium, it can be difficult to distinguish certain fruiting of closely packed (Stephenson, 2001)

Plasmodiocarps are sessile, branched, ring-shape, or netted type of fruiting bodies. When a plasmodium becomes concentrated in its main veins (without breaking up into smaller units) driving fruiting. An example of a striking reticulate

plasmocarpous fruitification is that of *Hemitrichia serpula* (Alexopoulos 1969; Alexopoulos *et al.,* 1996)

Within each fruiting body type, fruiting bodies of different species (or even in the same colony of a myxomycete) are also various in size, shape and color. For example sporangium of Echinosthalium minitum is very minute, usually 0.5 mm high but that of Cribaria untricata may reach 3.5 mm high. *Physarum roseum* is characterized by rose red color, but the bright yellow sporangia are an outstanding characteristic to recognize *Physarum viride* (Stephenson and Stempen, 1994)

Morphological characteristics of a myxomycete fruiting body

A sporangium of a typical myxomycete consists of the following parts: hypothallus, stalk, peridium, collumella, capillidium and spores. Not all sporangia have all these parts but all contain spores. The present or absent of all these structures and their characteristics, when present, are the criteria for identification (Stephenson, 2003 b)

The hypothallus (pl. hypothalli)

The hypothallus is the plasmodium sheath deposited on the substrate. It may be dull or bright in color, thin and delicate or coarse. In some case, the hypothallus may be composed of calcium carbonate; the composition of the hypothallus is proteinaceous (Harold *et al.,* 1999)

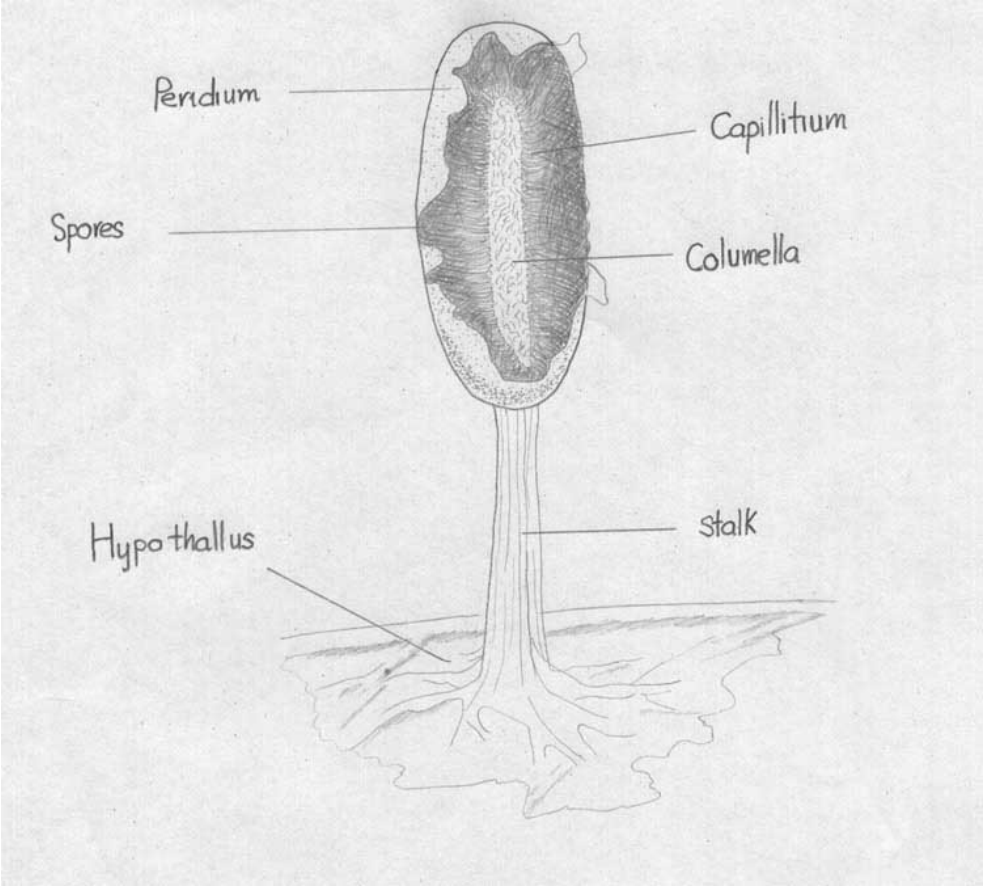


Figure 1. Basic structural components of a typical myxomycete fruiting body

The stalk

The stalk is an exceeding important characteristic for identification. The stalk may very in length, color and texture. In some species the stalk is opaque, while in others it is translucent. The stalk may also be coated with lime or filled with granular or spore like structures (Stephenson, 2001)

Peridium (pl. peridia)

The peridium is a covering and encloses the spore mass of the fruiting body. It may or may not be evident in mature fruiting body. In some species the peridium

persists as a calyculus, a cup-like structure holding the bottom of the spore mass (Stephenson, 2003)

The peridium may split open long clearly discernible lines of dehiscent, as a preformed lid, or in an irregular pattern, crusted with lime or lime lack
In an aetharium, the peridium is relatively thick so it referred to cortex rather than a peridium (Martin *et al.,* 1983; Harold *et al.,* 1999)

Collumella (pl. collumellae)

Collumella is an extension of the stalk into the sporotheca; it may not resemble the stalk in a sessile fruiting body. The collumella may appear as a dome-shape structure on the inside of the peridium, where the latter contacts the substrate

A pseudocollumella is collumella like-structure that does not attach to the stalk, exists in the form of a lime mass within the spore mass and is of only the order Physarales (Harold *et al.,* 1999; Stephenson, 2003a)

Capillitium (pl. capillitia)

The capillitium is a system of sterile elements found within the spore mass. Many species of myxomycetes have a capillitium but some have a pseudocapillitium. The capillitium can be either as a single connected network or as free elements called elaters. Capillitial elements may be smooth, scultured or encrusted with lime (the latter characteristic of the Physarales) (Martin *et al.,* 1983; Stephenson, 2003a)

The capillitia are separated from spores within the spore mass and are not connected to them. However capillitial elements may be attached to the columella, pseudocolumella, or to the inner surface of peridium (Marie *et al*., 1981; Martin *et al.,* 1983)

A pseudocapillitium is present in some aethalia and pseudoaethalia producing species. Pseudocapillitial elements are highly variable in size and shape, and may appear as brustles, threads or perforated plates (Alexopoulos *et al.,* 1996; Harold *et al.,* 1999)

The distribution of myxomycetes

Myxomycetes are regarded as common inhabitants in decaying plant material in terrestrial ecosystems (Stephenson and Stempen, 1994); however, some species have been reported from aquatic habitats (Shearer and Crane, 1986). Some myxomycetes are restricted to alpine areas, while some are found in high latitudes and deserts (Stephenson and Stempen, 1994). Myxomycetes have been reported from a large number of microhabitats including bark of living trees (Mitchell, 1980); forest litter (Gray and Alexopoulos, 1969); dung (Lister, 1918); soil (Thom and Raper, 1930), and dead aerial plant parts including inflorescences (Lado, 2002; Schnittler and Stephenson, 2002). More than 100 species of myxomycetes have been reported from bark; many of these taxa are also known to occur in other microhabitats, but some species appear to be specific to bark of living trees (e.g. *Echinostelium, Licea*, and *Macbrideola*) (Mitchell, 1980; Stephenson and Stempen, 1994). At least 80 species have been recorded from dung (Eliasson and Lundqvist, 1979). Thirty-one different taxa were found among 652 specimens of myxomycetes recorded in the field or yielded from 358 moist chambers prepared with decaying floral parts in Costa Rica, Ecuador, and Puerto Rico (Schnittler and Stephenson, 2002). Twenty-five species of myxomycetes were collected around melting snow banks in mountainous areas of Tyrol (Singer *et al*., 2001). Interestingly, a myxomycete species, *Physarum pusillum,* was firstly found on the body of a living animal, the lizard *Corytophanes cristatus* (Townsend *et al*., 2005)

Study on ecology and biodiversity of myxomycetes

History

The name, myxomycetes (in Greek, *myxa* – slime, *myketes*- fungi) was first used by Heinrich Link in 1883. As the name implied, Link (1883) considered myxomycetes as fungi. However, this view was not commonly supported by other biologists at that time. Later, Anton de Barry regarded the myxomycetes as protozoan and proposed the name Mycetozoa (in Greek, *zoon*- animal, *mykes*- fungi). A number of authors such as Lister (1894), Hagelstein (1944), and Olive (1975) have adopted this name. However, Martin (1949), Alexopoulos (1963, 1973), Farr (1976), and Bremekamp (1991) have perpetuated the name given by Link, myxomycetes, and classified the group with the fungi (Stephenson and Stempen, 1994).

Lately, based on small-subunit ribosomal-DNA (SSU rDNA) sequence phylogeny, myxomycetes are placed into the Protozoa (Cavalier-Smith, 1993). However, only one species of myxomycetes, *Physarum polycephalum* was included in the analysis. Gene analysis of the elongation factor EF-1 α revealed that the clade formed by *Physarum* (myxomycetes), *Dictyostelium* (Dictyostelids), and *Planoprotostelium* (Protostelids) is the sister group of Animalia and Fungi (Baldauf, 1999). In general, literature on the origin and evolution of myxomycetes based on molecular methods is not well defined (Matín *et al*., 2003). However, nowadays, most of myxomycologists and mycologists agree with the classification of myxomycetes as a class in the Phylum Myxostelida that belongs in the Kingdom Protozoa (Stephenson, 1993; Kendrick 2000; Lado, 2001). Irrespective of their relationships to other living organisms, the study of myxomycetes has been carried out by botanists and mycologists (Martin, 1983)

In the past, the studies of myxomycetes were only based on the field collections (e.g. Stephenson and Stempen, 1994). Direct observation of myxomycete fruiting bodies developing under natural conditions resulted in a relatively poor understanding of myxomycetes associated with microhabitats such as the bark surface

of living trees and forest floor litter. This is because fruiting bodies of many of these myxomycetes are tiny or sporadic in their occurrences and thus easily overlooked (Martin and Alexopouslos, 1969). The use of moist chamber for culturing myxomycetes was first introduced by Gilber and Martin (1933). Since its introduction, the technique has been effectively applied by many researchers such as Keller and Brooks (1976), Blackwell and Gilbertson (1980) and Stephenson (1989).

Methods of studying diversity and ecology of myxomycetes

The sources of myxomycetes in almost every study are mainly from moist chamber and field collections. The identification of myxomycetes has been mainly based on morphological characteristics including types and structural components of the fruiting body e.g. capillitium, columella, hypothallus, peridium and spores (Martin 1983; Chung, 1997; Lado, 2001; Stephenson, 1994, 2003). The morphological identification is sometimes intensively diagnosed by SEM technique in studies of some confusable myxomycetes species for example *Diderma niveum* complex (Moreno *et al*., 2003).

Dichotomous keys are used for myxomycete identification. Each key consists of a series of couplets, with each couplet made up of a pair of statements composed of one or two more contrasting characters. To identify a particular specimen, one should begin with the key to Orders, and then proceed on the portion of the monograph where taxa belonging to that order are considered. Once reaching the appropriate Order, the process is repeated for additional keys to determine the species. If illustrations are available, comparisons can be used to confirm the identification (Lado, 2001; Stephenson *et al.*, 2001).

The diversity of assemblages of myxomycetes has been mainly evaluated by establishing the number of species at a particular place, and the distribution of these species in myxomycete genera. The larger the number of species for a given genera, the greater its diversity (Stephenson, 1993).

A few attempts to exploit biological and molecular characteristics in myxomycetes classification have been undertaken, such as the study about reproductive systems of some species of myxomycetes (Clark *et al*., 2004) or primer design for amplification and direct sequencing of ITS region of rDNA from myxomycetes (Martín *et al.*, 2003). Even though, the results are still limited they provide a methodology for myxomycetes identification based not only morphology, but also molecular sequencing.

Study on worldwide diversity and ecology of myxomycetes

Numerous studies on the taxonomy and ecology of myxomycetes have been carried out in various parts of the world during the past two decades (Table 2). Notably, most of studies on biodiversity and ecology of myxomycetes have been carried out in temperate regions, including Austria (Singer *et al*., 2001), eastern North America (Stephenson *et al*., 1989, 1993), Europe (Moreno *et al*., 2003), high latitude regions of the Northern Hemisphere (Stephenson *et al*., 2000), New Zealand (Stephenson, 2003 b), Turkey (Sesli and Denchev, 2005) and Upper Egypt (Abdel-Raheem, 2002). Although several studies have taken place in tropical regions, including Costa Rica (Schnittler and Stephenson, 2000), Puerto Rico (Novozhilov *et al*., 2001), and Mexico (Lado *et al*., 2003), the tropics as a whole have received relatively less attention. As a result, our understanding of the taxonomy and ecology of the assemblages of myxomycetes that occur in the tropics is still incomplete.

Table 2. List of number of myxomycetes reported in the recent publications (2000-2005).

Locality	Author and year	Sources of myxomycetes	No of species
Costa Rica	Schnittler and Stephenson, 2000	Field collection and moist chamber of bark surface of living trees and leafy litter	60
Western Oregon	Ukkola Tarja and Rikkinen, 2000	Field collection and moist chamber of wood and bark	77
Twelve high latitude regions of the Northern Hemisphere	Stephenson, Novozhilov and Schnittler, 2000	Field collection and moist chamber of wood, bark of living trees, litter and dung	150
Puerto Rico	Novozhilov *et al*., 2001	Field collections	44
The Mexican state of Sonora	Pérez-Silva *et al*., 2001	Field and moist chamber collection	17
The Great Smoky Mountains National Park	Stephenson *et al*., 2001	Field and moist chamber culture collections	92
Upper Egypt	Abdel-Raheem, 2001	Field collection and moist chamber of wood, bark of living and dead trees, and leafy litter	20
Tyrol (Austria)	Singer *et al*., 2001	Field collection and moist chamber of substrate of melting snow banks in mountainous and alpine areas	25
Boheian Karst and Hřebeny Mts (Czech Reublic)	Dvořáková, 2002	Field collection and moist chamber of bark of living trees, twigs, and dead leaves	95
Two tropical forest reserves in Mexico	Lado *et al*., 2002	Field collection and moist chamber of bark of living trees, fallen wood; decaying stems of woody lianas at a height of 1.5-2.5; leafy litter, grass litter, aerial litter of cactus herbaceous plant part, , and palm; epiphyllic liverworts	99

Table2. (Cont'd)

Locality	Author and year	Sources of myxomycetes	No of species
Chihuahua, Mexico	Lizárraga *et al*., 2002	Field and moist chamber collections	62
The State of Bahia, Brazil	Góes-Neto *et al*., 2002	Including a historical review and field surveys	63
8 localities from Costa Rica, Ecuador, and Puerto Rico	Schnittler and Stephenson, 2002	Field collection and moist chamber of inflorescences of herbs	31
The Sierra Nevada National Park (Spain)	Moreno *et al*., 2003	Nivicolous substrate	16
Argentina	Crespo *et al*., 2003	Revision	167
A Maquipucuna cloud forest reserve in Ecuador	Stephenson, Schnittler, and Lado, 2004	Field collection and moist chamber of wood, litter and inflorescence	77
Changbai mountains of northeastern China	Yang *et al.,* 2004	Field and moist chamber collections	210
The lowland of northern Quintana Roo, Mexico	Schnittler and Stephenson, 2004	Field collection and moist chamber of coarse woody debris, bark surface of living trees, forest floor litter, and aerial litter	74
Cuba	Camino *et al*., 2005	Revision	83
the Western Black Sea region of Turkey	Ergul *et al*., 2005	Field and moist chamber collections	78
Ecuador	McHugh and Roland, 2005	Field collection and moist chamber of bark	61
Mezit Stream Valley of Turkey	Ergul *et al*., 2005	Field and moist chamber collections	36

Our understanding of myxomycete populations associated with agricultural areas in temperature and tropical regions is limited as compared with natural habitats. There have been investigations concerning the density of myxomycete populations in non- woodland soils (Feest and Madelin, 1988) and in the root zones of cabbage and broad beans (Amewowor and Madelin, 1991) in temperature regions. These studies however, were based on the plasmodium- forming units (PFUs), and as the plasmodium is the vegetative stage, they exist for short periods and numbers are

changeable (Alexopoulos *et al*., 1996). The nature of the PFUs has not been definitely resolved but they are probably myxamoebae, myxoflagellates and microcysts and do not represent the number of species (Amewowor and Madelin, 1991). As a consequence, the understanding of myxomycetes of agricultural systems in temperate regions is limited. In the tropics, there appears to be no previous studies that have considered myxomycetes associated with agricultural areas.

Study on the ecology and biodiversity of myxomycetes in Asia and Thailand

There have been few studies concerning myxomycetes in Asia, with the exception of China (Teng, 1996; Li, 2002), Hong Kong (Chung 1996, 1997), India (Stephenson *et al*., 1993), Israel (Nissan, 1997) and Taiwan (Chung and Liu, 1996) where there have been a small number of reports on myxomycetes. The research however, only concentrated on the assemblages of myxomycetes in certain regions within each country, and no checklist is available for the whole country.

Little is known concerning the myxomycetes of Thailand. The first records of myxomycetes from Thailand were made by Rostrup (1902) who listed *Lycogala epidendrum* and *Stemonitis fusca* from the Koh Chang area. Heim (1962) noted that myxomycetes of Thailand were abundant but gave no details. Reynolds and Alexopoulos (1971) reported 42 species collect from localities in south Thailand (one of them is undeterminable). The latest study on myxomycetes of Thailand was that of Siwasin. Thirty-four species were reported, mostly from northern Thailand (Siwasin and Ing, 1982) of which sixteen were new record for Thailand. Therefore, total 59 species of myxomycetes of Thailand were reported.

Table 3. List of myxomycetes species of Thailand reported by Rostrup, 1902; Reynolds and Alexopoulos, 1971; Siwasin and Ing, 1982.

Arcyria cinerea (Bull.) Pers.
A. denudata (L.) Wettst.
A. insignis Kalch. and Cooke.
A. magna Rex.
A. oerstedtii Rost
Ceratiomyxa fruticulosa (O.F. Müll.) T. Macbr
Clastoderma debaryanum Blytt.
Collaria arcyrionema (Rost.) Nann.-Berm.
Comatricha elegans (Racib.) G. Lister
C. laxa Rostaf.
C. longa Peck.
C. tenerrima (M.A. Curtis) G. Lister
C. typhoides (Bull.) Rost.
Cribraria cancellata (Batsch) Nann.-Berm.
Cr. languescens Rex
Cr. microcarpa (Schrad.) Pers.
Cr. rufa (Roth) Rost
Cr. violacea Rex.
Diachea leucopodia (Bull) Rost
D. radiate Lister and Petch.
Diderma radiatum (L.) Morg
Didymium bahiense Gottsb.
D. clavus (Alb. and Schwein.) Racib.
D. iridis (Ditmar) Fries.
D. nigripes (Link) Fr.

Table 3. (Cont'd)

D. squamulosum (Alb. & Schw.) Fr.
Echinostelium minutum de Bary.
Erionema aureum Penzig.
Fuligo septica (L.) F.H. Wigg.
Hemitrichia calyculata (Speg.) Farr.
H. serpula (Scop.) Rostaf. ex Lister
H. stipitata (Massee) Macbr.
Lamproderma scintillans (Berk and Broome) Morgan
Licea biforis Morgan
L. erecta Thind and Dillton.
Lycogala epidendrum (L.) Fr.
L. exiguum Morgan
Perichaena chrysoperma (Curr.) Lister
Physarella oblonga (Berk. & Curt.) Morg.
Physarina echinocephala von Höhnel
Physarum compressum Alb. and Schwein
Ph. flavicomum Berk.
Ph. melleum (Berk. & Br.) Massee
Ph. nucleatum Rex.
Ph. nutans Pers.
Ph. pezizoideum (Jungh.) Pav. & Lag
Ph. oblatum Macbr.
Ph. rigridum G. Lister.
Ph. stellatum (Massee) Martin.
Ph. tenerum Rex.
Ph. viride (Bull.) Pers.
Stemonitis fusca Roth.
S. herbatica Peck.
S. smithii Macbr.
S. splendens Rost.
Stemonitopsis gracilis (G. List.) Nann.-Brem
Trichia affinis de Bary
T. verrucosa Berk
Tubifera microsperma (Berk. & Curt.) Martin

The existing problems in myxomycete diversity study

Unlike some other organisms, there is little known concerning the genetic diversity of myxomycetes (Cavalier-Smith, 1993). The diversity and taxonomy of myxomycetes have been entirely determined through morphological identification. The phylogenetic relationships among the Orders, or among the families, or genera; and between myxomycetes with the other two groups of slime molds (dictyostelids and protostelids) are not yet known yet (Stephenson, 2003b; Matín *et al*., 2003).

The classification of myxomycetes is based almost entirely upon the characteristics of the fruiting stage. Even though this is relatively constant, and readily observable, inherent genetic and environmental variations may sometimes create difficulties in preparing precise morphological descriptions (Clark *et al*., 2003). In addition, unlike other eukaryotic microorganisms, myxomycetes have a relatively limited morphological number of traits; geological distribution and frequent asexuality can make species definitions especially difficult (Clark, 1995). Different subpopulations of a morphospecies can be genetically isolated apomictic clones, incompatible sibling species, or part of a single panmictic species (Clark, 1995; Clark and Haskins, 1998). Therefore, when using morphological characteristic only it may be difficult to avoid making overlap in species identifications.

MATERIALS AND METHODS

Materials

The general geographical features of Thailand

Thailand is located in the Southeast Asia from 6 to 20^0 N latitudes, elevation ranges from sea level to 2565 m. The lowest point is Gulf of Thailand 0 m, and the highest point: Doi Inthanon 2,576 m. The total country's area is 513. 115 km^2, of this about 136.698 km^2 is forest (RFD, 1992)

Climate of Thailand is various at the different regions, ranging from humid tropics to alpine and/or subtropical forms (Gardner *et al*., 2000)

Situated at the junction, Thailand has three main floristic types, named Indo – Burmese (the northern, northwestern, and western parts), Indo – Chinese (the northeast part), and the Malaysian (the southern and eastern parts of the). Therefore, Thailand is considered as one of the most bio - richness countries in the world (RFD, 1992)

Climate of northern Thailand

In northern Thailand, there are two distinct seasons each year, a dry season that extends from November to May and a rainy season that begins in June and lasts until October (Table 4). The dry season can be divided further into a cool/dry period (October to February) and a hot/dry period (March to April). Annual precipitation ranges from 1100 to 1500 mm, but the months of December, January and February are virtually without rain (Gardner *et al*., 2002). The average annual temperature is 26.2^{o}C. In the rainy season, temperatures in the lowlands are around 32^{o}C in the mid-afternoon and drop to around 23^{o}C at night. From June until the first two weeks of July, it rains on most days, although rarely continuously. On a typical day, it is often bright and sunny in the morning, but in the afternoon clouds build up, and then a

heavy rain occurs for one or two hours. Clear conditions return in the evening. From the last two weeks of July until September, rains rarely occur but are heavy and continuous when they do. In the cool period, the temperature is above 28^{o}C during the afternoon, but following sunset the temperature drops rapidly, frequently to below 10^{o}C, so that early mornings are quite cool and misty. The sky is generally cloudless all day, and rain is very rare, perhaps only one time each month, and then light. In the hot period, daytime temperatures approach 40^{o}C, and humidity increases.

Table 4. Average temperatures, humidity and rainfall throughout northern Thailand (Gardner *et al*., 2000)

	DRY - HOT			**RAINY**					**DRY - COOL**				
	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	ANNUAL
Average Temperature (o 'C)	27.4	29.4	29.1	28.1	28.0	28.3	27.6	23.6	23.0	22.5	22.0	25.6	26.2
Mean Max. Temperature (o' C)	38.5	38.4	36.2	34.0	33.6	34.2	33.0	33.2	31.9	32.0	32.9	36.2	34.5
Mean Min. Temperature (o' C)	16.3	20.5	22.0	22.3	22.4	22.4	22.3	14.0	14.2	13.0	11.2	15.1	17.9
Rainfall in (cm.)	18.2	2.3	20.0	12.9	14.6	33.3	25.8	7.5	4.8	4.8	-		144.2
Mean Max. Relative Humidity (%)	32.0	35.5	32.8	31.4	31.0	29.7	31.3	30.8	30.2	28.8	31.3	34.0	31.5
Mean Min. Relative Humidity (%)	20.0	22.9	23.6	23.8	23.5	23.2	23.1	20.5	17.6	16.6	15.0	17.1	20.3

Study area for monitoring myxomycetes in the field

Mush Room Research Center Forest

This study was carried out in the general vicinity of the Mushroom Research Centre (19° 07.123' N, 98° 44.009' E), which is located about 70 km from the city of Chiang Mai in northern Thailand. The forests surrounding the Centre are representative of the mid-elevation (ca 900 m) tropical forests that occur throughout the entire region, and some of the more common genera of trees are *Cinnmomum*, *Dipterocarpus*, *Lithorcapus* and *Macaranga* (Gardner *et al*., 2000)

Study plots

Five study plots, each measuring 10 by 10 m (100 m^2), were established (Fig.3). Each of the plots was placed in a different ecological setting, based on the presence of different kinds of trees and/or substrates potentially available to myxomycetes. Plot 1 was in an area with a large amount of decaying wood present, plot 2 was in an area with an abandoned fence, plot 3 was in an area dominated by *Macaranga denticulate*, plot 4 was in an area dominated by *Cinnmomum iners*, and plot 5 was in an area dominated by *Dipterocarpus* sp. In plots 3, 4 and 5, the leaves from the dominant trees present made up the litter layer on the forest floor

Figure 2. Plots and leafy litter: A. Plot 1. The decaying wood; B. Plot 2. The abandoned fence; C. Plot 3. The surrounding of *Macaranga denticulate* tree**;** D. Plot 4. Leafy litter of *Cinnmomum iners* tree; E. Plot 5- Leaf litter of *Dipterocarpus* sp

Study Sites for the research on seasonal affection on the assemblages of myxomycetes

Study sites were established in three types of tropical forests and three types of agricultural areas in Papae and Doi Inthanon of Chiang Mai, Thailand. Each of these is described below. Classification of forest types follows Gardner *et al.* (2000)

Lowland Forest (Mae Sae King Project forest; KP)

This study site (4.128° N, 98°43.493' E) is located at an elevation of 733 m. Common emergent trees include members of the Leguminosae, Dipterocarpaceae and Anacardiaceae; bamboo is present in the understory. Gardner *et al.* (2000)

Mid-elevation Forest (Mae Sae forest; MS)

This study site **(**19°14.599' N, 98°38.456' E) is located at an elevation of 962 m. Mae Sae is considered to be a mixed forest type that contains both lowland and highland tree species. Among the dominant trees are *Dipterocarpus costatus*, *D. turbinatus* (Dipterocarpaceae), *Balakata baccata* (Euphorbiaceae), *Nyssa javanica* (Cornaceae), *Irvingia malayana* (Irvingiaceae) and *Pinus merkasii* (Pinaceae). As is the case for the lowland forest, bamboo is present in the understory. Gardner *et al.* (2000)

Highland Forest (Doi Inthanon forest; DI)

This study site (18° 31.58' N, 98° 29.64' E) is located at an elevation of 1703 m. This is a typical highland forest of the type that occurs throughout northern Thailand, and almost 100% of the trees are evergreen. Overall diversity of tree species is slightly less than found at lower elevations but still considerably higher than is the case for dry forests. *Pinus* spp, *Lithocarpus echinops* and representatives of the families Lauraceae, Magnoliaceae, and Theaceae are common. The shrub layer consists largely of *Pandanus* (Pandanaceae), *Arecatriandra* spp and *Pinnanga sylvestris* (Palmae). (Gardner *et al*., 2000)

Figure 3. Northern route map of Thailand and the two study regions, Papae and Doi Inthanon (pointed with the arrows) (thaiwaysmagazine.com, 2006)

Banana (Musa) Plantation

This site (19° 07.448’ N, 98° 46.490’ E) is located at an elevation of 538 m. This site had not been subjected to applications of pesticide and insecticide, and the only fertilizer came from animal dung.

Mango (Mangifera) Orchard

This site (19° 06.872’ N, 98° 46.732’ E) is located at an elevation of 650 m. Chemical fertilizers were applied and the site was subjected to removal of plant material. Chemicals are applied to promote fruiting in the mango trees when necessary. When the project began, commercial trees in the orchard were mature. All collecting for the two seasons was carried out after the mangoes had been harvested. There was however, a major difference in the ground cover between the two seasons. During the dry season, the ground was mostly bare, exposed to direct sunlight and very dry, but during the rainy season, it was mostly covered by grass and small climbing woody plants.

Sweet corn (Maize) farm

This site (19° 07. 012’ N, 98° 44 069’ E) is located at an elevation of 550 m. This field produces three crops per year, the first occurring from mid-February to June, the second from mid-June to mid-October and the third from mid-October to mid-January. Pesticide, fertilizer, and insecticides are applied as considered necessary. The litter on the ground consisted almost entirely of leaves and stems of dead maize plants, with parts of corn ears and old inflorescences much less common**.**

Figure 4. Agricultural ground litter

Figure 5. Forest floor litter

Methods

Field collection

Each study site was visited at regular intervals for a period of one year (October 2004 to October 2005).

In the field, collected specimens were wrapped gently in foil paper before being transported to the laboratory. A "specimen" was defined as one or more fruiting bodies sharing the same substrate and considered to have originated from a single plasmodium. In almost every instance, this could be determined without difficulty. The method used in collecting a specimen involved removing all or most of the fruiting bodies along with a portion of the substrate upon which they occurred

Moist chamber collection

Fruiting bodies of some myxomycetes especially of those associated with litter and bark of trees are so small or rare that they can be difficult to locate or easy to be overlooked on the field. Moist chamber technique is a laboratory method to increase detection.

In addition to the field collections, samples of forest floor litter or agricultural ground litter were collected in the various study sites and used to prepare a series of moist chamber cultures in the manner described by Stephenson and Stempen (1994). Thirty moist chambers were prepared for each study site for each season (this means, from each study site of the agricultural and forest areas, there were 60 moist chambers made). These were maintained for a period of three months, and samples were checked twice per week

Figure 6. Fruiting bodies of *Physarum roseum* developed on moist chamber

Myxomycete identification and nomenclature

Myxomycete identification was based upon overall morphological characteristics of the fruiting bodies (Martin, 1983; Lado, 2001; Stephenson, 2003b). Spore size was measured under a 100X oil immersion objective; the ornamental portion of spore was not included in these measurements. Acetic acid was used to test for the presence of lime (calcium carbonate).

Except for *Stemonitis nigrescens*, which we consider to be a distinct species and not just a variety of *Stemonitis fusca*, the nomenclature used herein follows Lado (2001) and Hernández-Crespo and Lado (2005), with the conserved names of several genera (Lado *et al*., 2005) approved recently by the Committee for Fungi (Gams, 2005) of the IAPT (International Association for Plant Taxonomy)

Myxomycete storage

Specimens were air-dried and glued in small boxes for permanent storage or if fruiting bodies of myxomycetes appearing on the Petri-dish wall or lid of the moist-chambers, they were left in place and the Petri dish was sealed by using parafilm to prevent the specimen from getting moist.

The following information was marked on the herbarium specimens: the species name, the substrate, the locality name, the collection date, the collector's name and the collection number, and the name of the person who identified the specimens if not the same with the collector (Stephenson and Stempen, 1994)

All specimens were deposited in the herbarium of the Mushroom Research Center, 128 Moo 3, Bahn Pha Deng, T. Pa Pae, A. Mae Taeng Chiang Mai 50150, Thailand.

Data analysis

The mean number of species per genus (S/G) was calculated from the data sets obtained for each of the areas. Consequently, a low value for S/G implies a higher overall taxonomic diversity than a high value (Stephenson *et al*., 1993)

Abundance indices were assigned to all of the species represented among the collections from a particular plot in the manner described by Stephenson *et al*. (1993). Indices were here were "Rare" (for species represented by <0.5% of the total number of collections), "Occasional" (species represented by >0.5% but <1.5%). "Common" (species represented by >1.5% but <3%), and "Abundant" (species represented by >3%).

With a number of zero values of fruiting bodies recorded, the data compiled on the occurrence of myxomycete fruitings in the five study plots are obviously non-

parametric (the data are not normally distributed). The analysis of these data were carried out by a non-parametric test, named Friedman, and run with the SPSS program (Field, 2000) to compare mean rank positions of the numbers of species recorded for each month.

RESULTS AND DISCUSSION

Fruiting phenology

Field collections made from the five plots in the Mushroom Research Center during the period of October 2004 to October 2005 yielded a total of 62 species of myxomycetes representing 18 genera (Table 5). All of the materials collected had fruited in the field under natural conditions. Data on the number of species collected from each plot and the total number of species recorded for each month are given in Table 6. The rank positions of the monthly totals based on the number of species of myxomycetes collected from all five plots in each month are given in Table 7.

Table 5. Species of myxomycetes recorded from the five plots from October 2004 to October 2005.

Species	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5
Arcyria cinerea (Bull.) Pers.	C	C	C	C	A
A. denudata (L.) Wettst.	O	O	-	-	C
A. globosa Schwein.	-	-	C	-	-
Badhamia cf. melanospora Speg.	-	-	-	-	R
Ceratiomyxa fruticulosa (O.F. Müll.) T. Macbr.	C	-	O	O	C
Collaria arcyrionema (Rostaf.) Nann.-Bremek. ex Lado	O	-	O	-	O
Comatricha elegans (Racib.) G. Lister.	-	-	O	-	-
C. laxa Rostaf.	-	-	O	-	O
C. nigra (Pers. ex J.F. Gmel.) J. Schröt.	-	-	O	O	-
C. pulchella (C. Bab.) Rostaf.	-	-	-	-	O
Craterium aureum (Schumach.) Rostaf.	-	-	O	-	-
C. concinnum Rex	-	-	C	-	-
C. leucocephalum (Pers. ex J.F. Gmel.) Ditmar	-	-	O	-	O
C. minutum (Leers) Fr.	-	-	O	A	C
Cribraria aurantiaca Schrad.	C	-	-	-	-
C. cancellata (Batsch) Nann.–Bremek.	R	-	-	-	-
C. microcarpa (Schrad.) Pers.	C	-	-	-	-
C. tenella Schrad.	-	-	R	-	-
C. violacea Rex	-	-	R	-	-
Diachea bulbillosa (Berk. & Broome) Lister.	-	-	O	-	R

Table 5. (Cont'd)

Species	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5
D. leucopodia (Bull.) Rostaf.	-	-	R	R	O
D. splendens Peck	-	-	O	-	O
D. sp. A	-	-	-	-	R
Diderma effusum (Schwein) Morgan	-	-	R	-	R
D. hemisphaericum (Bull.) Hornem.	-	-	O	O	C
D. rugosum (Rex) T. Macbr.	-	-	R	-	-
Didymium clavus (Alb. & Schwein.) Rab	-	-	O	O	O
D. iridis (Ditmar) Fr.	-	-	C	O	C
D. minus (Lister) Morgan	-	-	C	C	C
D. nigripes (Link) Fr.	-		A	O	A
D. squamulosum (Alb. & Schwein.) Fr.	-	-	C	-	C
Fuligo septica (L.) F.H. Wigg.	O	-	-	-	-
Hemitrichia calyculata (Speg.) M.L. Farr	R	R	-	-	-
H. serpula (Scop.) Rostaf. ex Lister	R	-	O	O	O
Lamproderma scintillans (Berk. & Broome) Morgan	O	-	C	-	C
L. sp. A	-	-	-	-	R
Licea erecta var. *erectoides* (Nann.-Bremek. & Y.Yamam.) Y. Yamam.	-	R	-	-	-
Lycogala epidendrum (L.) Fr.	A	-	-	-	-
L. exiguum Morgan	O		-	-	-
Physarella oblonga (Ber. & M.A. Curtis) Morgan	-	-	-	-	R
Physarum album (Bull.) Chevall.	C	O	-	-	-
Ph. bivalve Pers.	-	-	-	-	O
Ph. bogoriense Racib.	-	-	-	-	O
Ph. cinereum (Batsch) Pers.	-	-	R	-	A
Ph. compressum Alb. & Schwein.	-	-	-	-	C
Ph. cf. *flavicomum* Berk.	-	-	-	-	R
Ph. cf. *galbeum* Wingate	-	-	-	-	R
Ph. globuliferum (Bull.) Pers.	-	-	-	-	O
Ph. hongkongense Chao H. Chung.	-	-	-	-	O
Ph. cf. lateritium(Berk. & Ravenel) Morgan	-	-	-	-	R
Ph. melleum (Berk. & Broome) Massee	-	O	O	C	C
Ph. penetrale Rex	-	-	-	-	O
Ph. pusillum (Berk. & M.A. Curtis) G. Lister	-	-	R	-	C
Ph. serpula Morgan	-	-	-	-	O
Ph. roseum Berk. & Broome	-	C	-	-	-
Ph. viride (Bull.) Pers.	-	C	-	-	-
Ph. sp. A	-	-	-	-	O
Ph. sp. B	-	-	-	-	O
Stemonitis axifera (Bull.) T. Macbr.	C	-	-	-	-

Table 5 (Cont'd)

Species	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5
S. fusca Roth	C	-	-	-	-
S. nigrescens Rex	C	-	-	-	-
S. cf. *virginiensis* Rex	O	-	-	-	-

Note: A: Abundant; C: Common; O: Occasional and R: Rare

Table 6. Number of species of myxomycetes collected from each plot in each month from October 2004 to October 2005

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Plot 1	0	0	0	0	2	10	7	4	3	2	1	0
Plot 2	0	0	0	0	1	9	8	3	1	0	0	0
Plot 3	0	0	0	0	2	14	11	4	10	4	1	0
Plot 4	0	0	0	0	2	7	6	2	1	1	0	0
Plot 5	0	0	0	0	2	35	20	3	1	1	0	0
Total	0	0	0	0	2	45	33	7	12	4	1	0

December, January, February, March and April have the lowest (and same) rank position because no myxomycetes were collected during these months. June had the highest total number of species (45), and in June each plot also was characterized by the highest total (when compared with the same plot in the other months). Remarkably, 35 species were collected from plot 5 alone in June. In July, both the total number of species and number of species collected from each plot were still quite high, with a total 33 species collected during the month.

From August onwards, the number of species appearing as fruitings in the field decreased, even though the total number of species collected in September (12) was higher than the total recorded for August (7). In terms of mean rank position,

September was lower than August because the distribution of numbers of species in each plot was not equal. A single plot (plot 3) produced a relatively high number of species, but the totals recorded for the other plots were much lower in comparison with the corresponding plots in August.

Table 7. Rank positions of the numbers of species of myxomycetes collected in each month from the five plots.

Months	**Mean Rank**	**Months**	**Mean Rank**
January	3.40	July	11.00
February	3.40	August	9.60
March	3.40	September	8.50
April	3.40	October	7.00
May	8.30	November	4.60
June	12.00	December	3.40

During the period of December to April, there were no records of either fruiting bodies of myxomycetes or any evidence (e.g., slime tracks) of plasmodia in any of the plots. Presumably, this was because the period was very dry and sunny, with almost no rain. Myxomycete spores require favorable conditions of moisture and temperature for germination, and even if by chance spores were exposed to enough water to germinate, any amoeboid cells and plasmodia that might result would not remain active under such harsh conditions. Instead, it is likely that they would survive as one of the resistant structures (e.g., microcysts or macrocysts) produced by myxomycetes.

Two species (*Arcyria cinerea* and *Ceratiomyxa fruticulosa*) were collected in May, but these fruitings did not appear until the very last week of May. As soon as the rains began, the two species were present in all of the study plots except for plot 2. However, fruitings were relatively small. It seems likely that the amount of rainfall received in May was not sufficient to permit the growth and development of most myxomycetes

In June, when rainy and sunny periods alternated daily (Gardner *et al*., 2000), spore germination should have been stimulated. Moreover, the other microorganisms upon which myxomycetes feed would be expected to flourish under such conditions. This combination of factors probably explains why fruitings collected during this period of time often were quite large. Common species during June were *Arcyria cinerea, Ceratiomyxa fruticulosa Didymium iridis*, *D. minus*, *D. squamulosum*, *D. clavus*, *D. nigripes*, *Diachea splendens*¸ *Dia. leucopodia*, *Diderma hemisphaericum, Lycogala epidendrum*, *Physarum melleum*, and *Ph. pusillum*.

In July, numbers of fruitings of myxomycetes were lower than in June. Moreover, the majority of collections were made during the two first weeks of July. Common species of myxomycetes during the the month were *Craterium aureum*, *C. leucocephalum*, *C. minutum*, *Diachea bulbillosa*, *Lamproderma arcyrionema*, *L. scintillans, Stemonitis axifera, S. fusca* and *S. nigrescens.*

From mid-July until September, the rain did not occur almost everyday, as had been the case in June; rains became rarer but sometimes were heavy and continuous, so the forest floor was generally either very dry or very wet. The number of species collected decreased considerably. In August, numbers of records and species were remarkably lower in every plot. For example, only three species were collected in plot 5, whereas the total recorded for July was 20. All of the species collected during August also were recorded in June and July. A few species, including *Arcyria cinerea* and *Stemonitis nigrescens,* seemed especially prominent in this period.

In September, the only species recorded in plot 1 were *Arcyria cinerea*, *Cribraria aurantiaca* and *Cribraria microcarpa*, and only *Arcyria cinerea* was present in plots 2, 4 and 5. However, a number of other species were collected in plot 3, where they occurred on the litter from *Macaranga denticulate*. However, except for *Craterium concinnum*, all of these species also were recorded in June. The most common species during September were *Arcyria globosa*, *Craterium concinnum*, *Cribraria aurantiaca*, *Cribraria microcarpa*, and *Hemitrichia serpula.* The reasons for the greater number of myxomycete species appearing in plot 3 during this month

possibly can be attributed to the presence of a layer of grass on the ground and the timing of leaf fall for *Macaranga denticulate*. From the end of August onwards, a thick cover of dead leaves from *M. denticulate* was present in this plot, and the combination of the two types of plant debris may have provided for a more favorable microclimate (e.g., higher levels of moisture) than was the case for the other plots, where the ground cover was less apparent.

October was sunny and cold, with almost no rain. The forest floor appeared totally dry. Only a few species such as *Cribraria aurantiaca* and *C. microcarpa* were recorded, and these were associated with the decayed wood in plot 1. The apparent fruiting season for myxomycetes ended in November, and no fresh fruitings were observed for almost half a year. This same pattern was noted in another study carried out during the same period of time as the present study. In this second study, in which the occurrence of myxomycetes in northern Thailand was investigated in six study sites (three in forests and three in agricultural areas), only three species were collected from the field during the dry season (all in May), but 52 species were collected during the rainy season. However, the number of species obtained from moist chamber cultures prepared with samples collected in the dry season was much higher (47) when compared with the total (16) from the rainy season. As a result, the total number of species recorded for the dry season (48) was not appreciably lower than the total (59) recorded for the rainy season. These data provide additional evidence that any effort to assess the total biodiversity of myxomycetes in a particular locality should include both field collections and collections obtained with the use of the moist chamber culture technique, as has been recommended in a number of recent studies (e.g., Stephenson *et al*., 2004 a, b).

Studies that have involved direct observation of myxomycetes in the field over a period of time have been limited almost exclusively to temperate regions of the world. In perhaps the most intensive of these studies, Stephenson (1988) carried out a comparative study of five study areas in a mountainous region of eastern North America. Collections and observations made over a period of five years indicated that myxomycetes displayed seasonal patterns of absolute abundance, species richness and

species diversity. All three measures were low early in the field season (May), but increased to their highest levels in late summer (August) and then declined throughout the remainder of the season (September and October). Allowing for the major differences in climate (temperate versus tropical), the pattern observed by Stephenson in this earlier study is not unlike the pattern noted in the present study. Other field-based ecological studies of myxomycetes that have extended over a period of more than just a few days or weeks include those by Maimoni-Rodella and Gottsberger (1980) and Eliasson (1981). The former study involved a comparison of the myxomycetes occurring in two different tropical vegetation types (an evergreen forest and a semideciduous xeromorphic woodland) in Brazil. In the latter study, patterns of occurrence of selected species of myxomycetes were investigated in a spruce forest in Sweden. The vegetation types considered in these two studies are very different from those examined in the present study, but the results were similar in that both the assemblages of species present and their relative abundance were found to vary from one place to another, on different substrates and in different times of the year.

Most of the published information relating to the total number of species of myxomycetes associated with tropical forests at a particular locality has been derived from studies carried out in the Neotropics of Central and South America. We are not aware of any previous study in Southeast Asia; although Stephenson *et al*. (1993) included data from southern India in a comparative biogeographically study of myxomycetes in the mid-Appalachians of eastern North America and two regions of India. The data set from southern India was compiled over a period of several years and most of the collections were made in parks, coffee plantations, and in wooded areas surrounding towns and villages rather than in forests. However, the climate of southern India is fairly comparable to that of northern Thailand, although there are two definite rainy seasons and not just one as is the case in Thailand. In southern India, at least some fruitings of myxomycetes can be collected throughout the entire year. As the data presented herein indicate, this is different from the situation in northern Thailand. The total number of species reported from southern India (99) was higher than what we recorded. For the Neotropics, Lado *et al*. (2003) reported 76 species for a study area (El Eden) in the Yucatan Peninsula of Mexico and 63 species

for a tropical forest reserve (Los Tuxtlas) in Veracruz, Mexico. Schnittler *et al*. (2002) listed a total of 77 species from three cloud forest study sites in Ecuador. However, all three of these totals were based on results obtained from field collecting as well as collections from moist chamber cultures. When only field collections have been considered, the totals tend to be much lower, and Novozhilov *et al*. (2001) reported just 44 species from a survey carried out in Puerto Rico. As such, the total (62) recorded in the present study, which was based only on field collections, is lower than the total reported for southern India but as high or even higher than those known for other tropical forests in which comparable studies have been carried out.

Substrate relationships

An examination of the data in Table 6 reveals that more than half (39/62) of the species of myxomycetes collected were recorded from plot 5 (which was dominated by *Dipterocarpus* sp.) and almost a half (29/62) were recorded from plot 3 (dominated by *Macaranga denticulate*). This suggests that the litter derived from these two trees is an especially favorable substrate for myxomycetes. However, the S/G value (Table 8) calculated for plot 5 was also higher than for any other plot, so overall biodiversity in plot 5 was low, with relatively fewer genera contributing to the present species. Some of the more common species for this plot were *Diderma hemisphaericum, Didymium clavus*, *D. iridis*, *D. minus*, *D. nigripes*, *D. squamulosum Physarum melleum* and *Ph. pusillum*.

As, diversity depends on the number of species at a particular place, and the distribution of these species in genera, and family. The larger number of genera and families for a given number of species, the greater the diversity, since the species in the same higher taxon (genera and family) are more similar than species in different taxa. Consequently, a low value for S/G implies a higher overall taxonomic diversity than a high value.

With an S/G value of 2.42, the assemblage of myxomycetes associated with plot 3 was more diverse than the assemblage recorded for plot 5 but was not as low as

plots 1, 2 and 4. The occurrence of myxomycetes in plot 3 differed from that of the other plots. In plots 1, 2, 4 and 5, the numbers of species were highest in June and then decreased dramatically over the next three months. In contrast, in plot 3 the numbers followed the same pattern in July and August but then become high again in September. Plot 3 had a different ground cover (consisting largely of grasses) than any of the other plots and it is possible this grass layer allowed favorable conditions for myxomycetes when the other plots were either too dry or very wet. A difference in the decomposition rate and nutrient status of the litter (mostly fallen leaves of *Macaranga denticulate*) also may have been a factor. Common species in plot 3 were *Arcyria globosa*, *Craterium concinnum***,** *Comatricha laxa, Didymium nigripes*, *Lamproderma scintillans*, and *Physarum melleum*.

Table 8. Numbers of genera and species of myxomycetes and the value of S/G calculated for each plot for an over period of a year (October 2004-October 2005)

Parameter	**Plot 1**	**Plot 2**	**Plot 3**	**Plot 4**	**Plot 5**
No.of species	18	8	29	12	39
No.of genera	10	4	12	9	14
S/G value	1.80	2.00	2.42	1.33	2.79

Plot 4, in which the ground litter was derived largely from *Cinnmomum iners*, yielded the lowest number of species (only 12). However, in contrast with plot 5, the S/G value calculated for plot 4 was only 1.33, the smallest value for any plot, which indicates that the overall biodiversity was actually highest. *Craterium minutum* and *Physarum melleum* were the most common species in this plot.

The differences noted in the assemblages of species recorded for the three plots (3, 4 and 5) dominated by a single type of tree is a clear indication that the nature of the litter present (e.g., such factors as leaf surface, size, texture, and nutrient status) plays a major role in determining the distribution and occurrence of myxomycetes. Just how these factors come into play is not known, but a leaf with a

rough or pubescent surface (which is the case for *Dipterocarpus* sp. and *Macaranga denticulate*) would appear to have a higher potential for trapping myxomycete spores from the air than a leaf with a smooth surface (Stephenson, 1989). Leaf size is possibly an important influence on loss of moisture from the litter layer, with a layer of overlapping larger leaves retaining more moisture than a similar layer of small leaves. A difference in the rate of decomposition certainly represents a factor that needs to be considered, with thin and soft leaves decaying much faster than their thicker and harder counterparts (Stephenson, unpub. data). The leaves of *Cinnmomum iners* were smaller, smoother and harder than those of both *Dipterocarpus* sp. and *Macaranga denticulate*, and it is interesting to note that the plot (4) in which this tree was dominant supported the fewest species of myxomycetes.

Relatively few studies have examined the ecological associations of particular species of myxomycetes with certain types of substrates, but the limited data available from these studies suggest that the morphological differences that exist between *Dipterocarpus* sp. and *Macaranga denticulate* are of sufficient magnitude to influence distributional relationships of these organisms. For example, in a study carried out in the temperate forests of eastern North America, Stephenson (1989) examined the assemblages of myxomycetes associated with the bark microhabitat of 13 species of trees, found that different trees supported quite different assemblages of myxomycetes. In another study in which the myxomycetes associated with palm fronds were investigated in the forests of northern New Zealand, Stephenson (2003) reported that many of the species commonly collected from palm fronds were encountered rarely or not at all on other substrates in the same locality. Clearly, myxomycetes are not found with equal abundance on all of the substrates potentially available to them.

The assemblage of myxomycetes associated with plot 1 was different from those of the other plots. This plot was not particularly high in term of either the number of species present or overall taxonomic biodiversity, but many of the common myxomycetes recorded from the plot 1 were not found in any other plot. Prominent examples include *Cribraria aurantiaca, C. microcarpa, Fuligo septica, Lycogala*

epidendrum, *L. exiguum, Stemonitis axifera, S. fusca,* and *S.* cf. *virginiensis*. This difference can be attributed, at least in part, to the presence of a large amount of coarse woody debris in this plot, and all of the species listed above are considered to be lignicolous (Martin and Alexopoulos, 1969).

Plot 2 was characterized by the lowest number of myxomycetes, with only eight species being recorded from this plot. However, one of these was *Licea erecta* var. *erectoides***,** which is known from only a few other localities throughout the world (Wrigley de Basanta and Lado, 2005). Our collection is the first from Southeast Asia. Because of the lack of canopy cover, this plot was subject to wide fluctuations in microclimate, which may have attributed, at least in part, to the paucity of fruitings. *Physarum viride* and *Ph. roseum* were two most common species in this plot.

Conclusion on the distribution of myxomycetes in the Mushroom Research Center forest

Based on the data obtained in this study, the distribution of myxomycetes in the forests of northern Thailand is not random. Major differences were noted for both the time of occurrence and the substrates upon which fruitings occur. Myxomycetes were most common during the period of the year (June through early July) during which rainy and sunny periods alternated and overall conditions were neither too wet nor too dry. In the months that followed, numbers of fruitings declined, and from December to April no fruitings were observed. Forest floor litter derived from trees of *Dipterocarpus* sp. and *Macaranga denticulate* appear to be particularly favourable substrates for many different species of myxomycetes. The project described herein also demonstrated the feasibility of monitoring assemblages of myxomycetes directly in the field with the use of a series of plots that represent the different habitats (and combinations of substrate and microclimate) found within a particular region of the world. Moreover, the body of data that we were able to generate from these plots suggests that the plot size (10 by 10 m) used is adequate for assessing differences in species composition and abundance.

Seasonal occurrence of myxomycetes in the six study sites

The ecological distribution and seasonal patterns of occurrence of myxomycetes associated with agricultural ground litter and forest floor litter were investigated in six study sites in northern Thailand during the period of October 2004 to October 2005. Both specimens that developed under natural conditions in the field and specimens obtained in moist chamber cultures were considered. The agricultural study sites were a banana plantation (BN), a mango orchard (MG) and a sweet corn farm (SC), whereas forest study sites consisted of a lowland forest (King Project Forest, KP), a mid-elevation forest (Mae Sae forest, MS) and a highland forest (Doi Inthanon forest, DI)

Field and moist chamber collections from the six study sites produced a total of 85 species of myxomycetes representing 20 genera. Forty-eight of these were recorded during the dry season, and 59 species were recorded during the rainy season. Although the species totals were only slightly different for the two seasons, distinct differences were noted for numbers of positive moist chambers, numbers of both moist chamber and field collections, and (especially) species composition for the six study sites when data obtained for the two seasons were compared (Table 9, 10 and Fig 7).

For the dry season, 129 of the 180 (72%) moist chambers cultures prepared with samples of litter were positive, and these produced 47 species of myxomycetes. Samples collected from the banana plantation were the most productive, both in terms of the number of positive cultures (29/30 or 97%) and the total number of species (24) recorded. Moist chamber cultures prepared with samples of litter from the Doi Inthanon forest were the least productive, with only 10/30 (or 33%) positive cultures and just six species. During the dry season, only three species (*Ceratiomyxa fruticulosa*, *Arcyria cinerea* and *A. denudata*) were collected in the field.

Table 9. Numbers of positives moist chambers, species of myxomycetes collected from moist chambers and species collected in the field for each of the seasons.

Parameter	Dry season	Rainy season
No. Positive moist chamber	129/180	75/180
No. Species recorded from moist chamber cultures	47	16
No. Species recorded as field collections	3	52
Total No. Species (S)	**48**	**59**

Note: Positive moist chamber was defined as the moist chamber that produced fruiting body of any myxomycete species or any evidence of the presence of a myxomycete (i.e., plamodia)

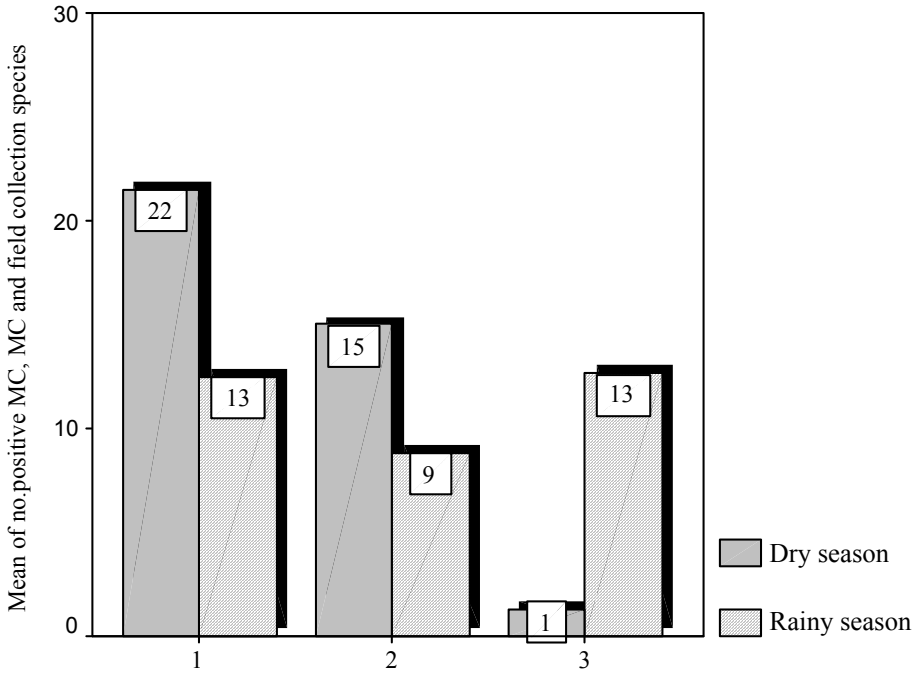
In the rainy season, the numbers of positive moist chambers and species recorded from these moist chamber cultures were appreciably lower. Only 75 of 180 (42 %) moist chamber cultures prepared with litter were positive, and these produced just 16 species. The banana plantation was characterized by the highest number of positive moist chambers (17/30 or 57%), but only 12 species were obtained from these moist chambers. The mango orchard, with 15/30 (50%) positive cultures and 13 species was the most productive study site. The sweet corn farm study site was the least productive in the rainy season, with only 10/30 (33%) positive moist chambers and just four species. However, the number of field collections obtained during the rainy season was much higher than the total obtained during the dry season, and 52 different species were recorded.

Table 10. Numbers of positive moist chambers, species collected from moist chambers and species collected in the field for each study site in each of the two seasons for an over period of a year (October 2004-October 2005)

Season	**Parameter**	**Agricultural site**			**Forest site**		
		BN	MG	SC	DI	KP	MS
Dry (48 species)	No.field collection species	0	0	0	2	3	3
	No.Positive moist chamber/ 30	29	22	23	10	22	23
	No.moist chamber collection species	24	19	8	6	18	15
	Total	**24**	**20**	**9**	**6**	**19**	**20**
Rainy (59 species)	No.Field collection species	2	25	0	11	15	23
	No. Positive moist chamber	17	15	10	5	13	15
	No. moist chamber collection species	12	13	4	5	7	12
	Total	**13**	**29**	**4**	**15**	**20**	**27**

Note: BN: Banana plantation; DI: Doi Inthanon forest; KP: Masae King Project forest; MG: Mango orchard; MS: Mae Sae forest; SC: Sweet corn field.

Some myxomycetes displayed major differences in abundance for the two seasons. For example, *Physarum pusillum* was the single most abundant species recorded from the 30 moist chamber cultures prepared with samples of litter from the banana plantation. During the dry season, *Ph. pusillum* was collected from 27/30 (90%) of these cultures, but during the dry season this species was collected only once from a single culture. This same pattern was apparent for *Ph. cinereum* in moist chamber cultures prepared with litter from the sweet corn farm. During the dry season, this species was recorded from 20/30 (67%) of all cultures, but during the rainy season *Ph. cinereum* was recorded from just two moist chambers.



1. Positive MC, 2. MC collection species, 3. Field collection species

Figure 7. Comparative data on numbers of positive moist chambers, species collected from moist chambers and species collected in the field in each study area for each of the two seasons (October 2004-October 2005)

The general pattern that emerges from a consideration of our data is that virtually all collections of myxomycetes were obtained from moist chamber cultures during the dry season, whereas the majority of collections recorded during the rainy season had developed in the field under natural conditions. This same pattern was evident in another study carried out at the same time as the study reported herein (Tran *et al*., 2006) who examined the fruiting phenology of myxomycetes in five study areas in northern Thailand. Sixty-two myxomycete species were collected from the field during the rainy season, but only two species were collected during the dry season. Myxomycetes require at least some moisture for growth and development, so a low level of abundance during a period when there was little or no precipitation is expected. However, this would not necessarily account for the differences in communities obtained for moist chamber cultures in the two seasons.

Litter samples collected for moist chamber preparation during the rainy season probably have fewer propagules (spores and microcysts) of myxomycetes present. As, spores of myxomycetes are relatively small (with those of the majority of species falling within the size range of 8 to 15 μm), and few of them have spore wall features that enable them to adhere readily to the surface of most substrates with which they come into contact (Alexopoulos *et al*., 1996). Heavy rainfall would seem to have the potential of "flushing away" many of the spores present on such substrates as ground litter (Stephenson, 2003). If this is the case, samples collected in the dry season are likely to have a greater "spore load" than samples collected during the rainy season. During the dry season, dispersal of myxomycete spores by wind could be more effective, since a film of water tends to be present on most surfaces during the rainy season and this would reduce the chances of spores being introduced into the atmosphere (Stephenson, 1993)

In addition, micro environmental conditions within the actual moist chamber cultures also may have represented a factor of some importance. All cultures were maintained in the same laboratory, but humidity was much lower and temperature and light intensity were much higher during the dry season. Moist chamber cultures lose moisture readily when the surround atmosphere is dry (Krug, 2000), and water must to be added periodically to maintain a level of moisture suitable for the growth and development of myxomycetes (Stephenson and Stempen, 1994). This would not be the case when levels of atmospheric moisture are already exceedingly high, which would be the case during the rainy season. In the present study, water had to be added to moist chambers every three days during the dry season but only once every week during the rainy season.

Although the number of species of myxomycetes recorded for the rainy season was slightly higher (a difference of 11 species) than that recorded for the dry season, nine genera (*Craterium*, *Diachea*, *Fuligo*, *Hemitrichia, Lycogala*, *Tubifera*, *Stemonitis, Stemonitopsis* and *Willkommlangea*) were never encountered during the dry season. However, with the exception of *Perichaena* and *Licea*, all genera recorded

during the dry season also were encountered during the rainy season. Overall, the assemblage of myxomycetes associated with the rainy season was characterized by higher levels of both species richness and total biodiversity. The S/G value calculated for the rainy season was 3.28, whereas that calculated for the dry season was 4.36 (Table 11).

Table 11. Values of S/G calculated for the assemblages of myxomycetes recorded for the dry season and the rainy season.

	Dry season	**Rainy season**
No. Species (S)	48	59
No. Genera (G)	11	18
S/G	4.36	3.28

The Physarales contributed the largest number of species to the assemblage of myxomycetes recorded during the present study, whereas only a single member of the Ceratiomyxales was every collected. However, the latter (*Ceratiomyxa fruticulosa*) was exceedingly common. Interestingly, fruitings of *C. fruticulosa* first appeared at the very beginning of the rainy season and the species was relatively common in most study sites during the remainder of the season. For the Physarales, more species (36) were collected during the rainy season than during the dry season (24 species). In contrast, members of the Trichiales were evident during the dry season (15 species) than during the rainy season (five species), (Table 12). This can be attributed to the fact that seven species of *Arcyria* and eight species of *Perichaena* were recorded for the dry season, but only two species of *Arcyria* and no species of *Perichaena* were recorded for the rainy season. The Liceales and Stemonitales followed the opposite pattern of the Trichiales, with more species recorded for the rainy season. Several genera (e.g., *Lycogala* and *Tubifera*) in the Liceales were restricted to the rainy season, primarily because species in these genera appear only rarely in moist chamber cultures. The predominance of member of Physarales in forest floor litter of the tropics has been noted by a number of authors such as Martin (1940); Stephenson *et al*. (1993); Schnittler and Stephenson (2000), the detail data of each regions and

explanations for this phenomenon are presented in the next chapter (Tran *et al*., 2006). However, there is a poor understanding concerning the seasonal dynamics of orders of myxomycetes in the tropics, and only a little is known about that of central European myxomycetes (Dvořáková, 2002). The data of Dvořáková (2002) was derived from only field collection, however, it also shows that the occurrence of myxomycetes is seasonal; for example Physarales and Liceales reached the highest number of records in July, but species of Trichiales appeared to be dominant in September and otherwise fructified in a small numbers during the rest of the year (however, the data was not given in the report). It seems that substrate preference is important in the seasonal occurrences of each myxomycete order (Dvořáková, 2002). In the present study, the xylophilous genera Liceales and Stemonitales appeared, or appeared more often in the rainy season, in contrast Trichiales were less abundant in the rainy season, as large genera of Trichiales occurring on leaves such as *Perichaena* only appeared in the dry season from moist chambers

Table 12. Taxonomic distribution of species of myxomycetes within each genus for the five major orders represented among the collections made during the present study.

Order	**Genus**	**No. Species**	
		Rainy season (59 species)	Dry season (48 species)
Ceratiomyxales	*Ceratiomyxa*	1	1
	Total	**1**	**1**
Liceales	*Cribraria*	4	1
	Licea	0	1
	Lycogala	2	0
	Tubifera	1	0
	Total	**7**	**2**
Physarales	*Craterium*	4	0
	Diachea	3	0
	Diderma	3	2
	Didymium	7	7
	Fuligo	1	0
	Physarum	17	15
	Willkommlangea	1	0
	Total	**36**	**24**
Stemonitales	Collaria	1	1
	Comatricha	4	3
	Lamproderma	1	2
	Stemonitis	3	0
	Stemonitopsis	1	0
	Total	**10**	**6**
Trichiales	*Arcyria*	3	7
	Hemitrichia	2	0
	Perichaena	0	8
	Total	**5**	**15**

Twenty-two of the 85 species were recorded in both seasons, although a particular species tended to be relatively more common in one season. The most abundant species of the dry season (and thus the most abundant species appearing in moist chamber cultures during that season) were *Arcyria cinerea*, *Lamproderma scintillans*, *Cribraria microcarpa*, *Physarum cinereum, Ph. pusillum, Didymium iridis, Didymium minus*, *Lamproderma arcyrionema*, and *Didymium nigripes*. The most abundant species of the rainy season were *Arcyria cinerea, A. denudata,*

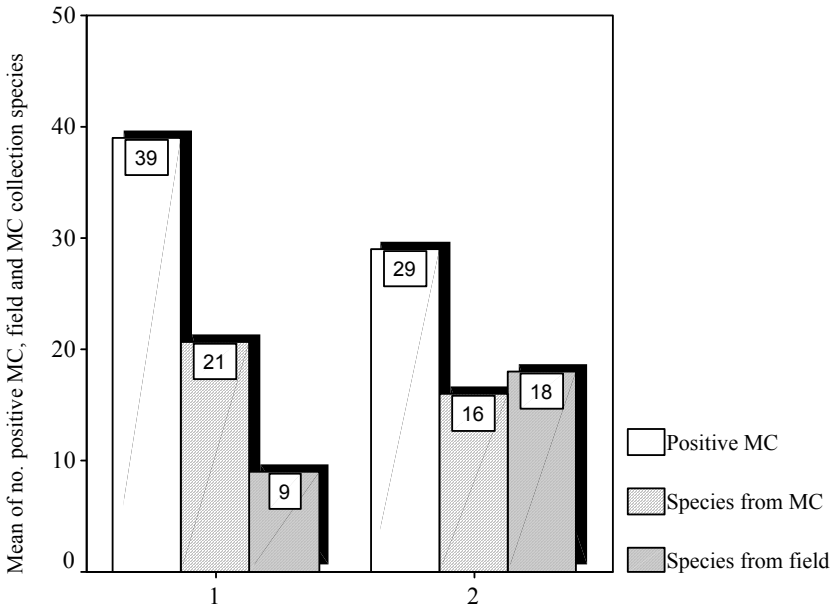
Ceratiomyxa fruticulosa, *Craterium minutum*, *Physarum melleum*, *Hemitrichia serpula, Physarum viride*, *Ph. roseum*, *Didymium squamulosum, D. nigripes*, *D. hemisphaericum*, *Lamproderma arcyrioinema*, *Cribraria violacea,* and *C. microcarpa*. I am not aware about any information on the seasonal occurrence of common species of myxomycetes of any other locality in the world, however (Tran *et al*., 2006) observed myxomycetes directly in the field for a period of year and also recorded the same common species in the rainy season (but not possible for the dry season as only field collection was concerned). However, the concern here is as the common species for different seasons is not much in comparison with the total number (in this study is twenty-two of the total of 85), this suggests that seasonality should be intensively investigated in any study about myxomycete diversity in seasonal regions in the world.

Comparison of the assemblages of myxomycetes associated with agricultural ground and forest floor litter

Sixty-two of the 85 species were recorded from agricultural study sites, and 58 species were recorded from the forest study sites. The total for the former included seven species (one in *Lamproderma*, two in *Perichaena* and four in *Physarum*) that could not be identified completely, while the total for the latter included nine examples (two in *Arcyria* and seven in *Physarum*) for which a complete identification was not possible. Differences in the assemblages of myxomycetes associated with forest floor litter and agricultural ground litter were apparent for numbers of species obtained from moist chamber cultures, numbers of species collected in the field, and numbers of positive moist chamber cultures (Table 13 and 14, Fig. 8).

Table 13. Numbers of positive moist chamber, species obtained from moist chamber and species collected in the field for each of the study sites.

Parameter	**Agricultural sites**			**Forest sites**		
	BN	MG	SC	DI	KP	MS
pH substrate	6.9 – 7.2	7.3 – 7.5	7.5 - 7.6	7.0 – 7.2	7.3 -7.5	7.2 – 7.4
Positive moist chambers	46/60	38/60	33/60	15/60	35/60	37/60
No. Species from moist chambers	30	24	8	11	18	19
No. Field collection species	2	25	0	11	20	23



1. Agricultural site, 2. Forest site

Figure 8. Comparative data on numbers of positive moist chamber cultures, species obtained from moist chambers, and species collected in the field for the two different types of study sites.

Table 14. Numbers of positive moist chamber cultures, species obtained from these cultures, species represented by field collections and totals for the two different types of study sites.

Parameter	Agricultural sites	Forest sites
No. Positive moist chambers	117/180 (65%)	87/180 (48%)
No. Species obtained from moist chambers	48	33
No. Field collections	25	41
Total number of species	**62**	**58**

Table 15. Coefficient of community (CC) values calculated for all pairwise combinations of study sites (upper right portion of table) and numbers of species shared in common (lower left portion of table).

CC	BN	MG	SC	DI	KP	MS
BN	***	0.411	0.205	0.307	**0.537**	0.514
MG	15	***	0.120	0.508	0.462	0.617
SC	4	3	***	0.069	**0.091**	0.127
DI	8	16	1	***	**0.386**	0.466
KP	18	18	2	11	***	0.613
MS	18	25	3	14	2	***

No myxomycetes were collected in the field from the sweet corn farm and only two were recorded from the banana plantation. The mango orchard was relatively more productive, yielding 25 species, all of which were recorded in the rainy season. On average, the totals recorded for the three forest study sites were appreciably higher. Twenty-three species were recorded from Mae Sae forest, 20 from the King Project forest and 15 from the Doi Inthanon forest. Collectively, the three forest study sites yielded a total of 41 species from field collections. In contrast, numbers of positive moist chambers and numbers of species recorded from moist chamber cultures prepared with samples of agricultural litter were much higher

(117/180 or 65% and 48 species) than those prepared with samples of forest floor litter 87/180 or 48% and 33 species).

The low numbers of field collections from the sweet corn farm and the banana plantation could be the result, at least in part, of various agricultural activities (removal of grass, application of herbicides) that made the litter in these sites less variable to which the other study sites were not subjected. However, fundamental differences in substrate quality, as the latter relates to myxomycetes and the bacteria upon which they feed, cannot be discounted. Whatever differences do exist, they were not reflected in the productivity of moist chamber cultures, since those prepared with samples from the agricultural study sites (especially the banana plantation) were more productive than those prepared with forest floor litter. It is possible that spore dispersal is more effective in the agricultural study sites, where the predominant vegetation is rather open, than in the relatively dense vegetation of the forest study sites (Stephenson and Stempen, 1994). Morover, banana (Musa) subatrate has been well known as the favorable substrate for a numerious number of fungi including including endophytic, pathogenic and saprobic fungi (Photita *et al.,* 2004**)**; From northern Thailand, two-hundred and fifty-two new species, comprising 80 ascomycetes, 30 basidiomycetes, 139 anamorphic fungi and 3 myxomycetes have been described from *Musaceae* by Photita *et al*. (2002)

The assemblages of myxomycetes associated with the three agricultural study sites were quite distinct from one another. Coefficient of community (CC) values calculated for pairwise combinations of the various study sites ranged from a maximum value of 0.411 (BN-MG) to a minimum value of 0.12 (MG-SC) (Table 15). Assemblages of myxomycetes associated with the three forest study sites were relatively more similar. For example, the CC value for KP-MS was 0.613. These values suggest that a wider overall range of potential substrates existed for the three agricultural study sites, although the same types of substrates were not shared in common among the three sites. For example, all of the samples of litter from the sweet corn farm and the banana plantation consisted entirely of non-woody material, whereas samples of litter from the mango orchard also contained some woody

material (e.g., twigs). This type of difference did not exist among the three forest study sites. Myxomycetes are known to display substrate specificity to the extent that particular species tend to be associated with litter or wood but not both (Stephenson and Stempen, 1994). Interestingly, the S/G value calculated for the assemblage of species associated with agricultural study sites (3.44) was higher than that calculated for the assemblage of species associated with the forest study sites (3.22). Most myxomycete genera (15 of the 18 recorded during the entire study) were represented in both types of study sites. However, *Tubifera* was limited to forest study sites and both *Licea* and *Willkommlangea* were not found in agricultural study sites.

Species composition of the assemblages of myxomycetes recorded from the two different types of study sites

Examination of the species lists compiled for the two different types of study sites indicates that the assemblage of species associated with forests include a larger proportion of myxomycetes typically found on woody substrates, whereas the assemblage of species associated with agricultural areas contains a larger proportion of myxomycetes usually collected from litter substrates (Martin and Alexopoulos, 1969). This is reflected in the ecological distribution of members of the Liceales (Table 16). More species in this order were recorded from forests (7) than from agricultural areas (5), largely because species of *Cribraria* are invariably associated with woody substrates and these were uncommon (mango orchard) or absent (sweet corn farm and banana plantation) in the agricultural study sites. A similar pattern was evident in the Stemonitales, with more species recorded from forests (9) than agricultural areas (7). In this case, species of *Stemonitis* (another genus usually collected from woody substrates) were much more likely to occur in forests than in agricultural areas. On the other hand, the pattern displayed by members of the Trichiales was exactly the reverse, with more species recorded from agricultural study sites (12) than from forests (9). Species in the genera *Arcyria* and *Perichaena* were particularly common on samples of litter collected from the banana plantation.

Table 16. Taxonomic distribution of species of myxomycetes recorded from the two different types of study sites.

Order name	Numbers of species	
	Agricultural sites	**Forest sites**
Ceratiomyxales	1	1
Liceales	5	7
Physarales	**37**	**32**
Stemonitales	7	9
Trichiales	12	9

As already noted, members of the Physarales were the predominant group of myxomycetes in the study sites investigated in the present study, 37 species recorded from the agricultural sites and 32 species from the forests. This was not unexpected, since a similar pattern has been reported in a number of other studies of the myxomycetes associated with the litter microhabitat in tropical regions of the world. Martin (1940) was the first to suggest that this pattern might exist, and it has been substantiated by the data obtained in subsequent studies. Stephenson reported that more than half of the species collected in Southern India were members of Physarales (Stephenson *et al.*, 1993), and the corresponding figures obtained for four tropical forest types (dry forest, moist forest, wet forest and cloud forest) in Costa Rica ranged from 45 to 77% (Schnittler and Stephenson, 2000). Chung (1997) also reported that members of the Physarales made up the highest proportion of the myxomycetes recorded from Hong Kong.

Among the more common myxomycetes associated with agricultural ground litter were *Arcyria cinerea*, *Collaria arcyrionema*, *Didymium iridis*, *D. minus*, *Lamproderma scintillans*, *Physarum cinereum*, and *Ph. pusillum*.

Species common on forest floor litter included *Arcyria cinerea, A. denudata, Ceratiomyxa fruticulosa*, *Collaria arcyrioinema, Craterium minutum*, *Cribraria microcarpa*, *Didymium squamulosum, D. nigripes*, *D. hemisphaericum, Hemitrichia serpula, Lamproderma scintillans, Physarum cinereum, Ph. melleum*, *Ph. pusillum, Ph. viride*, and *Ph. roseum*,

Comparison of assemblages associated with litter of the three forests

Eleven of the 58 species collected from forest study sites were common to all three forests. These 11 species, which probably can be considered among the most consistently present myxomycetes in the forests of northern Thailand, were *Arcyria cinerea*, *Arcyria denudata*, *Ceratiomyxa fruticulosa*, *Cribraria microcarpa Cribraria violacea*, *Didymium squamulosum*, *Didymium nigripes*, *Hemitrichia serpula*, *Lamproderma scintillans*, *Physarum roseum*, and *Ph. viride*.

Mid-elevation forests such as the example at Mae Sae are considered to be the most diverse of the three forest types included in the present study. This is because it is a mixed forest and includes tree species found in highland forests and lowland forests (Gardner *et al.*, 2000). We anticipated that this diversity in the vegetation to be reflected in the assemblage of myxomycetes present, and the largest number of species (39) was recorded from this study site. However, the Doi Inthanon forest was characterized by the lowest S/G value (1.75). Only 21 species were recorded for Doi Inthanon, although one of these (*Tubifera microsperma*) was not collected in any other study site and was the only representative of the genus *Tubifera* known from northern Thailand (Table 17). A pattern of decreasing numbers of myxomycetes with increasing elevation in the tropics has been reported in other studies (e.g., Stephenson *et al*., 1999; Schnittler and Stephenson, 2000), so the results obtained in the present study would not be totally unexpected. Among the more common myxomycetes in the Doi Inthanon forest were species of *Cribraria* such as *Cribraria aurantiaca*, *C. cancellata, C. microcarpa*, and *C. violacea*. The association of *Cribraria* with the wood of conifers is well known (Martin and Alexopoulos, 1969), and Pinus was a predominant member of the tree stratum in this forest.

Table 17. Values of S/G calculated for the assemblage of species recorded for each study site.

Parameter	**Agricultural sites**			**Forest sites**		
	BN	MG	SC	DI	KP	MS
Number of species (S)	31	42	8	21	36	39
Number of genera (G)	11	18	4	12	15	14
S/G value	2.82	2.33	2.00	1.75	2.4	2.79

The King Project forest was characterized by the second highest S/G value (2.40), whereas the value for the Mae Sae forest was 2.79. The assemblage of myxomycetes from the King Project forest included an unusually high number of species that could not be identified completely, including four in *Physarum*, two in *Perichaena*, and one in *Lamproderma*. Several species (*Arcyria incarnata*, *Perichaena depressa*, and *Didymium cf. minus*) were restricted to this study site.

Among the more common myxomycetes recorded for the Mae Sae forest were *Arcyria cinerea*, *Arcyria denudata*, *Ceratiomyxa fruticulosa*, *Cribraria microcarpa*, *Physarum viride*, and *Ph. serpula*.

Comparison of the assemblages of myxomycetes of the three agricultural areas

When only the three agricultural areas are considered, samples of litter from the mango orchard and banana plantation appeared to be more favorable for myxomycetes than samples of litter collected from the sweet corn farm. Number of species harvested from the mango orchard (42) and banana plantation (31) were noticeably higher than the number (eight) recorded from the sweet corn farm.

However, in terms of taxonomic diversity, the assemblage of myxomycetes associated with sweet corn litter was actually higher, since it was characterized by the smallest S/G value (2.00).

In addition to *Physarum pusillum*, litter from the banana plantation seemed to represent a particularly good substrate for several other species. The most prominent examples were *Arcyria cinerea*, *Collaria arcyrionema*, *Comatricha elegans*, *Didymium iridis*, *D. minus*, and *Lamproderma scintillans*. Moreover, *Perichaena pedata* and *P. quadrata* were recorded only from banana litter. *Arcyria cinerea*, *Perichaena vermicularis* and particularly *Physarum cinereum* were extremely common in moist chambers prepared with litter collected from the sweet corn farm. Along with *Collaria arcyrioinema, Physarum echinosporum* and *Willkommlangea reticulata* were quite common on samples of litter from the mango orchard, but they were never recorded from any of the other sites

The data obtained in the present study indicate that distinct differences exist for the assemblages of myxomycetes associated with agricultural ground litter and forest floor litter in northern Thailand. However, members of the Physarales were predominant in both types of ecological situations. During the dry season, few fruitings were found in the field in any of the study sites investigated. Moist chamber cultures prepared with samples of litter collected from the various study sites in the dry season were more productive than cultures prepared with samples of litter collected in the rainy season. In general, agricultural ground litter was relatively more productive than forest floor litter during either season. Two types of agricultural sites areas (one a banana plantation and the other a mango orchard) were much more productive than a third area (a sweet corn farm). Certain species of myxomycetes (e.g., *Physarum cinereum* and *P. pusillum*) seem particularly abundant on agricultural ground litter. Agricultural activities such as the removal of potential substrate material may have some impact on the overall abundance of fruitings that develop in the field under natural conditions, since few field collections of myxomycetes were obtained from two of the three agricultural areas.

Characteristics of the assemblages of myxomycetes associated with litter in northern Thailand

The assemblages of myxomycetes associated with ground (including forest floor) litter in northern Thailand were investigated in the seven above mentioned study areas, including three agricultural sites (BN, MG, and SC) and four forest sites (MRC, KP, MS, and DI) from October 2004 to October 2005. One hundred species of myxomycetes representing 22 genera were recorded (Table 18) of which 78 species are new records for Thailand, *Licea erecta* var. *erectoides* is known from only a few other localities throughout the world (Wrigley and Lado, 2005).

Table18. List of myxomycete species associated with agricultural and forest floor litter in northern Thailand.

Herbarium number	Taxon
MRC-HT 0300	*Arcyria.* cf. *afroalpina* Rammeloo
MRC-HT 0301	*A. cinerea* (Bull.) Pers.
MRC-HT 0302	*A. denudata* (L.) Wettst.
MRC-HT 0303	*A. globosa* Schwein.
MRC-HT 0304	*A. incarnata* (Pers. ex J.F. Gmel.) Pers.
MRC-HT 0305	*Arcyria* sp. A
MRC-HT 0306	*Arcyria* sp. B

Table 18 (Cont'd)

Herbarium number	**Taxon**
MRC-HT 0307	*Badhamia cf. melanospora* Speg.
MRC-HT 0309	*Collaria arcyrionema* (Rostaf.) Nann-Bremek.ex Lado
MRC-HT 0310	*C. alta* Preuss
MRC-HT 0311	*C. elegans* (Racib.) G. Lister.
MRC-HT 0312	*C. laxa* Rostaf.
MRC-HT 0313	*C. nigra* (Pers. ex J.F. Gmel.) J. Schröt.
MRC-HT 0314	*C. pulchella* (C. Bab.) Rostaf.
MRC-HT 0315	*C. tenerrima* (M.A. Curtis) G. Lister
MRC-HT 0316	*Craterium aureum* (Schumach.) Rostaf. .
MRC-HT 0317	*C. concinnum* Rex
MRC-HT 0318	*C. leucocephalum* (Pers. exJ.F. Gmel.) Ditmar
MRC-HT 0319	*Craterium minutum* (Leers) Fr.
MRC-HT 0320	*Cribraria aurantiaca* Schrad.
MRC-HT 0321	*C. cancellata* (Batsch) Nann.– Bremek.
MRC-HT 0322	*C. microcarpa* (Schrad.) Pers.
MRC-HT 0323	*C. violacea* Rex
MRC-HT 0324	*Diachea bulbillosa* (Berk. and Broome) Lister.
MRC-HT 0325	*D. leucopodia* (Bull.) Rostaf.
MRC-HT 0326	*D. splendens* Peck

Table18. (Cont'd)

Herbarium number	Taxon
MRC-HT 0327	*Diachea* sp. A
MRC-HT 0328	*Diderma effusum* (Schwein.) Morgan
MRC-HT 0329	*D. hemisphaericum* (Bull.) Hornem.
MRC-HT 0330	*D. rugosum* (Rex) T. Macbr.
MRC-HT 0331	*Didymium bahiense* Gottsb.
MRC-HT 0332	*D. clavus* (Alb. and Schwein.) Rabenh.
MRC-HT 0333	*D. difforme* (Pers.) Gray
MRC-HT 0334	*D. iridis* (Ditmar) Fr.
MRC-HT 0335	*D. leoninum* Berk. and Broome
MRC-HT 0336	*D. minus* (Lister) Morgan
MRC-HT 0337	*D. nigripes* (Link) Fr.
MRC-HT 0338	*D. squamulosum* (Alb. and Schwein.) Fr.
MRC-HT 0339	*Fuligo septica* (L.) F.H. Wigg.
MRC-HT 0340	*Hemitrichia calyculata* (Speg.) M.L. Farr
MRC-HT 0341	*H. serpula* (Scop.) Rostaf. ex Lister
MRC-HT 0342	*Lamproderma scintillans* (Berk. and Broome) Morgan
MRC-HT 0343	*Lamproderma* sp. A
MRC-HT 0344	*Lamproderma* sp. B
MRC-HT 0345	*Licea biforis* Morgan
MRC-HT 0346	*Licea erecta var. erectoides* (Nann.-Bremek. and Y. Yamam.) Y. Yamam.

Table18. (Cont'd)

Herbarium number	Taxon
MRC-HT 0347	*Lycogala epidendrum* (L.) Fr.
MRC-HT 0348	*L. exiguum* Morgan
MRC-HT 0349	*Perichaena chrysoperma* (Curr.) Lister
MRC-HT 0350	*P. depressa* Lib.
MRC-HT 0351	*P. microspora* Penz. and Lister
MRC-HT 0352	*P. pedata* (Lister and G. Lister) G. Lister
MRC-HT 0353	*P. quadrata* T. Macbr.
MRC-HT 0354	*P.vermicularia* (Schwein.)Rostaf.
MRC-HT 0355	*Perichaena* sp. A
MRC-HT 0356	*Perichaena* sp. B
MRC-HT 0357	*Physarella oblonga* (Ber. and M.A. Curtis) Morgan
MRC-HT 0358	*Physarum album* (Bull.) Chevall.
MRC-HT 0359	*Ph. bivalve* Pers.
MRC-HT 0360	*Ph. bogoriense* Racib.
MRC-HT 0361	*Ph. cinereum* (Batsch) Pers.
MRC-HT 0362	*Ph. compressum* Alb. and Schwein.
MRC-HT 0363	*Ph. crateriforme* Petch
MRC-HT 0364	*Ph. decipiens* M.A. Curtis.
MRC-HT 0365	*Ph. echinosporum* Lister

Table18. (Cont'd)

Herbarium number	Taxon
MRC-HT 0366	*Ph. cf. flavicomum* Berk.
MRC-HT 0367	*Ph. galbeum* Wingate
MRC-HT 0368	*Ph. globuliferum* (Bull.) Pers.
MRC-HT 0369	*Ph. hongkongense* Chao H. Chung
MRC-HT 0370	*Ph. cf. lateritium* (Berk. and Ravenel) Morgan
MRC-HT 0371	*Ph. melleum* (Berk. and Broome) Massee
MRC-HT 0372	*Ph.* cf. *nucleatum* Rex
MRC-HT 0373	*Ph. penetrale* Rex.
MRC-HT 0374	*Ph. pusillum* (Berk. and M.A. Curtis) G. Lister
MRC-HT 0375	*Ph. retisporum* G.W. Martin
MRC-HT 0376	*Ph. roseum* Berk. and Broome
MRC-HT 0377	*Ph. serpula* Morgan
MRC-HT 0378	*Ph. straminipes* Lister
MRC-HT 0379	*Ph. superbum* Hagelst.
MRC-HT 0380	*Ph. viride* (Bull.) Pers.
MRC-HT 0381	*Physarum* sp. A
MRC-HT 0382	*Physarum* sp. B
MRC-HT 0383	*Physarum* sp. C
MRC-HT 0384	*Physarum* sp. D

Table18. (Cont'd)

Herbarium number	Taxon
MRC-HT 0385	*Physarum* sp. E
MRC-HT 0386	*Physarum* sp. F
MRC-HT 0387	*Physarum* sp. G
MRC-HT 0388	*Physarum* sp. H
MRC-HT 0389	*Physarum* sp. I
MRC-HT 0390	*Physarum* sp. J
MRC-HT 0391	*Physarum* sp. K
MRC-HT 0392	*Physarum* sp. L
MRC-HT 0393	*Stemonitis axifera* (Bull.) T. Macbr.
MRC-HT 0394	*S. fusca* Roth
MRC-HT 0395	*S. fusca* var. *nigrescens* (Rex) Torrend
MRC-HT 0396	*S.* cf. *virginiensis* Rex
MRC-HT 0397	*Stemonitopsis* [*Comatricha*] cf. *aequalis* (Peck) Y.
MRC-HT 0398	*Tubifera microsperma* (Berk. and M.A.Curtis) Lado
MRC-HT 0399	*Willkommlangea reticulata* (Alb. and Schwein.)

Note: The unnamed taxa were represented by relatively little material, which made detailed study impossible. With more material, it may have been possible to assign most of these to described species.

Characteristics of the assemblages of myxomycetes in northern Thailand

In terms of species richness, the total number of species of myxomycetes recorded for northern Thailand (100) was equal to that reported for several other regions of the tropics, such as Mexico (99) and Southern India (99), and much higher than those reported in some temperate regions, such as northwestern India (82) and Cheat Mountain (56) in the eastern United States. The myxomycete assemblage of northern Thailand however, has the highest S/G value (4.55) and is less diverse than any other region (Table 19).

Table 19. Comparison of the myxomycete taxa identified in northern Thailand as compared to those of other regions.

Parameter	Temperate regions[1]			Tropical regions		
	Mountain Lake	Cheat Mountain	North western India	Mexico[2]	Southern India[1]	Northern Thailand[3]
No. Species	113	56	82	99	99	100
No. Genera	31	25	27	26	27	22
S/G	3.65	2.24	3.04	3.81	3.04	4.55

Note: [1]Stephenson (1993); [2]Lado (2002), [3]obtained from the results of this study.

A lower level of biodiversity for myxomycetes in the tropics has been recognized and reported by a number of authors, including Stephenson *et al*. (1993, 2000) and Lado *et al*. (2002). Many factors could be involved, but in terms of evolution, the tropics has a dense vegetation and a strongly seasonal climate, and therefore food sources for myxomycetes should be more readily available (at least for a certain period of the year), especially in associations with ground litter. Therefore, myxomycetes would be able to complete their life cycle without the plasmodium needing to migrate far for food. In contrast, in temperate regions, where sources of food are less readily available, the plasmodium is more likely to have to migrate from place to place to obtain nutrition. This may explain why myxomycetes in temperate forests are found in a greater number of microhabitats, but in the tropics myxomycetes

are associated mostly with forest floor litter (Lado *et al*., 2002). If this occurred over a very long period in temperate forests, each of the available microhabitats could acquire its own specific community of adapted myxomycetes. Over time, the differences among the assemblages associated with each microhabitat would become larger, more new species could evolve, and eventually the entire assemblage would become increasingly diverse (Bush, 1969).

The high density of living organisms in tropical forests and (at least during the rainy season) very moist environmental conditions could pose some disadvantages for myxomycetes. Myxomycete plasmodia are more likely to be affected adversely by other organisms (e.g., insects, fungi) or by physical factors such as excessive rain (Stephenson, 1993). As a result, those myxomycetes with a more adaptable plasmodium (i.e., durable structures, fast movement, effective reproduction and capable of surviving high levels of moisture) would have more of a chance to obtain food, migrate to suitable substrates for fruiting and especially be able to "recover" in case the population is "broken" up. Among the three types of plasmodia, the phaneroplasmodium that is characteristic of the Physarales seems more advantageous than the other types (Martin and Alexopoulos, 1969). In northern Thailand, 58% of all species were members of this Order (Table 20). There were no records of any Echinosteliales and only a few specimens of *Licea* in the field. Members of the *Echinosteliales* and *Licea* have a protoplasmodium, the smallest and slowest among the three types of plasmodia (Alexopoulos *et al*., 1996). As a consequence, with the exception of the Physarales, conditions in the tropics may not be favorable for myxomycetes, which would have the effect of reducing the biodiversity of the assemblages of myxomycetes found there (Martin *et al*., 1983; Stephenson, 1993). The prominence assemblages of myxomycetes in the Physarales associated with forest floor litter in the tropics has been supported by the data reported by a number of authors. For example, Stephenson *et al*. (1993) indicated that more than half of the species they collected in southern India were members of Physarales. In four forest types in Costa Rica, percentages of species in the Physarales were 55.2% in tropical dry forests, 44.6% in tropical moist forests, 75.8% in tropical wet forests and 77.3 in cloud forests (Schnittler and Stephenson, 2000)

Table 20. Species distribution in the five main orders of the assemblages of myxomycetes of northern Thailand.

Proportion of species in the five main orders (%)	
Ceratiomyxales	1
Liceales	9
Physarales	58
Trichiales	17
Stemonitales	15

The total number of species reported from each region in the tropics included in the comparison is higher than that of any temperate region (Table 19) with the exception of Mountain Lake in eastern North America. Interestingly, even the numbers for the temperate regions exhibit considerable variation. For example, northwestern India (82 species) and Cheat Mountain (56 species) are both much lower than Mountain Lake (113 species). However, CC values calculated for the assemblages of myxomycetes in the tropics are relatively low, whereas those calculated for the temperate regions are higher (Table 21). This suggests that the potential species richness of the assemblages of myxomycetes in the tropics is probably as high as that of the temperate regions. Moreover, it provides evidence that to have a general view of the actual assemblages of myxomycetes in any region of the tropics, it is necessary to have a large number of studies including a series of different regions, with a different dominant vegetation type.

Table 21. The CC value between the assemblages of myxomycetes of some tropics and temperate regions in the world.

	Mountain Lake	**Cheat Mountain**	**North western India**	**Mexico**	**Northern Thailand**	**Southern India**
Mountain Lake	***	**0.533**	**0.523**	0.320	0.31	0.396
Cheat Mountain	45	***	**0.536**	0.338	0.192	0.194
Northwestern India	51	37	***	0.265	0.285	0.376
Mexico	34	11	24	***	**0.472**	**0.420**
Northern Thailand	33	15	26	47	***	**0.462**
Southern India	42	15	34	42	46	***

Note. The CC values given above are derived from the combination of the results of the assemblages of myxomycetes from two tropical forest reserves in Mexico reported by Lado 2002 and from the report of Stephenson *et al*. (1993).

Myxomycetes are known to display some degree of substrate specificity, and their spores are dispersed mainly by the wind (Stephenson and Stempen, 1994; Alexopoulos, 1996). In some tropical forests, such as those in northern Thailand, in the rainy season myxomycetes are prominent, but spore dispersal is likely to be less effective due to the heavy rains and the high density of the vegetation. In the dry season, spore dispersal would be more effective, but with very dry environmental conditions, there would be few myxomycetes in the field. As a result, myxomycetes are probably confined largely to the original places where their original ancestors survived. That is different from the situation in a temperate forest, with the lower density of the vegetation and thus more favorable conditions for spore dispersal (Stephenson, 1993). As such, different forests can have an exchange of myxomycetes. Therefore, a large enough area with typical vegetation could represent mainly assemblages of myxomycetes that are specific for a temperate climate. For, A larger number of habitats in different areas in tropical regions are needed because of lower spore dispersal abilities. Unfortunately, there have been only a few studies on myxomycetes in the tropics.

Common species of myxomycetes associated with ground litter in northern Thailand are *Arcyria cinerea, A. denudata, Ceratiomyxa fruticulosa*, *Collaria arcyrioinema, Craterium minutum*, *Cribraria microcarpa, Diachea leucopodia, Didymium squamulosum, D. iridis*, *D. nigripes*, *D. hemisphaericum, Physarum cinereum*, *Hemitrichia serpula*, *Lamproderma scintillans*, *Lycogala epidendrum*, *Ph. melleum*, *Ph. pusillum*, *Ph. roseum, Ph. Viride* (Fig 16). Among these, some species such as *Arcyria cinerea*, *Collaria arcyrioinema, Didymium iridis*, *D. squamulosum,* and *Lamproderma scintillans* are along the more common species reported for Costa Rica (Schnittler and Stephenson, 2000), and the same is true for *Arcyria cinerea, A. denudate, Collaria arcyrioinema, Hemitrichia serpula, Ph. melleum* in Mexico (Lado, 2002). In contrast, the most common species of myxomycetes associated with temperate regions are *Cribraria intricata, C. cancellata, Hemitrichia clavata, Leocarpus fragilis, Stemonitis axifera, Trichia favoginea, T. varia,* and *Tubifera ferruginosa* (Stephenson, 1993). This provides additional evidence that the distribution of myxomycetes is not random and that each region is characterized by a specific assemblages of myxomycetes, at least in terms of the more common species.

Descriptions of some rare species

Among the 100 collected species, some were rare, especially *Licea erecta* var. *erectoides* which is known from only a few other localities throughout the world (Wrigley and Lado, 2005). The descriptions of *Licea erecta* var. *erectoides* and some selected notable or rarely recorded species are presented below.

***Licea erecta* var. *erectoides* (Nann.-Bremek. and Y.Yamam.) Y. Yamam.**

A. Fruiting bodies.

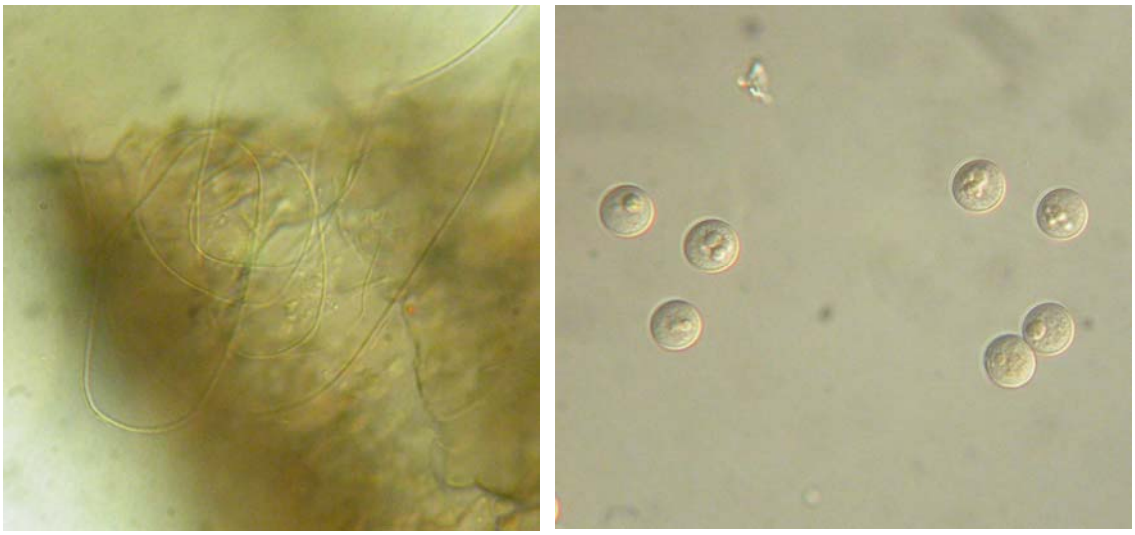
B. Peridium opening by regular cracking.

Figure 9. Fruiting bodies of *Licea erecta* var. *erectoides.*

Collection site: Mushroom Research Center, MRC-HT 0346.

Substrate: dead bamboo stem.

Fruiting body a stalked sporangium, scattered; *stalk* black, coarse, fairly rugose and 0.43 – 0.55 (mm) tall; *sporotheca* heart-shaped, 0.32 – 0.43 (mm) in diameter; *peridium* brown with alternating light and dark brown bands, base attached to stalk, one layered, and opening regularly by cracking into equal triangular fragments from the apex; *capillitium* present with independently fragile threads and hyaline; *spores* smooth, hyaline, and 9-10 μm in diameter.



A. Capillitia (x 20). B. Spores (x 20).

Figure 10. Capillitia and spores of *Licea erecta* var. *erectoides*.

***Craterium aureum* (Schumach.) Rostaf; MRC-HT 0316.**

Collection site: Doi Inthanon, at the elevation of 1700 m.

Substrate: decaying leaf.

Fruiting body a stalked sporangium, scattered, 0.8 mm tall; *sporotheca* nearly cylindrical, 0.6 mm long; *stalk* white, grooved, calcareous, 0.2 mm long and 0.045 mm in diameter; *hypothallus* small, discoid; *peridium* yellow, membranous, a single layer, encrusted with lime scales, dehiscence irregular with a circumscissile crack forming a rough circle rim; *capillitium* dense with rather large and irregular yellow lime nodes, aggregated in the center to form a *pseudocolumella*; spore dark brown in mass; *spores* pale gray in transmitted light, minutely warted, 9-10µ in diameter; *plasmodium* yellow.

***Diachea bulbillosa* (Berk and Broome) Lister**

Collection site: Mushroom Research Center; MRC-HT 0324.
Substrate: decaying leaf and small branch.
Fruiting body sporocarp, gregarious, 1.2 mm tall; *sporotheca* globose, iridescent, brown silvery, 0.5 mm in diameter; *stalk* sub-cylindrical, expanded at the base, calcareous, 0.7 mm long; *hypothallus* often inconspicuous; *columella* white, calcareous, the lime of both stalk and columella; *capillitium* a lax reticulum of purplish threads; *spore-mass* dark; *spores* violet-grey, sparsely and often irregularly but strongly warted, 7-11 µm diam; *plasmodium* white to deep yellow.

***Didymium leoninum* Berk. and Broome (1873).**

Collection site: Mango orchard; MRC-HT 0335
Substrate: decaying leaf of mango.
Fruiting body a stalked spororangium, scattered, 1.4 mm tall; *sporotheca* subglobose, 0.6 mm diameter, dark purplish brown and glossy, broadly veined with white or buff deposits of large, stellate lime crystals, or sometimes completely covered with lime and then uniformly pale buff or whitish; *stalk* stout, yellow, brown, 0.8 mm high; *peridium* cartilaginous, chestnut-brown, dehiscence into scale-like fragments. *Columella* subglobose, orange; *hypothallus* spongy charged with crystalline lime; *capillitium* of slender, branched and anastomosed dark brown threads, pale at the extremities where they are often attached to the peridium; *spores* violet-grey, verruculose, the warts sometimes arranged in lines, 7-9 µm diameter; *plasmodium* orange-red.

***Perichaena microspora* Penz. and Lister**

Collection site: mango orchard; MRC-HT 0351.
Substrate: moist chamber prepared from mango leafy litter.
Fruiting body plasmodiocarpous, short, 0.25-0.35 mm diameter, ochraceous buff; *pridium* one layer, yellow, membranous, strongly papillose on the inner surface, thickened with granular matter at the base; *capillitium* reticulate, lax, concolorous,

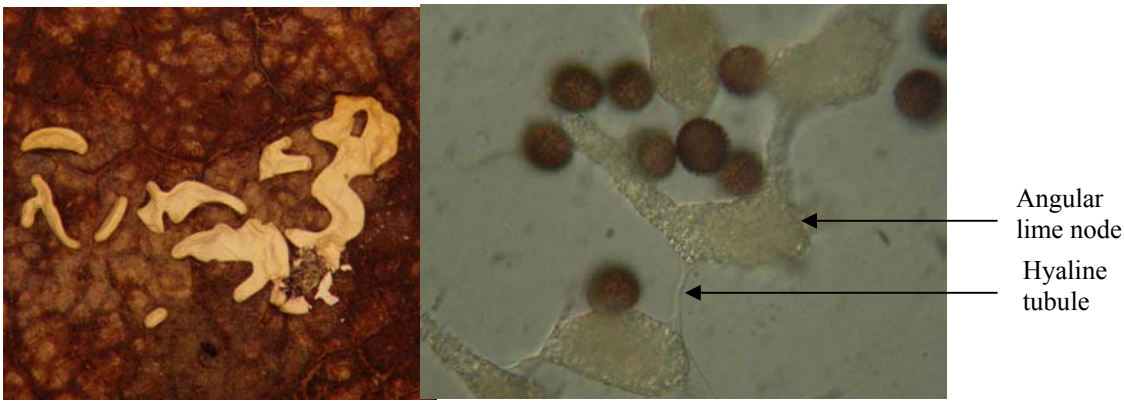
yellowish pink in the mass, almost colourless when mounted, the tips attached to the peridium; *spore-mass* yellowish pink. Spores pale yellow, minutely spinulose, 6-7 µm diam; *plasmodium* unknown.

***Physarum echinosporum* Lister**

Collection site: Mango orchard; MRC-HT 0365.

Substrate: decaying leaf of mango.

Fruiting body plasmodiocarp, elongate, laterally compressed; *peridium* two layers, the outer layer smooth, white, calcareous, the inner layer membranous, fragile, pale purple, iridescent, opening by means of a preformed apical split; *capillitium* consisting of dense white, angular lime nodes, connected by short hyaline tubules; *spore-mass* black; *spores* purple, 10µm diameter, conspicuously spiny.



A. plasmodiocarpous fruiting bodies. B. capillitium and echinus spores.

Figure 11. *Physarum echinosporum*.

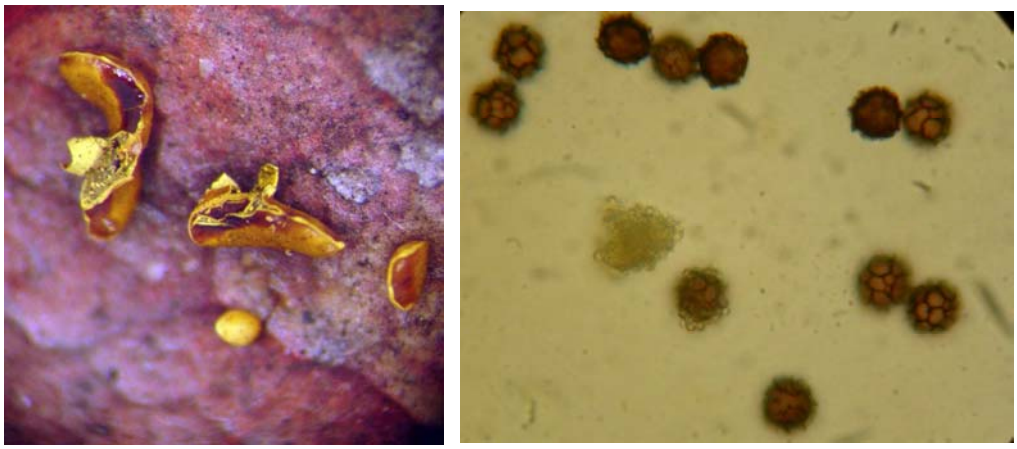
***Physarum retisporum* W.G. Martin**

Collection site: mango orchard; MRC-HT 0375.

Substrate: decaying leaf of mango.

Fruiting body a plasmodiocarp, bright yellow, laterally compressed; *peridium* double, the outer layer smooth, yellow, except at the white dehiscent margin, closely attached

to the inner layer as dehiscence, tendentiously separated. Inner layer membrane, fragile, transparent, iridescent; Dehiscence by a preformed fissure along the outer margin; *capillitium* dense, containing the large pale yellow, angular, attached to base or Peridium and connected by the thin pale yellow, non-calcareous threads; *spore-mass* black; *spores* dark purplish brown, strongly reticulate, 9-11 μm diameter; *plasmodium* bright yellow or yellowish orange.



A. plasmodiocarpous fruiting bodies.

B. reticulate spores.

Figure 12. *Physarum retisporum*.

Some common species of myxomycetes associated with litter in northern Thailand

Figure13. *Arcyria cinerea*

Figure 14. *Lycogala epidendrum*

Figure15. *Hemitrichia serpula.*

Figure16. *Physarum viride.*

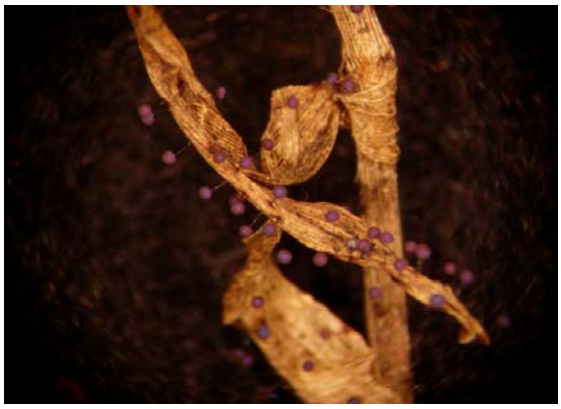


Figure 17. *Collaria arcyrioinema.*

Figure18. *Craterium leucocephalum.*

Figure 19. *Diachea leucopodia.*

Figure 20. *Physarum melleum.*

CONCLUSION

This study was among a very small number of studies on diversity and ecology of myxomycetes of Thailand (Reynolds and Alexopoulos, 1971; Siwasin and Ing, 1982). It is however, different from previous studies in type and scale of survey. The other works on myxomycetes of Thailand are small-scale studies resulting in brief notes. In this study, myxomycetes assemblages associated with 7 study sites, including agricultural and natural habitats, through different seasons of a year, were investigated and this study is considerably more intensive and effective in revealing the myxomycete assemblages of Thailand.

With the collection and identification of 100 myxomycete species representing 22 genera, this study has added 78 new records for Thailand. One of the species (*Licea erecta* var. *erectoides*) known from only a few other localities throughout the world was also found in a tropical forest in northern Thailand.

Remarkably, this research is also one among very small number of studies on myxomycetes associated with agricultural habitats in the world. The study provides the first description on myxomycetes associated with banana, mango and sweet corn litter, in terms of species richness, composition and distribution. The results provide baseline knowledge for future study on myxomycetes of the tropics in general and in agricultural habitats in particular.

This project also demonstrated the feasibility of monitoring assemblages of myxomycetes directly in the field with the use of a series of plots that represent the different habitats (and combinations of substrata and microclimates) found within a particular region of the world. Moreover, the body of data that I was able to generate from these plots suggests that the plot size (10 × 10 m) used is adequate for assessing differences in species composition and abundance.

Moreover, I discovered that myxomycetes were most common during the period of the year (June through early July) during which rainy and sunny periods alternated and overall conditions were neither too wet nor too dry. In the months that followed, numbers of fruitings declined, and from December to April no fruitings were observed. This could be useful information for those wishing to study myxomycetes in the rainforests; June through early July is "exciting" time for myxomycetes field collection.

Even though the number of field collections in the dry season is small, moist chamber cultures prepared with samples of litter collected from the various study sites in the dry season were more productive than cultures prepared with samples of litter collected in the rainy season. However, the assemblage of myxomycetes in the rainy season was much more diverse than that of the dry season. Therefore to obtain a complete understanding of the diversity of myxomycetes, collections should be made from both moist chamber and field collection in different seasons (if the study area is seasonal)

Distinct differences in the assemblages of myxomycetes associated with agricultural ground litter and forest floor litter in northern Thailand were revealed. However, members of the Physarales were predominant in both types of ecological habitats. In general, agricultural ground litter was relatively more productive than forest floor litter during both seasons. Two agricultural sites (one a banana plantation and the other a mango orchard) were much more productive than the sweet corn farm. Certain species of myxomycetes (e.g., *Physarum cinereum* and *Ph. pusillum*) were particularly abundant on agricultural ground litter.

Agricultural activities such as the removal of potential substrate material may decrease the overall abundance of fruitings that develop in the field under natural conditions, since few field collections of myxomycetes were obtained from two of the three agricultural areas.

Forest floor litter derived from trees of *Dipterocarpus* sp. and *Macaranga denticulate* appear to be particularly favorable substrates for many different species of myxomycetes.

In general, the results of this study provided sufficient data on the biodiversity and ecology of assemblages of myxomycetes in a number of tropical areas. By combining these with existing data of previous studies on myxomycetes of tropical forests the representation of myxomycetes in the tropics is more clearly understood, not only concerning the distribution and species composition, but also concerning potential species richness.

PROPOSED WORK FOR FUTURE STUDY

A major future study could involve studying the myxomycetes associated with more microhabitats using both field and moist chamber collections such as those of aerial litter, bark of living trees, dung, fallen wood; grass litter, aerial litter of cactus herbaceous plant part and epiphyllic liverworts; along an elevation gradient or in a series of different forests in some Asian countries for example Vietnam

Supplementary collections in the Mae Sae, King Project and Doi Inthanon forest should be made to recollect the undetermined taxa in this study

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