2. LITERATURE REVIEW

2.1 Biology of macrofungi in the Family Ganodermataceae, taxonomy and classification

Ainsworth *et al.* (1973) classified the Family Ganodermataceae to be in the Order Aphyllophorales, Subclass Holomycetidae, Class Hymenomycetes, Subdivision Basidiomycotina, Division Eumycota. It covers three genera i.e. *Ganoderma*, *Amauroderma* and *Elfvingia*. *Ganoderma* has the broadly ellipsoid spores with an apical thickening which collapses to appear truncate, brown, hyphal-system trimitic, cuticular hyphae light-colored while *Elfvingia* has the dimitic hyphal-system, cuticular hyphae dark-colored. *Amauroderma*'s spores are globose to broadly ellipsoid, not apically differentiated, pale to deep brown.

This family was used to be included in the Polyporaceae. The distinguishing feature is the double-walled spore with a dark-coloured inner layer bearing an ornamentation which pierces the outer hyaline layer, so that the spore appears to have a spiny surface (Furtado, 1965; Alexopoulos *et al.*, 1996). The spores are truncated at one end and the spore print is brown (Schalkwijk-Barendsen, 1994) to whitish but difficult to obtain (Arora, 1986). Most of the species form an enormous amount of spores in their lifetime but only a small percentage germinates (Schalkwijk-Barendsen, 1994). The hyphal structure of the fruit-body is trimitic. A characteristic feature is that the skeletal hyphae are of two types: (a) *arboriform*, showing an unbranched basal part with a branched tapering end, and (b) *aciculiform*, unbranched and usually with a sharp tip (Furtado, 1965).

Modern systems of classification of the Ganodermataceae tend to involve examination of the hyphal systems described by Corner and Cunningham as of three series, i.e. skeletal (trimitic), binding (dimitic) and generative (monomitic) (Thompson and Lim, 1965).

Generative hyphae: thin-walled near the growing margin, often thicker-walled behind, with or without clamps, usually with distinct cytoplasmic contents. This kind of hypha is universally present in all polypore fruit-bodies at some stage of development. The generative hyphae give rise to basidia and also to two other kinds of hyphae.

Skeletal hyphae: unbranched thick-walled hyphae with a narrow lumen which arises as lateral branches of the generative hyphae. The skeletal hyphae form a rigid framework.

Binding hyphae: much-branched, narrow, thick-walled hyphae of limited growth. These hyphae tend to weave themselves between the other hyphae of the flesh.

Where all three kinds are present together the fruit body is said to be trimitic. There are two types of dimitic construction:

(a) Dimitic with binding hyphae

(b) Dimitic with skeletal hyphae

Examining of the hyphal systems is facilitated by clearing in KOH, washing in water and staining with 1 percent aqueous eosin or with dilute lactophenol/cotton blue (Webster, 1970).

The genus *Ganoderma* is divided into 3 subgenera (Thaithatgoon, 1996). They are:

1. Subgenus *Ganoderma* which is divided into 2 sections

   a. Section Ganoderma

      (1) *Ganoderma atrum* Zhao, Xu et Zhang

      (2) *Ganoderma calidophilum* Zhao, Xu et Zhang

      (3) *Ganoderma capense* (Lloyd) Teng

      (4) *Ganoderma curtisii* (Berk.) Murr.

      (5) *Ganoderma daiqingshanense* Zhao

      (6) *Ganoderma flexipes* Pat.

      (7) *Ganoderma hainanense* Zhao, Xu et Zhang

      (8) *Ganoderma kunmingense* Zhao

      (9) *Ganoderma lucidum* (W. Curt.:Fr.) Karst.

      (10) *Ganoderma mongolicum* Pilat

      (11) *Ganoderma multiplicatum* (Mont.) Pat.

      (12) *Ganoderma ramosissimum* Zhao

      (13) *Ganoderma resinaceum* Boud.

      (14) *Ganoderma rotundatum* Zhao, Xu et Zhang

      (15) *Ganoderma shandongense* Zhao et Xu

      (16) *Ganoderma sichuanense* Zhao et Zhang

      (17) *Ganoderma subumbraculum* Imazeki

      (18) *Ganoderma tenue* Zhao, Xu et Zhang

      (19) *Ganoderma theaecolum* Zhao

(20) *Ganoderma tsugae* Murr.

(21) *Ganoderma valesiacum* Boud.

b. Section Phaeonema Zhao, Xu et Zhang

(22) *Ganoderma ahmadii* Steyaert

(23) *Ganoderma amboinense* (Lam.: Fr.) Pat.

(24) *Ganoderma austrofugianenes* Zhao, Xu et Zhang

(25) *Ganoderma boninense* Pat.

(26) *Ganoderma chenghaiense* Zhao

(27) *Ganoderma cochlear* (Bl.& Nees) Bres.

(28) *Ganoderma crebrostriatum* Zhao et Xu

(29) *Ganoderma dahlii* (Henn.) Aoshima

(30) *Ganoderma duropora* Lloyd

(31) *Ganoderma fornicatum* (Fr.) Pat.

(32) *Ganoderma fulvellum* Bres.

(33) *Ganoderma guinanens* Zhao et Zhang

(34) *Ganoderma luteomarginatum* Zhao, Xu et Zhang

(35) *Ganoderma magniporum* Zhao et Zhang

(36) *Ganoderma mastoporum* (Lev.) Pat.

(37) *Ganoderma mediosinense* Zhao

(38) *Ganoderma mirivelutinum* Zhao

(39) *Ganoderma ochrolaccatum* (Mont.) Pat.

(40) *Ganoderma parviungulatum* Zhao et Zhang

(41) *Ganoderma simaoense* Zhao

(42) *Ganoderma sinense* Zhao, Xu et Zhang

(43) *Ganoderma tibetanum* Zhao et Zhang

(44) *Ganoderma tropicum* (Jungh.) Bres.

2. Subgenus *Trachyderma* Imazeki

(45) *Ganoderma tsunodae* (Yasuda) Trott.

3. Subgenus *Elfvingia* (Karst.) Imazeki

(46) *Ganoderma annulare* (Fr.) Gilbn.

(47) *Ganoderma applanatum*(Pers. ex wallr.) Pat.or *Fomes applanatus* (Pers.) Wall

(48) *Ganoderma australe* (Fr.) Pat.

(49) *Ganoderma bawanglingense* Zhao et Zhang

(50) *Ganoderma brownii* (Murr.) Gilbn.

(51) *Ganoderma densizonatum* Zhao et Zhang

(52) *Ganoderma diaoluoshanense* Zhao et Zhang

(53) *Ganoderma gibbosum* (Nees) Pat.

(54) *Ganoderma limushanense* Zhao et Zhang

(55) *Ganoderma lobatum* (Schw.) Atk.

(56) *Ganoderma meijiangense* Zhao

(57) *Ganoderma phillippii* (Bres. et Henn.) Bres.

(58) *Ganoderma sanmingense* Zhao et Zhang

(59) *Ganoderma shangsiense* Zhao

(60) *Ganoderma triangulatum* Zhao et Xu

(61) *Ganoderma ungulatum* Zhao et Zhang

(62) *Ganoderma koningsbergii* (Lloyd) Teng

The basidiospores of species of *Ganoderma* are brown, ovate, with a rounded base and truncate to narrowly rounded apex. The surface of spores is slightly to strongly dimpled. The wall is complex and composed of several layers. The outermost wall is connected to the inner wall by inter-wall pillars. The spore is the most characteristic and distinguishing features of the Ganodermataceae. Basidiospores of species within the genus *Ganoderma* are morphologically similar, but basidiospores may show degrees of variation in size within a species (Adaskaveg and Gilbertson, 1988).

The fruiting body of *Ganoderma* is medium to very large size; tough, woody, corky, or punky, usually perennial (but some species annual); often thick; growing on dead or living trees or on the ground. The cap is knoblike to hooflike to shelflike or bracketlike, sometimes with a hard surface crust; often zoned, ridged, or grooved. Pores are fairly small to minute or barely visible; tubes often stratified (with more than one layer) in longitudinal section. Stalk is usually absent or rudimentary, but sometimes present as a lateral extension of the cap (*G. lucidum*) (Arora, 1986; Horn *et al.*, 1993).

Nobles (1958, 1965) reported the characters of possible taxonomic significance for some species in the genus *Ganoderma*. They are i) presence or absence of extracellular oxidase, ii) septation of hyphae, iii) occurrence of special structure formed by differentiation of hyphae, iv) occurrence of chlamydospore and conidia, v) color of hyphae and mycelial mats, vi) rate of growth, vii) odor of cultures and viii) host relationships. These characters are used for *Ganoderma applanatum*, *G. lobatum*, *G.*

lucidum, *G. oregonense*, *G. sessile and G. tsugae*. However, the growth rate can be used only rarely as a basis for the separation of species because most species show a range of the overlapping of the growth rate.

Hseu & Wang (1991) used some parameters to describe the clearer identification for *Ganoderma* species. The parameters used are i) macroscopic characteristics of the colony and fruiting body; ii) microscopic characteristics of the hyphae and basidiospores; iii) growth rate and optimum temperature; iv) extracellular hydrolytic enzymes assay by API-ZYM kits; v) electrophoretic patterns of extracellular laccase isozymes; vi) di-mon mating and mon-mon mating test; and vii) restriction fragment length polymorphisms in total DNA. These parameters can be used for *G. applanatum* (Pers.) Pat., *G. formosanum* Chang & Chen, *G. fornicatum* (Fr.) Pat., *G. microsporum* Hseu, *G. neo-japonicum* Imaz., *G. tropicum* (Jungh.) Bres., *G. tsugae* Murr., also the relationship between 10 different isolates of *G. lucidum*.

The recognition of the genus *Ganoderma* is based mainly on spore character. On the basis of hyphal system; the dimitic hyphal system with brown hyphae and without clamps are characteristic of *Elfvingia* represented by *E. applanata*, while trimitic hyphal system with hyaline hyphae and clamps in the generative hyphae characterise *Ganoderma*, represented by *G. lucidum* (Bakshi, 1971). Bakshi (1971) also indicated the different characteristics of *G. lucidum*, *G. colossum* and *G. applanatum*. *G. lucidum* and *G. colossum* have the upper surface red, laccate, shiny; but the sporophore of *G. lucidum* is usually stipitate, tough, leathery to woody, heavy, spores 8.3-10 x 5.8-6.7 µm, clamps present. While *G. colossum* has the sessile, light, corky sporophore, spores 14-16.5 x 8.5-10.3 µm, clamps present. *G. applanatum* has the upper surface which is not laccate, with grayish or darker crust; sporophore typically perennial, tubes stratified, spores 6.5-10 x 4.5-7.5 µm, surface hyphae protruding beyond the crust (McKnight and McKnight, 1987).

Ryvarden (1993) indicated that *Ganoderma tornatum* (Pers.) Pat. and *G. australe* (Fr.) Pat. *sensu* spores increased in size with increasing latitude and altitude.

The importance of the shape of the basidiospores as the basic characteristic in distinguishing *Ganoderma* and *Amauroderma* could be in two major aspects: (1) a few species of *Amauroderma*, instead of having globose to subglobose basidiospores, have oblong basidiospores, and (2) some species of *Ganoderma* produce globose to subglobose "gasterospores" in which the structure of the wall follows the basic pattern found in the basidiospores. The basidiospores are, therefore, the reliable character for distinguishing *Ganoderma* from *Amauroderma* in the Ganodermoideae. This basic distinction, however, is supplemented by secondary characters. *Ganoderma* comprises species having only derm and are distributed throughout the tropics and the temperate zones. *Amauroderma* encomposses species with derm and others with cortex and are confined within tropical boundaries. The presence of cortex only in *Amauroderma* suggests that this genus comprises species less differentiated than those of *Ganoderma* with derm. The geographical distribution of the genera under discussion indicates that the species of *Ganoderma* that extend beyond tropical limits have better physiological devices to cope with the environmental changes in temperature than the components of *Amauroderma* (Furtado, 1965).

Adaskaveg and Gilbertson (1986) studied the distribution of wood-rotting species in North America. They found that *Ganoderma lucidum* was restricted to hardwoods. Its basidiospores were "smooth" walled, characterized by narrow, numerous inter-wall pillars. Isolates of *G. lucidum* produced chlamydospores in culture and had an average growth rate of 7.8 mm/day at its optimum temperature range of 30-34 °C. *Ganoderma tsugae* was restricted to conifers. Its basidiospores were "rough" walled and had broad inter-wall pillars. Isolates of *G. tsugae* did not produce chlamydospores in culture and had an average growth rate of 2.1 mm/day at the optimum temperature range of 20-25 °C. Basidiospore sizes could not be used to distinguish the species. They considered the primary taxonomic characters to be host specificity, geographical distribution, and morphology of the fruiting body. The latter included context color, the shape of the margin of the pileus, and whether the fruiting body was stipitate or sessile. They recognized on four North American species in the *G. lucidum* group. The taxonomy was based on geographical distribution, host specificity, macroscopic morphology, and spore characteristics. The taxonomy of the species should be simplified to base on a new classification of basidiocarp developmental studies in the field. Nobles (1965) indicated differences in the cultural characteristics of *G. lucidum*, *G. tsugae*, and *G. oregonense*. Later, she changed the name of her isolates previously listed as *G. lucidum* to *G. sessile*, which Steyaert (1975) considered to be a synonym of *G. resinaceum*.

Currently, the best treatises discussing the taxonomy of these polypores are in the form of monographs. The spore size of *G. lucidum* is smaller than the inclusive range of 13-17 μm in length by 7.5-10 μm in width characteristic of *G. oregonense* and *G. tsugae*. Nevertheless, the consideration of this feature is more significant than the habitat when delineating these three taxa into their key to species. Placing emphasis on habitat may also be a dubious distinction when considering these species produce fruitbodies on non-native woods when cultivated. Features of higher taxonomic significance- such as interfertility studies and DNA fingerprinting- are needed to support accurate and defensible species delineation. Some species were argued to retain them as separate species which may be primarily ecological and host specific and not biological.

One of the few cultural distinctions described by Adaskaveg & Gilbertson (1986) is that *G. lucidum* produces chlamydospores in culture whereas *G. tsugae* does not.

Setliff (1988) stated that the mitic system in polypores is an importan character in their taxonomy. The proliferation of branched hyphae in the pores and the dynamic changes observed in the context and tramal tissues of *G. applanatum* suggest that the mitic system concept might be modified to include other, currently poorly understood phenomena. The branched thick-walled hyphae may serve as a different function apart from "binding" other hyphae in the sporophore together.

2.2 Macrofungi and the environment

2.2.1 Macrofungi as pollution bioindicators of a changing environment

Many forests in the European countries are dying from pollution. The macrofungi species are changed or disappeared, e.g. the distribution information from the help of records and specimens collected in the past. The disappearance of certain species may be a warning signal in polluted areas (Schalkwijk-Barendsen, 1994).

2.2.2 The long-term effects of macrofungi ingestion by adverse reactions of radioisotope contamination

The accumulation of radioisotopes in areas of contamination or downwind fade out has been documented in many countries. It has ever been suggested that macrofungi such as *Ganoderma lucidum*, which concentrate radioactive elements from their woody substrates and directly from the atmosphere, could be used as a biological monitoring tool for measuring radioisotope pollution. In Russia, radioisotope contamination is taken so seriously that efforts are underway to salvage valuable food sources such as mushrooms and fish by developing procedures that will remove the radioactive elements from them.

In Japan, the consumption of mushrooms can range as high as 3.5 kg per person per year. Fortunately, there is no evidence of radioisotope contamination of any of their commonly cultivated mushrooms. A recent study confirms that edible mushrooms from selected sites in North America also are free of dangerous levels of radioisotopes (Benjamin, 1995).

2.3 Macrofungi and Forest

2.3.1 Role of macrofungi in forest ecosystem functioning

The continuing flow of energy through forest ecosystems depends upon the maintenance of nutrient supplies to autotrophic green plants. Since there is only a limited input of nutrients from outside, a balanced cycle which makes nutrients available again is essential for continued functioning of the ecosystem. The most significant activity of such fungi is their special ability to break down cellulose as the important aspects of the saprotrophic fungi (Ingold and Hudson, 1993). The crucial role of wood decay fungi lies in the fact that they are the major agents of decomposition of bulky, lignocellulosic material, and hence also mediate transfer of mineral nutrients "locked up " in organic tissues back into the available soil pool. They may also play a role in soil organic matter formation (Boddy, 1991).

The relative importance of wood decay fungi to ecosystem functioning varies between ecosystems, depending on the amount of woody material available for recycling. Also, within any one area their relative importance may change because forests are not static either in space or time. Thus, bare ground will, under suitable conditions, become covered successively by herbaceous vegetation and then by woody forms, ultimately forming climax forest communities. Even in climax forest changes occur, and they are often unevenly aged and patchy because of localized loss and reestablishment of the canopy. In plantation forestry, stands are often evenly aged and much less species diverse, although again changes occur with time (Boddy, 1991). Wood resisting fungal attack depends largely upon its moisture content. Dry wood is not liable to invasion. It cannot be colonized unless the moisture content is above 26-32% on a dry mass basis depending upon the wood (Ingold and Hudson, 1993).

Some macrofungi are serious parasites of forest and shade trees, causing root rot and heart rot, although the vast majority are saprobes and play an important role in nature as decomposers of wood and of the remains of herbaceous plant. Dead trees and lumber are commonly attacked by certain species of fungi (Alexopoulos *et al.*, 1996)

2.3.2 The importance of the Ganodermataceae as plant pathogen in forest ecosystems

Commercial losses of standing timber result from white and brown rot decay of central, nonliving tissues (heart rot), and from death and decay of sap-wood by active pathogenic mechanisms. Also, attached branches die or are killed, sometimes termed natural pruning, and subsequently decompose. Although the latter does not result in large economic loss, as such wood is not used for timber, it is important in recycling essential mineral nutrients. For many years, heart rot was thought to be the main or only cause of decay in standing trees. There are several types of decay, heart rot is still a major cause of economic loss and deterioration in high forest and trees. However, in many commercial forest plantations, trees are grown and harvested on short rotation and the incidence of heart rot is greatly reduced (Boddy, 1991).

With regard to decay caused by fungi, two classes of heart rot are often recognized: butt rot, which spreads upwards from the root or root collar, and top rot, which spreads downwards from the crown. Butt rot, where wounds large enough to expose heartwood in the root system probably seldom occur, entry may therefore be largely dependent on the mechanisms of active pathogenesis, for example, *Ganoderma adspersum* or *G.applanatum* causes the butt and top rot in beech (*Fagus*) and horse chestnut (*Aesculus hippocastanum*) (Webster, 1970; Boddy, 1991), *Ganoderma pfeifferi* causes butt rot and top rot in beech (*Fagus*); *G. lucidum* and *G. resinaceum* cause butt rot in oak (*Quercus*). *G. applanatum*, a wound parasite causes active heart rot of beech and other trees. Both cellulose and lignin are attacked (Webster, 1970).

2.3.3 The importance of the Ganodermataceae as determinants of animal activity

Some members in the Ganodermataceae are poisonous and many have inedible fruit bodies, e.g., many of them are tough and leathery. Some species are grown commercially, notably the Ling Chih, *Ganoderma lucidum*. Not only do fungal sporocarps serve for human, but also they are used by other vertebrates and a wide variety of invertebrates. Furthermore, they improve the nutritional quality of the food of wood-inhabiting invertebrates and affect their behavior. Consequently, wood decay fungi also play an important role in the overall balance of decomposer organisms within the forest ecosystems. Some species of wood decay fungi can influence the behavior of animal as a result of the production of attractive and repellant chemicals, for example, wood decayed by white-rot fungus *Ganoderma applanatum* was toxic to *Microtermes edentatum* (Boddy, 1991; Ryvarden, 1993)

In terms of the use of the forest and forest products, the Ganodermataceae can have both beneficial and detrimental effects. The former includes the crucial role that they play in maintaining the nutrient cycling of the ecosystem, biological control of plant pathogens and sources of medicine for man, while detrimental effects are largely concerned with loss of timber (Boddy, 1991).

2.4 The importance of the Ganodermataceae as active pathogen in commercial plantation

It was reported that the pathogens in the Ganodermataceae is *Ganoderma* spp.. *Ganoderma* spp. are found worldwide and again colonized by active pathogenesis and also cause butt rot and top rot. They are particularly damaging in the tropics where they colonize economically important plantation crops such as rubber (*Hevea brasiliensis*), tea (*Camellia sinensis*), cocoa (*Theobroma cacao*), and oil palm (*Elaeis guineensis*). Infection is probably via root contacts (Ingold and Hudson, 1993), with stumps of previously infected trees being the important foci.

Ganoderma applanatum causes a debilitating rot. Initially, mycelia arising from germinating spores enter the trees through wounds and then colonize and destroy the healthy wood. This species is parasitic and must gain access to the wood of a suitable tree in order to survive and reproduce. However, the mycelia arising from germinating spores can only penetrate wood through the exposed wounds (Cooke, 1981).

2.5 The Ganodermataceae and human

2.5.1 Causes of allergenic problems

Hasnain *et al.* (1985) carried out an aerobiological study of the Auckland region using Burkard volumetric spore traps from September 1979 to August 1980. This study indicated that one of the potential allergens is the basidiospores of *Ganoderma*, which was recorded as the nocturnal spore type. The seasonal pattern of airborne basidiospores of the region indicated a close relationship with the pattern of acute asthma admissions. In the later years, Cutten *et al.* (1988) found the *Ganoderma* fungal spores to be a major component of the Auckland air-spora. About 16% of asthma and rhinitis patients reacted positively (by skin prick test) to ganoderma extracts.

There is a further medical aspect of the fungi, for spore may act as allergic substance. The respiratory tract, consisting of the nasal system, trachea, bronchial tubes and alveoli of the lungs, is a kind of impactor trap (Ingold and Hudson, 1993). It has been calculated that a large specimen of *Ganoderma* may release as many as 20 million spores per minute during the five or six months from May to September. Spore discharge can continue even during periods of drought, undoubtedly associated with the uptake of water from the host tree (Webster, 1970). Due to the abundance of spores discharged to the air, with the maximum production by one sporophore of 5 g. dry weight of spores in one week, equivalent to 11 billion spores, the susceptible people will have the allergenic asthma and rhinitis (Cutten *et al.*, 1988).

2.5.2 The importance in the Asian pharmacopoeia

Apart from causing allergic symptoms in susceptible patient, some species of *Ganoderma* are used as medicinal agent. In China, medicinal mushrooms had a long history of almost 2,000 years. Nowadays with the progress of medical science, the medicinal mushrooms in China goes on to some new developments. Investigation on the resources and the separation of the spawns revealed 107 kinds of medicinal mushrooms. Several species of the Ganodermataceae are grouped in the Chinese medicinal herbs. These are *Ganoderma lucidum*, *G. sinense*. The medicinal part is usually the carpophore. Eventhough some *Ganoderma* are poisonous, using these mushrooms will make the effect of "using poison as an antidote for poison" or " Like cure like". Table 1 shows the names of the mushrooms in the Family Ganodermataceae, their medicinal parts, methods of using them and application for diseases.Many species in the Family Ganodermataceae have the medicinal properties. Most of them are claimed to have the anticancer activities and improve the immune system. Those species are shown as follow:

Ganoderma lucidum is the most well known mushroom in the Family Ganodermataceae. It is known to contain polysaccharides that can reduce the growth of cancerous cells and stimulate the human immune system (Trakullertsatein, 1995). It is also claimed to cure heart disease, diabetes, arthritis, high altitude sickness, sexual impotency, and even chronic fatigue syndrome. It is no wonder that this mushroom has been for centuries heralded as "The Mushroom of Immortality" (Stamets, 1993).

Ganoderma applanatum (*Elfvingia applanatum*) has been claimed for anticancer properties (Benjamin, 1995; Thaithatgoon, 1995).

Ganoderma sinense is used for strengthening the brain and improve the respiratory system (Benjamin, 1995).

Ganoderma neojaponicum, *Ganoderma boninense* and *Ganoderma lucidum* are claimed for anticancer activities, improve blood pressure etc. (Thaithatgoon, 1995).

Table 1: The Ganodermataceae used in Chinese Traditional and Herbal Drugs (Yang and Jong, 1989).

Scientific Name	Medicinal Parts	Indication
Amauroderma longipes	Carpophore	Strengthening health, strengthening the brain
Amauroderma rude	Carpophore	Strengthening health, strengthening the brain
Amauroderma rugosum	Carpophore	Strengthening health, strengthening the brain
Ganoderma applanatum	Carpophore	Resisting cancer of the esophagus
Ganoderma capense	Carpophore	Rejuvenerating effect
Ganoderma japonicum	Carpophore	Rejuvenerating effect
Ganoderma lucidum	Carpophore	Rejuvenerating effect, curing neurasthenia
Ganoderma neo-japonicum	Carpophore	Rejuvenerating effect
Ganoderma tsugae	Carpophore	Rejuvenerating effect

2.6 Macrofungi diversity, distribution, natural habitat and host

Fungi are now known to be less widely distribution around the world than earlier research had indicated. It is true that some species do have a wide distribution. Fungi are not easily dispersed between continent because the spores, especially if small and thin-walled, while being blown for long distances, do not remain viable for long. Furthermore, in order for a fungus to establish itself on a new continent two viable spores have to land within a millimeter or so of each other to ensure fusion between the resulting mycelia. In many instances the chance of such occurring is greatly reduced owing to the fact that the spores have to be of the correct mating type. Assuming that fusion does occur the local soil and climatic factors must be such as to encourage fruiting body formation (Pacioni, 1981; Pacioni, 1985).

The distribution of the fungi is largely habitat controlled. A report may cite a fungus as occurring in a certain location, region, or continent, but without considering the preferred habitat of the fungus, such statements are relatively meaningless (Myers and Shelton, 1980). These preferences are based on enzymes systems adaptable to use by the fungus on specific fractions of the substratum such as simple sugars, cellulose, lignin, starch, chitin, and other natural compounds. Among parasitic fungi, those restricted to one species of host appear to have the greatest geographic restriction if that host is geographically restricted. However, where a host is widespread, its parasites may become geographically widespread. Those parasitic fungi which are capable of living saprobically with the dead remains of the host whose range, in the wild or in cultivation, is restricted (Cooke, 1979).

Dispersal of fungi from one continent to another does occur but it is usually the result of the activity of man either transporting mycelial fragments in soil on his boots, or in soil adhering to the roots of imported plants. Indeed, many countries have legislation to prevent accidental import of pathogenic species in soil or on infected plants (Pacioni, 1981; Pacioni, 1985).

Factors that limit geographical distributions of fungi (Krebs, 1994)

(1) Habitat selection

Habitat selection is one of the most poorly understood ecological processes. Since fungi cannot actively move from one habitat to another, so spores arrive in different habitats through dispersal, and then either survive and grow or die because of biological or physical factors. For any particular species, a habitat is defined as any part of the earth where that species can live, either temporarily or permanently. Each habitat is assumed to have a suitability for that species. Suitability is equivalent to fitness in evolutionary time, and it is assumed that mature population produce more young in more suitable habitats than they do in less suitable habitats. Suitability is not constant but will be affected by many factors in the habitat, such as the food supply, shelter, and predators. In addition, suitability in any habitat is usually a function of the density of other individuals, so that overcrowding reduces suitability. Individuals would be crowded in the best habitats and at low density in the poor habitats. Problems can arise whenever habitats change, and this has been a source of difficulty for many organisms since humans have modified the face of the earth. People provide many new habitats and destroy others.

(2) Temperature and moisture

Temperature and moisture are the two main limiting factors on the distribution of life on earth. Especially, temperature is one of the chief factors of successful production of fungi (Alexopoulos *et al.*, 1996; Krieger, 1967). Water, alone or in conjunction with temperature, is probably the most important physical factor affecting the ecology of terrestrial organisms. Each kind of species is affected by moisture in a variety of ways. Humidity of the air is important in controlling water loss from the body of living thing. Macrofungi are affected by the soil water levels as well as the humidity of the surrounding air, without adequate moisture there can be no life. The rates of evaporation depend primarily on temperature; consequently, there is a strong interaction between temperature and moisture in affecting the water relations of living things. The absolute amounts of rainfall and evaporation are less important than the relationship between the two variables.

The organisms at any site is usually considered a product of the climate of the area. This implies that climatic factors, temperature and moisture primarily, are the main factors controlling the distribution of vegetation. Organisms have two options in dealing with the climatic conditions of their habitat. They can simply put up with the temperature and moisture as they are, or they can escape by some evolutionary adaptation. Temperature and moisture may act on any stage of the life cycle and can limit the distribution of a species through their effects. If temperature or moisture act to limit a distribution, what aspect of temperature or moisture is relevant-maximums, minimums, averages, or the level of variability. No overall rule can be applied here; the important measure depends on the mechanism by which temperature or moisture acts and the species involved. Living things respond differently to the same environmental variables during different phases of their life cycle. For this reason, mean temperatures or average precipitation will not always be correlated with the limits of distributions, even if temperature or moisture is the critical variable.

Temperature or moisture limits the distribution of an organism in the following aspects:

i) Determination of the phase of the life cycle that is most sensitive to temperature or moisture.

ii) Determination of the physiological tolerance range of the organism for this life cycle phase.

iii) The microclimate where the organism lives is permissible for site within the geographic range and lethal for the sites outside the normal geographic range.

In some cases, the moisture requirements of fungi and plant can restrict their geographic distribution. In other cases, moisture and temperature interact to limit geographic distributions and the ecologist must consider explanations like "both-temperature-and-moisture" rather than "either-temperature-or-moisture". The drought also determines ranges of species, In tropical area, soil drought is the usual "drought" in which soil moisture is deficient; it can usually be described as an absolute shortage of water in the soil. The physical factors can be condensed into three primary variables: temperature, moisture, and wind. Proceeding up a mountain, temperature decreases, rainfall increases, and wind velocity increases.

There are certain physiological tolerances built into all the individuals of a particular species. Species could extend their distribution by local adaptation to limiting environmental factors, such as temperature.

Temperature and moisture may also act indirectly to limit distributions through their effects on competitive ability, disease resistance, predation, or parasitism. In case of fungi, temperature is one of the cardinal factors which determines the distribution (Ingold and Hudson, 1993).

(3) Others physical and chemical factors

Light is important to organisms for two different reasons. Light is used as a cue for the timing of daily and seasonal rhythms in living things. Timing is a central issue in the life cycles of organisms. Nocturnal organisms use light as a cue for their activity cycles. Production period in most organisms occurs during a part of the year only, and organisms thus need a reliable cue to trigger their production physiology. Some organisms cannot tolerate shade, and their local distribution is affected by light requirements. Despite fungi, unlike green plants, are relatively independent of light, there are some species that their activity depends on light (Alexopoulos *et al.*, 1996)

Soil structure and nutrients are important. Intricate connections among climate, soil, and vegetation make it difficult to separate the cause and effect with regard to organism distribution. The soil is affected by the vegetation that grows on it and can in turn affect the nature of the vegetation. Most organisms are tolerant of a wide range of soil types; consequently, soil factors are not generally a major limitation to organism distribution.

Water chemistry, pH, and salinity are important factors affecting the distribution of organisms, especially marine and freshwater organisms.

Fire, although an important source of disturbance in many plant communities, is rarely a major factor affecting geographic distributions.

Many physical and chemical factors, in addition to temperature and moisture, can limit the distributions of organisms. Most of these cases involve details of local distributions rather than continental or worldwide distributions. They are often concerned with the factors involved in habitat selection.

Ganoderma lucidum is widely distributed throughout the world . In North America and Europe, *G. lucidum* is known as one of the "Artist's Conk" fungi. (The true Artist Conk is *Ganoderma applanatum*) (Stamets, 1993). Each species has its own specific conditions to grow in the preferable regions. For instance, *G. applanatum* (Pers. ex S.F. Gray) Pat. is restricted to northern temperate regions. *G. tornatum* is circumglobal in the tropical and subtropical belts (Steyaert, 1975).

According to Ryvarden (1993), the genera of the Ganodermataceae are classified geographically as cosmopolitan or climate dependent. *Ganoderma* is classified to be the "Cosmopolitan genera" which is known in all continents and in all major climatic zones. While *Amauroderma* is classified to the "Pantropical genera", distributed throughout the forest parts of the tropical zones.

Schalkwijk-Barendsen (1994) recorded that *G. applanatum*, *G. lucidum and G. tsugae* occurred in Northwest, North America . *G. tsugae* was found in the coniferous wood on Vancouver Island, it occurs from Eastern Canada to Maine, North Carolina and the Midwest. While *G. applanatum* is worldwide distributed (Bakshi, 1971), occurring from the subarctic to the subtropics as a decomposer of old logs and stumps of both deciduous and coniferous wood. *G. lucidum* is cosmopolitan and widespread in deciduous wood (Bessey, 1950).

G. oregonense favors colder climates whereas *G. lucidum* is found in warmer regions. *G. curtisii* grows in eastern North America. The North American species- *G. lucidum, G. curtisii, G. oregonense*, and *G. tsugae* represent a constellation of closely related individuals, probably stemming from a common ancestry (Stamets, 1993).

According to Arora (1986) *G. curtisii* is distributed mainly in the southeastern United States but rare northward. *G. lucidum* is widespread in the temperate and tropics, from Canada to Argentina and Europe to Siberia, China, India, Australia, and Africa. It is fairly common in Eastern North America but rather infrequent in California. It occurs in a wide range of hosts, but in North America is partial to maple. *G. oregonense* is known only from western North America occurring on conifers. *G. applanatum* is very common on conifers in some areas, very widely distributed, and found all year-round. Its hosts include virtually every hardwood found in North America, including numerous conifers. In coastal California, it is especially common on bay laurel, but can also found on oak, magnolia, pepper trees, acacia, eucalyptus, elm, and Douglas-fir.

The species found in the midcontinental United States are *G. applanatum* and *G. lucidum* on hardwoods or on ground (Huffman *et al.*, 1989) .

Dennis (1970) found 8 species of *Ganoderma* in the following places; *G. opacum* in Trinidad, British Guiana; *G. colossum* in Venezuela; *G. fornicatum* in British Guiana, Colombia; *G. tuberculosum* in British Guiana; *G. lucidum* in Trinidad, Venezuela; *G.nitidum* and *G. applanatum* in Trinidad, Venezuela, Colombia and Panama; and *G. applanatum* var. *tornatum* in Trinidad and British Guiana. 12 species of *Amauroderma* was found: *A. brittonii* on logs and at the foot of trunks in Trinidad.; *A. miqueliana* (Mont.) Reid (*A. partitum* (Berk.) Wakefd.) in British Guiana, Venezuela ; *A. renatum* (Berk.) Murr. in British Guiana, Colombia; *A. dubiopansum* (*Polyporus dubiopansus* Lloyd) in Trinidad and British Guiana; *A. exile* in British Guiana; *A. ocellatum* (Berke.) Wakefd. in Trinidad, British Guiana and Panama; *A. schomburgkii* (Berk.) Wakefd. in Trinidad and British Guiana; *A. longipes* in British Guiana; *A. auriscalpium* (Pers.) in Venezuela and Colombia; *A. omphalodes* (Berk.) in Venezuela and Colombia; *A. macrum* (Berk.) Wakefd. in British Guiana and *A. variabile* (Bk.) Lloyd in British Guiana.

Bakshi (1971) found that *G. applanatum* occurred on dead trees, logs, stumps and also as wound parasite on sissoo, teak, mulberry, babul, bamboo, toon, dathal, *Mallotus philippinensis* and cinnamon throughout India, both in the plains and in the temperate region of the Himalayas. *G. lucidum* is a serious root parasite on many broad leaf species entering the host plants through wounds. It occurred on living sissoo, siris, babul, khair, bamboo, gold mohur, neem, mulberry, mundani, areca palm, coconut palm, *Pongamia glabra*, casuarina, *Cassia javanica* and *C. siamea*, all over the plains and the subtemperate region of the hills. *G. australe* (Fr.) Pat. grows on wood, East Nepal and Khasi hills; Arnigadh, Mussoorie, on *Grevillea* and *Coffea* roots, South India (McRae), India. Bakshi (1971) also found *G. subtornatum* on logs in Darjeeling.

G. lucidum grows on a wide variety of woods, typically on dead or dying trees, primarily on deciduous woods, especially oak, maple, elm, willow, sweetgum, magnolia, locust, and in the Orient, on plums. It is found on stumps, especially near the soil interface, and occasionally on soils arising from buried roots, occurring from May through November, and more common in warm temperate regions. In the southeastern and southwestern United States, *G. lucidum* was frequently found in oak forests. In the northeastern states, this species is most common in maples groves (Stamets, 1993).

In 1983, the mushroom encyclopedia had the record about 113 races of *Ganoderma* found in the natural condition all over the world , 86 of which (76% of the total races) are in China (Rakpratoom and Santikijroongruang, 1995).

The Royal Institute (1996) reported some species of Ganodermataceae found in Thailand. They are *G. applanatum* (Pers. ex S.F. Gray) Pat., *G. lucidum* (Fr.) Karst., *Amauroderma rugosum* (Blume ett Nees ex Fr.) Torr. and *A. sericatum* (Lloyd) Wakefd. Several species of *Ganoderma* have been especially in the cool and high moisture areas. It is not only found in the forests, but also in the urban areas (Thaithatgoon, 1995). They were found in the following parts of the country and provinces (Thaithatgoon, 1996):

Northern Part: Chiang Rai, Chiang Mai, Lamphun, Mae Hong Son, Lampang, Payao and Phetchabun; North-Eastern Part: Loei, Khon Kaen, Si Sa Ket, Ubon Ratchathani, Nakhon Ratchasima, Surin, Mukdaharn, Kalasin, Chaiyaphum, Nakohrn Phanom and Sakon Nakhon; Central Part: Nakhon Sawan, Bangkok, Nakhon Pathom, Suphan Buri, Ayuthaya, Pathum Thani, Samut Sakhon, Samut Songkhram, Chai Nat and Uthai Thani; Eastern Part: Samut Prakan, Chon Buri, Chachoengsao, Rayong, Chanthaburi and Trat; Western Part: Kanchanaburi and Ratchaburi; and Southern Part: Chumphon, Surat Thani, Nakhon Si Thammarat, Krabi, Songkhla, Narathiwat, Ranong and Prachuap Khiri Khan.