

CHAPTER 5

DISCUSSION

The genus *Astraeus* is associated with a wide range of tree species around the world and particularly dipterocarps in Thailand, however knowledge of its hosts is far from complete. *In vitro* experiments have shown that *Astraeus* can form associations with *Dipterocarpus alatus* Roxb. ex G. Don, *Eucalyptus camaldulensis* Dehnh. (Myrtaceae), and *Pinus densiflora* Sieb. and Zucc. (Pinaceae) (Phosri *et al.* 2007; Sangwanit, 1991). Plots were dominated by *Dipterocarpus tuberculatus* var. *tuberculatus*, *Dipterocarpus obtusifolius* var. *obtusifolius*, and *Shorea obtusa*, as well as *Quercus kerrii* Craib, *Gluta usitata* (Wall.) Hou, and *Dalbergia cultrata* Grah. ex Bth. The study sites also included many grasses and other herbs, treelets, and vines consistently growing in areas that produce *Astraeus* sporocarps. Most *in vitro* studies have focused on tree species as *Astraeus* hosts, however it is possible that non tree species are also *Astraeus* hosts and having faster growth rates which may be better candidates for inoculation trials.

The genus *Astraeus* in Asia has been taxonomically studied in the last decade. *Astraeus* in Thailand was thought to be only *A. hygrometricus*. Phosri *et al.* (2004, 2007) showed that *A. odoratus* is a separate species and is commonly found throughout the north and north-east. Morphologically the two species are very similar, but *A. hygrometricus* sporocarps tend to have a whiter color and more basidial rays once they open (5-12 compared to 3-9 rays for *A. hygrometricus* and *A. odoratus*, respectively).

Further differences are apparent on a microscopic scale. The basidiospores of *A. odoratus* are slightly smaller (8.75-15.2 μm , 7.5-12 μm for *A. hygrometricus* and *A. odoratus*, respectively) and have longer and narrower spines. *Astraeus asiaticus* is another species in Thailand, but was not encountered in this study.

This survey of *A.odoratus* sporocarp yield over two years with very different rainfall and consequent fire regimes allows for interesting insights into the ecology of this species. The results show that fire is not a prerequisite for *A. odoratus* sporocarp production because sporocarps were found in both unburned and burned areas of DOF in 2010, however in 2011 no *Astraeus* sporocarps were found in either condition. This suggests that other factors are influencing sporocarp production besides fire. Rainfall for 2010 and 2011 were very different. Between January and May 2010, 76.3 cm of rain had fallen, while at that same time in 2011, 396.5 cm had fallen. This rainfall variation had a significant effect on the fire regime since in 2010 fires were pervasive and many areas were burned twice. In contrast, fires in 2011 were almost absent as the leaf litter never reached a critically low moisture level that would allow it to sustain a fire. The amount, average fresh weight, and dimensions of sporocarps from the burned area were significantly larger than the unburned area in 2010. The burned area surveyed for 2010 was much larger than the unburned area so it is difficult to make direct comparisons between the two conditions.

Weather is an important factor controlling *A. odoratus* sporocarp production.

Astraeus hyphae can encyst into sclerotia during unfavorable conditions including water stress and nutrient scarcity. Sclerotia can then develop hyphae, or under appropriate

conditions specific to the species, produce sporocarps. Buscot (1993), studying *Morchella* sp., North America's famous pyrophyllic fungal delicacy, found that sclerotia are only formed once all available nitrogen has been depleted. Some commercial production operations of *Morchella* sp. have been attempted, but to date no one has published a reliable method for consistently inducing primordia formation from *Morchella* sclerotia. Soil at CD from points of *A. odoratus* collection before and after a fire showed a sharp decline in nitrogen which was lost during fire. Trappe and Cormack (2009) conducted soil analyses and examined fungal communities in Ponderosa pine forests in Oregon subjected to controlled burns found that specific fungal guilds were present where the C:N ratio was either above or below a threshold of 26:1. Of 24 species of mushrooms collected only one species was present in soils both above and below the C:N ratio of 26:1, all other species were present in either one or the other, but not both. Autumnal burns significantly reduced the C:N ratio and produced specific fungal species that were also present in unburned areas with a similarly low C:N ratio. In the present study, the C:N changed in burned *Astraeus* habitat immediately after a fire as nitrogen was lost. Whether this is a catalyst for *Astraeus* sporocarp production is a topic that can be explored in future research.

This survey of *Astraeus* sporocarp production in burned and unburned areas was complicated by many other people collecting *Astraeus* at the study sites. Locals were employed to assist with collection, however many people came from other places and entire tracts of forest were quickly scoured during the short period in which *Astraeus* sporocarps are underground and still edible. The collection method involves digging up

areas with a metal claw or crowbar (Figure 3.2) and it is reasonable to assume that this can have an adverse effect on the underlying host roots, soil structure, and hyphae. Furthermore, only immature sporocarps are collected which do not have a chance to release spores before they are removed from the forest. Only sporocarps that are overlooked or emerge after an area has been harvested have a chance to open and spread their spores. 2010 was a bumper year for *Astraeus* collection and it is possible that intensive harvesting contributed to the dearth of sporocarps produced in 2011.

Spatial autocorrelation analysis of *Astraeus* sporocarp clusters collected at CD were not randomly distributed, however the method of collection was not entirely random as the local collectors employed had specific places that they knew were areas of high yield. At the CD site gatherers tended to stay along the ridge running through the plot and generally avoided the steep slopes of the western and eastern sides, or ascending the steep knoll in the southern end of the plot. Locals generally avoided looking extensively in unburned areas. There was a consensus that *Astraeus* does not need fire to produce sporocarps, however most stated that yield is much greater in burned areas. Whether this is a result of specific conditions created by fire that induce sporocarp formation or whether fire simply makes it easier to find submerged sporocarps once the leaf litter has been removed can be examined in future research.

A small amount of *Astraeus* was found in unburned patches with particularly gravelly soil at the CD site in 2010. At the DS site *Astraeus* was found under a thick leaf litter layer with rich soil. Locals highlighted areas under burned logs as places likely to produce a high yield and this is something that can be further examined. Based on this

initial survey, the soil and vegetation conditions where *Astraeus* sporocarps are found varies significantly. Helfferich (2005) mapped the location of individual *Morcella* sp. basidia after a fire in Alaska using a GPS accurate to 5 cm. They found that the distribution was very clustered though the mechanism that caused sporocarp development in the specific areas was unclear.

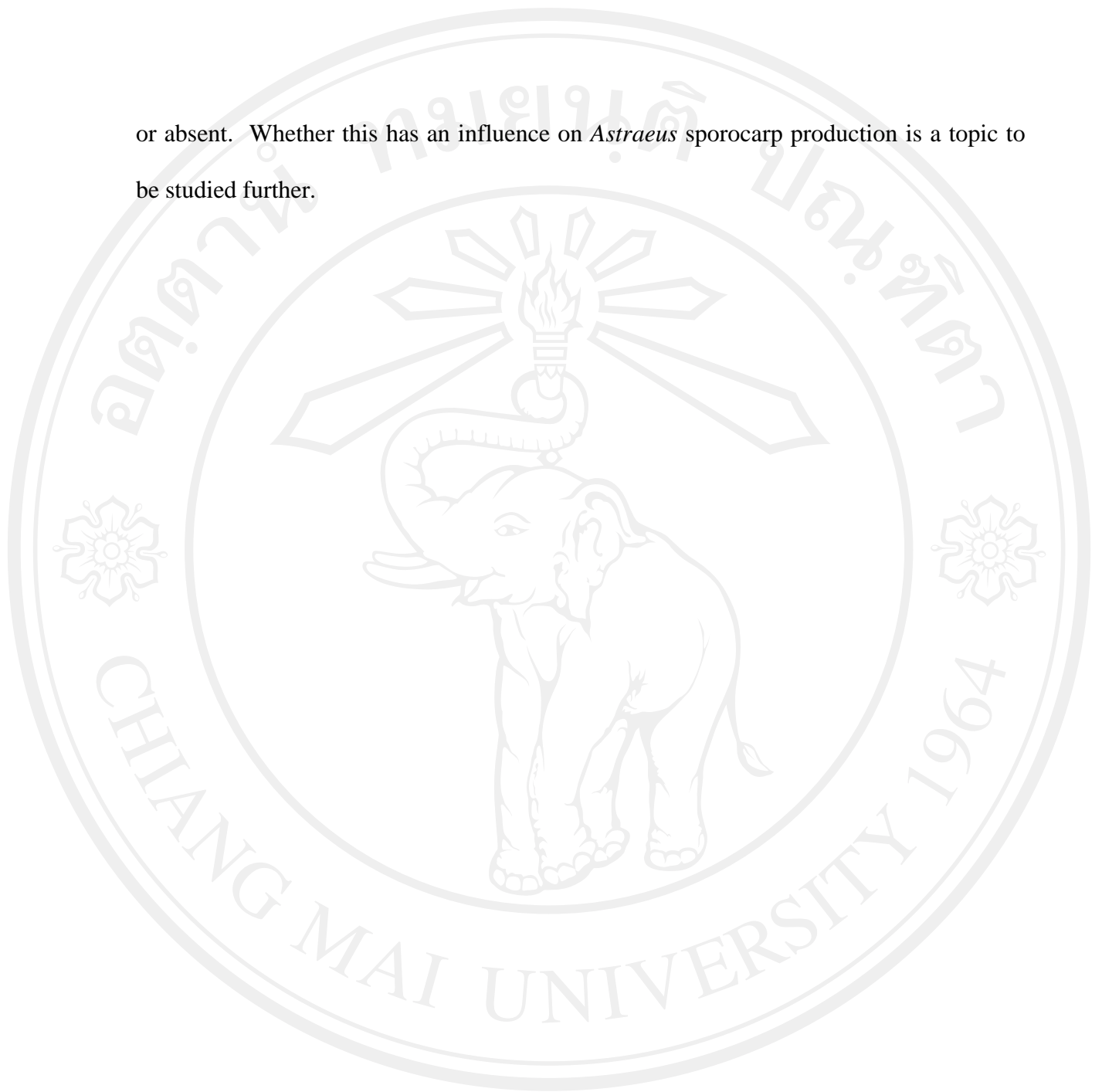
Fire, a frequent and characterizing component of DOF, has been previously studied. Stott (1988) found that a heat sensitive paint with a threshold of 35°C at a depth of 5 cm was not triggered during a fire. Wanthongchai *et al.* (2011) showed that the length of period between fires did not significantly affect soil temperatures in DOF. They measured ambient soil temperature with thermocouples 5 minutes after a fire and found that soil at 1 cm did not exceed 48°C in either frequently or infrequently burned stands. Gradient indicators at a range of depths showed that even at a depth of 2 cm heat will not always be significantly greater than air temperatures experienced during the hot season. The soil structure of DOF, which is often very compact, rocky, eroded, and has little organic matter, causes minimal heat transfer into the soil profile and allows for the survival of underground parts of many DOF plants and fungi.

Though the effects of fire on soil microbe communities has been extensively researched in other parts of the world, particularly in boreal forests in North America, little research has been conducted on this topic in south-east Asian DOF. Treseder *et al.* (2004) used hyphae length of soil fungi and microbial respiration to estimate abundance in chronosequenced stands of boreal forests in Alaska. They found that a year after a fire there was no significant difference in fungal biomass, however 6-25 years after a fire

there was a significantly lower fungal biomass than the control site which hadn't been burned in 85 years. Results from the spread plate technique shows that the amount of fungal microbes in DOF surface soil decreases immediately after a fire. Widden and Parkinson (2011) also showed that the fungi composition in boreal forests is changed by fire. They grew soil fungal cultures in Petri dishes with aqueous extracts of burned and unburned leaf litter to show that certain fungi, including *Trichoderma polysporum* and *Penicillium janthinellum*, were inhibited by the fire. *Cylindrocarpon destructans* was not inhibited and *Gelasinospora* sp. was only found in burned plots. The present study demonstrates that initially after a fire there is a substantial decrease in the overall level of fungal microbes in surface soil, but further research needs to be conducted in order to determine the specifics of *Astraeus*' life cycle as well as the long term changes in DOF fungal species composition resulting from fire and.

The soil nutrient analysis in *Astraeus* habitat showed that immediately after a fire there were significant changes in all measured characteristics relative to the control where pH, EC, P, and K all increased, while moisture, organic matter, and N all decreased. By the rainy season nutrient levels and soil moisture had returned to roughly the same level as the control, as ash and fire residues were leached away and the soil was becoming saturated with water. Electrical conductivity and pH remained relatively high compared to the control during the rainy season. Hirobe *et al.* (2003) found that there are larger amounts of inorganic N and faster N mineralization in forest that had longer fire prevention times. This work shows that between a fire and the rainy season, N is limited

or absent. Whether this has an influence on *Astraeus* sporocarp production is a topic to be studied further.



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