ภาวะไมคอร์ไรซ่าของไม้ล้มลุกในพื้นที่ใช้ประโยชน์แบบต่างๆ ณ ตำบลนาแห้ว อำเภอนาแห้ว จังหวัดเลย

บทคัดย่อ

ของ

ปนัดดา ลาภเกิน

เสนอต่อบัณฑิตวิทยาลัย มหาวิทยาลัยศรีนครินทรวิโรฒ เพื่อเป็นส่วนหนึ่งของการศึกษา
ตามหลักสูตรปริญญาการศึกษามหาบัณฑิต สาขาวิชาชีววิทยา
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การศึกษาเรื่องภาวะไมคอร์ไรซ่าของไม้ล้มลุก ณ ศูนย์วิจัยมหาวิทยาลัยศรีนครินทรวิโรฒ ตำบลนาแห้ว อำเภอนาแห้ว จังหวัดเลย พืชที่ศึกษาส่วนใหญ่จัดเป็นพวกวัชพืช ศึกษาโดยเก็บตัวอย่างรากพืชจากพื้นที่ใช้ประโยชน์แบบต่าง ๆ (พื้นที่การเกษตร พื้นที่รกร้าง และป่าไม้) มาตรวจสอบทั้งหมด 58 ชนิด พบว่ารากพืช 57 ชนิด (98%) มีเชื้อราอาร์บัสคูลาร์ ไมคอร์ไรซ่า หญ้าแห้วหมู (*Cyperus rotundus* L.) เป็นพืชเพียงชนิดเดียวที่ไม่พบเชื้อรา ผักโขม (*Amaranthus viridis* L.) หญ้าสามเหลี่ยม (*Cyperus* sp.) และ ย่านลิเภา (*Lygodium flexuosum* (L.) Sw.) มีเปอร์เซ็นต์การเข้าไปอยู่อาศัยของเชื้อราน้อยกว่า10 % ส่วนผักยอดเดียว และ เกล็ดลิ่น *Phyllodium longipes* (Craib) Schindl. จะมีเชื้อราอาร์บัสคูลาร์ ไมคอร์ไรซ่า เฉพาะรากที่เก็บมาจากบางพื้นที่ สาบเสือ (*Chromolaena odorata* (L.) R. M. King & H. Rob.) เป็นวัชพืชที่พบในทุกพื้นที่ มีเปอร์เซ็นต์การเข้าไปอยู่อาศัยของเชื้อราระหว่าง 27% ถึงมากกว่า 90% พืชการเกษตรที่นิยมปลูกในท้องถิ่นได้แก่ ข้าวเหนียว (*Oryza sativa* L. var. *glutinosa* L.), ถั่วลิสง (*Arachis hypogaea* L.) กระชายดำ (*Kaempferia parviflora* Wall. ex Baker) และหม่อน (*Morus alba* L.) มีเชื้อราอาร์บัสคูลาร์ ไมคอร์ไรซ่าเจริญอยู่ร่วมกัน ผลจากการศึกษาครั้งนี้ แสดงว่าเชื้อราอาร์บัสคูลาร์ ไมคอร์ไรซ่ามีบทบาทสำคัญในระบบการเกษตรป่าไม้ ผลผลิตทางการเกษตร ในการฟื้นฟูพื้นที่โดยปล่อยให้เป็นพื้นที่รกร้างระยะเวลาหนึ่ง และ การเปลี่ยนแปลงแทนที่ของป่าระยะต่าง ๆ

MYCORRHIZAL STATUS OF HERBACEOUS PLANTS
IN DIFFERRENT LAND USE TYPES
AT NA HAEO, LOEI PROVINCE

AN ABSTRACT

BY

PANADDA LARPKERN

Presented in partial fulfillment of the requirements
for the Master of Education degree in Biology
at Srinakharinwirot University
April 2003

Panadda Larpkern. (2003). *Mycorrhizal status of herbaceous plants in different land use types at Na Haeo, Loei province.* Master Thesis, M. Ed. (Biology). Bangkok: Graduate School, Srinakharinwirot University. Advisor Committee: Dr. La-aw Ampornpan and Professor Dr. Shivcharn S. Dhillion.

The study on the mycorrhizal status of herbaceous plants was carried out at Srinakharinwirot University-Field Research Station (SWU-FIRS), Tambon Na Haeo, Loei province. Most of the plant species in this study are classified as weeds. Roots of 58 plant species were collected from areas with different land use types (agricultral field, fallow and forest). Colonization by arbuscular mycorrhizal (AM) fungi was found in the roots of 57 species (98%). Only *Cyperus rotundus* L. was not colonized by AM fungi. Others three, *Amaranthus viridis* L., *Cyperus* sp. and *Lygodium flexuosum* (L.) Sw., had less than 10% colonization. Phak yod dieo (unidentified) and *Phyllodium longipes* (Craib) Schindl. were not colonized at some sites. The weedy species *Chromolaena odorata* (L.) R. M. King & H. Rob., that was found in every site had colonization ranging from 27% to more than 90%. The most common crops grown in the area, glutinous rice (*Oryza sativa* L. var. *glutinosa* L.), groundnut (*Arachis hypogaea* L.), kra chai dam (*Kaempferia parviflora* Wall. ex Baker) and mulberry (*Morus alba* L.) were colonized by AM fungi. This study suggest that arbuscular mycorrhiza must play an important role in this agro-forestry system, in food production, in restoring fields through fallow periods and in forest succession.

MYCORRHIZAL STATUS OF HERBACEOUS PLANTS IN DIFFERRENT LAND USE TYPES AT NA HAEO, LOEI PROVINCE

THESIS

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THESIS

MYCORRHIZAL STATUS OF HERBACEOUS PLANTS IN DIFFERENT LAND USE TYPES AT NA HAEO, LOEI PROVINCE

By

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Panadda Larpkern

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Introduction

Background

The forest of Thailand once covered more than half of the country's land area, but today small fragments remain. In 1936, 70% of the country's land area was covered by forest. By 1998 the forest had decreased to 25.28% (RFD. 1998). The main causes of deforestation are the uncontrolled expansion of commercial timber industry, and to some lesser degree agricultural conversion (Panayote and Parasuk. 1990). Large areas of the forest are cleared for agriculture, especially in Northeast, due to the increase in the need for agricultural areas to supply food for population growth, and for export of cash crops like rice, cassava, sugarcane, corn and jute (Sponsel and Natadecha. 1998). Shifting cultivation remains the common form of agriculture throughout these areas. The forests are cleared by slash and burn before cultivation. Forestland cleared can be cropped for a limited number of years because of soil degradation and weed invasion. Thus, the farmers expand into areas normally forested because of their cheap holding (Santasombat. 1995). Abandonment from agriculture provides time for plant community to re-establish to form a fallow phase (Santasombat. 1995, Kellman and Tackaberry. 1997). Deforestation and consequent loss of biodiversity and change in land use may alter key processes, such as nutrient cycling and soil organic matter development, on which sustainable ecosystem functioning depends (Kellman and Tackaberry. 1997). Furthermore, the loss of critical organisms, such as mycorrhizal fungi, have been linked to altering of ecosystem function elsewhere (Perry *et al.* 1989, Read. 1991).

Mycorrhizal fungi form mutualistic associations with the roots of land plants, providing the plant with phosphorus and other nutrients in exchange for photosynthate (Allen. 1991, Smith and Read. 1997). Mycorrhizal fungi have been hypothesized to be important in recovery of disturbed and highly exploited systems because they have been shown to increase nutrient uptake, establishment, drought resistance and survival of plants in the field (Dhillion and Ampornpan. 1992, Marschner and Dell. 1994, Gange *et al.* 1993, Sylvia *et al.* 1993). The most common group of mycorrhizal fungi is the arbuscular mycorrhiza (AM), which colonize the roots of over 80% of land plant families (Dodd. 2000). Mycorrhizal fungi have for long been recognized as an important symbiosis in the tropical forest. Most plant species rely on mycorrhizal fungi for uptake of nutrients and water. These associations are obligate for many tropical plants (Janos. 1980a, b., Gianinazzi-Pearson and Diem. 1982). In Thailand over 80% of the forest trees are known to form symbiotic associations with AM (Chalermpongse and Ramanwong. 2000). Therefore, mycorrhizal fungi are likely to be important in ecological processes leading to reforestation.

In agricultural systems, mycorrhizal fungi have been shown to enhance the economic viability of many crop plants, used as forage or biomass crop, improve stand establishment, and give higher yields (Dhillion and Ampornpan. 1992, Nopamornbodi. 1999). Mycorrhizal importance in high input systems is unclear due to their sensitivity to fertilizers (Johnson. 1993) and biocides (Sukarno *et al.* 1996). However the associations are likely valuable and needed in agro-forestry systems which use low fertilizer inputs, particularly nitrogen (N) and phosphorus (P). Furthermore, the mycorrhizal role and status in traditional agricultural systems is not known. The primary functions of traditional fallow systems are to restore soil fertility and to reduce weed pressure as well as encouraging sustainable management systems and conservation (Dhillion. 2000). Mycorrhizal fungi are important in structuring early successional communities by enhanced seedling establishment (Gange *et al.* 1993). Thus, fallow and forest systems may depend on the presence of mycorrhiza for aiding the establishment of plant. Nevertheless, little is known about the mycorrhizal status of fallows in tropical areas.

Objective of the study

To obtain information about the mycorrhizal status of herbaceous plants in different land use types in an agro-forestry system in northeastern Thailand.

Significance of the study

AM fungi are utilized as biofertilizers. Most studies have been done in crop species. There are only a few studies of mycorrhizal plants in nature, especially the herbaceous. This study will build up the information on the AM status of plants in natural environment in general. In addition, the research results could be used as an advisory concerning management and restoration of agro-forestry systems.

Scope of the study

The study was carried out at Srinakharinwirot University-Field Research Station (SWU-FIRS), Tambon Na Haeo, Loei province (Fig. 2 and 3). The roots of various herbaceous plants in different land use types were examined. Land use types in this study are divided into 3 different types, which are agricultural fields with different crops (n=4), fallows in different phase (n=3), and forest (n=1) (Fig. 4-11).

Definition of terms

1. ***Mycorrhiza*** is a symbiotic relationship between plant and fungus localized in a root or root-like structure in which energy moves primarily from plant to fungus and inorganic resources move from fungus to plant (Allen. 1991).

2. ***Herbaceous plants*** are plants with a small or rather small stature, soft and green, containing little woody tissue, and the plant or an aerial shoot lasts only as long as necessary to develop the reproductive organ (Collocott and Dobson. 1981).

3. ***Mycorrhizal plants*** are plants containing AM fungal hyphae within the root or root tissues, in which there usually is a symbiotic relationship (Allen. 1991).

4. ***Non-mycorrhizal plants*** are plants in which the root or root tissue may be colonized with AM fungi to a limited extent, but which do not derive any benefit from them; or can also be plants that reject mycorrhizal fungi (Allen. 1991).

5. ***Obligatorily mycorrhizal plants*** are plants that will not survive to reproductive maturity without being associated with mycorrhizal fungi in the soil or at the fertility levels of their natural habitats (Janos. 1980b).

6. ***Facultatively mycorrhizal plants*** are plants that benefit from mycorrhizal associations only in some of the least fertile soils in which they naturally occur (Janos. 1980b).

Chapter 2
Literature Review

The term "Mycorrhiza" was used by A.B. Frank in the late 1800s to characterise the association between plant roots and soil fungi. The partners in this association are members of the fungus kingdom (Basidiomycetes, Ascomycetes and Zygomycetes). and most vascular plant in nearly all ecosystems (Allen. 1991, Read. 1991). The mycorrhizal association is widespread among plant families and appear to have evolved and spread with the earliest land plants (Allen. 1991, Allen and Allen. 1992). A plant may get infected by several mycorrhizal fungi, and form symbiosis with them. However, some members of a few families, including Brassicaceae and Zygophyllaceae lack the mycorrhizal symbiont (Dhillion and Zak. 1993).

Classification of mycorrhiza

Based on the mode of hyphal penetration, mycorrhiza is divided into two basic kinds, endomycorrhiza (hyphae penetrating the cell wall), and ectomycorrhiza (no penetration of the cell wall). In some cases, the combination of endomycorrhiza and ectomycorrhiza is referred to as an ectendomycorrhiza (Allen. 1991). Involving different groups of fungi and host plants, and distinct morphology patterns, seven types of mycorrhiza have been recognised. They are vesicular-arbuscular mycorrhiza (VAM), also called arbuscular mycorrhiza (AM), ectomycorrhiza (EM), ectendomycorrhiza, arbutoid mycorrhiza, monotropoid mycorrhiza, ericoid mycorrhiza and orchid mycorrhiza (Smith and Read. 1997). Among the types of mycorrhiza observed in nature, arbuscular mycorrhiza (AM) is found in the vast majority of land plants with approximately 90% of world's herbaceous species (Dhillion and Zak. 1993).

Arbuscular mycorrhiza (AM)

Taxonomically, AM fungi belong to the Class Zygomycetes and the order Glomales. They fall under three families (Glomaceae, Acaulosporaceae, Gigasporaceae) and six genera (*Glomus, Sclerocystis, Acaulospora, Entrophospora, Gigaspora, Scutellospora*) (Dodd. 2000).

Table 1 Classification of AM fungi (after Dodd. 2000)

Class	Order	Families	Genera
Zygomycetes	Glomales	Glomales	*Glomus* *Sclerocystis*
		Acaulosporaceae	*Acaulospora* *Entrophospora*
		Gigasporaceae	*Gigaspora* *Scutellospora*

AM infection

The development of AM infection begins with formation of an appressorium on the root surface by external hyphae originating from spores or other infected roots in the soil (Fig.1a). Like pathogenic fungi, AM fungal hyphae penetrate within or between the epidermal cells from the appressorium then spread inter- and intra-cellularly within the outer cortical cells (Gianinazzi-Pearson and Diem. 1982, Smith and Read. 1997). Apart from the mycelium, arbuscules and vesicles are typically formed in root tissue.

Arbuscules are where the nutrient exchanges between the host and the symbiont take place. They are formed intra-cellularly by repeated bifurcation of an infecting hypha, are relatively short-lived, and they degenerate to form a granular mass of fungal wall material within the host cell (Gianinazzi-Pearson and Diem. 1982) (Fig. 1b).

Vesicles are most often ovoid swellings with lipidic contents terminally formed in the infecting hyphae and thought to act as temporary storage organs (Gianinazzi-Pearson and Diem. 1982) (Fig 1c).

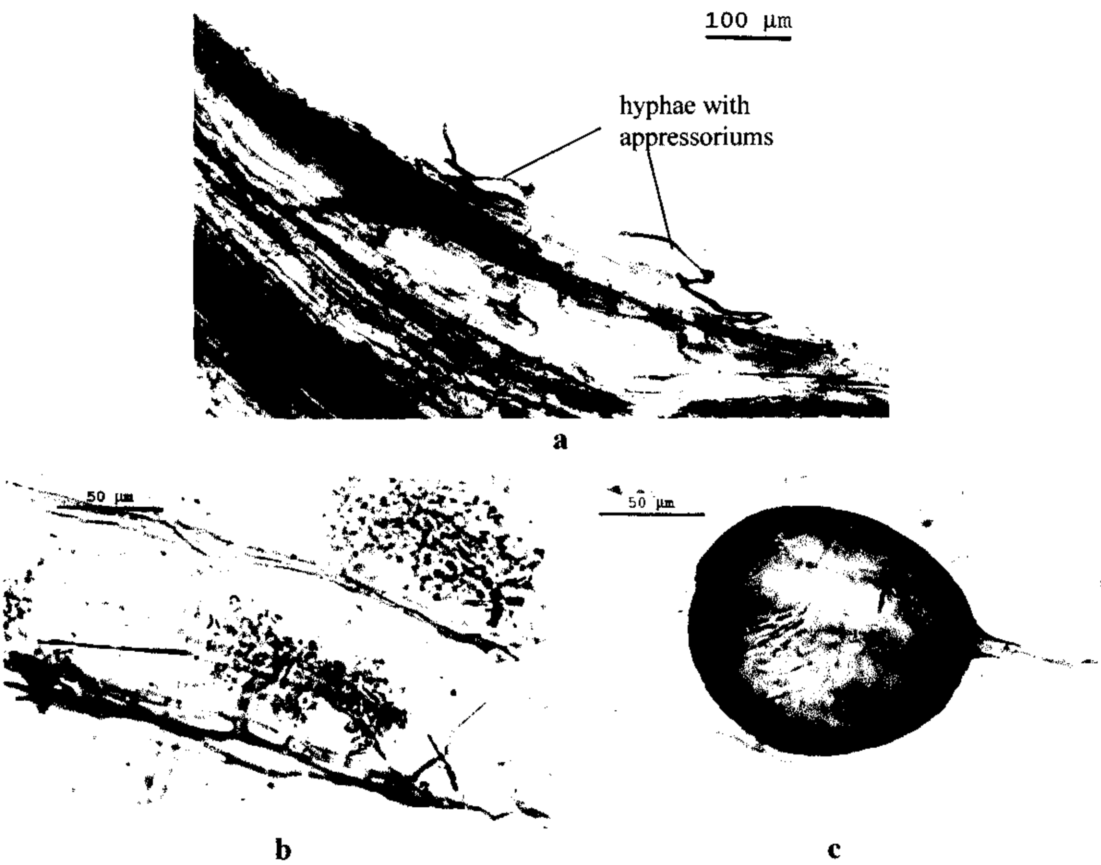


Figure 1 Arbuscular mycorrhizal structures in roots: **a.** infected root in *Sida rhombifolia* L., **b.** arbuscules in *Crassocephalum crepidioides* (Benth.) S. Moore (Asteraceae), **c.** vesicle in *Conyza sumatrensis* (Retz.) Walker (Asteraceae)

AM fungi normally produce spores as other fungi. The size of AM spores is up to 450 µm (0.45 mm) in diameter (Smith and Read. 1997). Reproductive spores can be formed either in the root or more commonly in the soil. Some aggregate spores are also produced in sporocarps. The nature of spores are used as basic morphology for fungus identification. Unlike many of the fungi involved in other types of mycorrhiza, the AM fungi have not yet been cultured in the absence of roots or a root organ culture (Allen. 1991, Smith and Read. 1997).

Fungi differ in the manner and extent to which they colonize roots. They also differ in their capacity to form propagules. The importance of hyphae, spores and living or dead mycorhizal roots acting as inoculum, also differs among species and for the same species in different habitats. The relationships between colonization of roots and propagule formation, and between propagule distribution and abundance and subsequent mycorrhiza formation, for different fungi in field environments, are not well understood. Emphasis is also required on study of diversity within these processes with mixed populations of mycorrhizal fungi, since thus is virtually unexplored (Abbott and Gazey. 1994).

Symbiotic relationship of AM fungi and the host plant

AM fungi offers several benefits to the host plant, including improved nutritional uptake (Dhillion and Ampornpan. 1992, Marschner and Dell. 1994, Fagbola *et al.* 1998, Galvez *et al.* 2001), greater drought resistance (Sylvia *et al.* 1993), protection from pathogens (Perrin. 1990, Azcon-Aguilar and Barea. 1997) and enhanced seedling establishment (Dhillion and Ampornpan. 1992, Gange *et al.* 1993). In return, the plant provides the fungus with sugars, amino acids and vitamins essential to its growth (Smith and Read. 1997). AM fungi have a large potential host range, allowing a fungus to infect several plants in one area, and also several different fungi to infect a single plant, and they have poor means of dispersal (Smith and Read. 1997). Species rich communities will therefore suit them well, because it will be easy for the fungus to find a host. AM fungi can significantly influence plant diversity and community productivity (Van der Heijden *et al.* 1998, Burrows and Pfleger. 2002, Dhillion and Gardsjord. 2003).

The benefits of the association are related to the timing and extent of colonization of the root, and differ in their contribution to plant growth and presumably to soil aggregation (Abbott and Gazey. 1994). The extent of the symbiosis depends on soil fertility. High fertility leads to low mycorrhizal infection and poor development of symbiosis, while low fertility leads to high mycorrhizal infection and effective symbioses, if the appropriate mycorrhizal fungi are present (Johnson. 1993, Treseder and Vitousek. 2001). The beneficial effect of mycorrhiza on plant growth is prominent in phosphorus deficient soil. Phosphorus is generally considered to be the most important plant-growth limiting factor which can be supplied by mycorrhizal associations, because of the many abiotic and biotic factors which can restrict its mobility in soils (Dhillion and Ampornpan. 1992, Dhillion. 2000, Treseder and Vitousek. 2001).

AM in the ecosystem

Natural and seminatural ecosystems

In nature each mycorrhizal type is associated with an ecosystem and soil environment with distinctive characteristics in which selection has favored development of a particular range of attributes (Allen. 1991, Read. 1991). AM is an essential component in many species rich ecosystems. In various habitats in Hawaii endemic, indigenous, naturalized and cultivated species were examined for mycorrhiza. Of the 147 species examined 122 were mycorrhizal, and 89% of the latter formed AM. Mycorrhiza were most frequent in the endemic species (90.3%) and least in the indigenous (71.9%) (Koske *et al.* 1992). In traditionally managed boreal grasslands, the species diversity is high and the availability of phosphate is low. Eriksen *et al.* (2002) found AM fungi in 74 out of 82 plant species examined. AM also dominates in tropical ecosystems where soil with low phosphate availability prevail (Janos. 1980a, Read. 1991). Shamsuddin (1979) reported that out of about 200 species of Malaysian forest trees, only one lacked mycorrhiza. All forty species of Dipterocarpaceae examined, and some Pinaceae, Fagaceae and Myrtaceae had ectomycorrhiza (EM), the rest had AM. AM does also occur in many economic species which are recommended for farmers to plant e.g. *Lagerstroemia calyculata* Kurz, *Tectona grandis* L. f, *Melia azedarach* L., and for fast growing species e.g. *Tetrameles nudiflora* R Br. and *Spondias pinnata* Kurz. Along with AM fungi some trees are infected by microbes such as EM fungi and nitrogen-fixing bacteria. (Chalermpongse and Ramanwong. 2000). Janos. (1980b) stated that mycorrhiza influence tropical succession by affecting which species of plants that can subsequently occur in the community.

Agricultural systems

A lot of studies have been conducted on the mycorrhizal relationships in crops, but safe proof that mycorrhizal colonization contributes to plant growth or yield in the field is difficult to obtain, because roots are normally colonized and appropriate non-mycorrhizal controls are hard to produce. Still, McGonigle (1988) evaluated 78 field trials with AM fungi and found that inoculation resulted in an average yield increase of 37%. He could not find correlation between yield and colonization, but this can be explained by the fact that rate of colonization differs in different species (Smith and Read. 1997).

Dhillion (1992) examined the mycorrhizal associations of three varieties of rice, *Oryza sativa* L. The rice plants were positively responsive to colonization by AM fungi. He did not examine the glutinous rice variety. Dhillion and Ampornpan (1992) showed that pretransplant mycorrhizal rice plants may have better establishment possibilities than non-mycorrhizal plants. Nopamornbodi (1999) reported on the role of AM in increase of nutrient absorption in many economic plants, among them mulberry (*Morus alba* L.) and rice (*Oryza sativa* L.). Setua *et al.* (1999) did also report that mulberry showed a positive response to AM, if combined with an optimal doze of phosphate fertilizer. A lot of work has been conducted concerning mycorrhiza in groundnut (*Arachis hypogaea* L.). Ahiabor and Hirata (1994) reported positive growth response to mycorrhizal infection by two different AM fungi in this species.

Several reports state that AM fungal activity or ability to colonize plant roots may be affected by different management practices, for instance burning (Dhillion and Anderson. 1993a,b) tilling, crop rotation, fallowing (Smith and Read. 1997, Galvez *et al.* 2001) and fertilization. Laboratory experiments have shown that the efficacy of AM hyphae in the soil to act as propagules and organs for uptake of phosphorus decreases with increasing soil disturbance (Jasper *et al.* 1989, Fairchild and Miller. 1990, McGonigle *et al.* 1990a). A field study showed that maize had greater fungus colonization early in the growing season in soils under no-tillage than in moldboard plowing (McGonigle and Miller. 1993). But, disturbance may have no effect on AM colonization in soils where spore populations are big (Jasper *et al.* 1991), and spore populations may actually increase with cultivation (Kruckelmann. 1975).

Since colonized plants are often found to be better able to obtain their nutrients from the soil and to resist different kind of environmental stress, the increased uptake of soil minerals by colonized plants means that it is possible to consider reducing applications and fertilizers substantially, and at the same time obtain equivalent or even higher crop yield (Galvez *et al.*2001).

Members of some plant families may be colonized with AM fungi to a limited extent but do not derive any benefit from them and are therefore considered to be non-mycorrhizal. Allen *et al.* (1989) described nonmycotrophic plants as those that reject mycorrhizal fungi, while facultative mycotrophic plants, which are perhaps the most common group, can survive with or without these fungi. Some plant families that have nonmycotrophic species include Brassicaceae and Chenopodiaceae (Fitter and Moyersoen. 1996). A lot of weeds belong to these families. Partly because of this, weeds are commonly thought to be non-mycorrhizal. This view is changing, and the investigation of AM colonizations in some seasonal weed species in Japan shows that a high percentage of AM colonization occurs in some spring and summer weed roots (Ishii *et al.* 1998).

Increased knowledge concerning the relationship between crops, AM and weeds can be useful in low-input agriculture. Douds *et al.* (1995) showed that soil from low input plots produced greater colonization in greenhouse assays than soil from conventionally farmed plots. Boyetchko (1996) points at the possibility to select crop cultivars for susceptibility to mycorrhizal colonization where the crop derives a benefit from the symbiosis, and she points at the possibility to increase the competitive ability of the crops in presence of different weeds growing in the field.

Chapter 3
Materials and Methods

The study was conducted in the field at SWU-FIRS and in the laboratory at Department of Biology, Srinakharinwirot University. The work was conducted during the period from November 2001-October 2002.

Study sites

The SWU-FIRS (Fig. 2 and 3) is situated at the latitude 17° 29′ to 17° 31′ north and longitude 101° 04′ east, just south of the Hueang River (Thai-Laos border). Geographically, the SWU-FIRS is situated on a plateau at 523 m above sea level with 13-degree slope. The average temperature is 26 °C. The warmest month is April (max 36 °C), while December is the coldest month (min 0 °C). The area is annually influenced by the southwest and northeast monsoons. The average relative humidity is 73% and it is the highest in September (91%). The amount of rainfall is highest in May (about 206.8 mm.) and lowest in January (5.11 mm.). The soil is mainly sandy loam. The area is approximately 1019 rais (407.6 acres) in total, comprising 1008 rais (403.2 acres) of mostly mixed deciduous forest with some areas of fallows and agricultural systems (Austreng. 2001, Punyawichai and Choosang. 2000).

The sites are described in an earlier study (Austreng. 2001). In order to cover several types of crop species and fallow stages, a mulberry field and the 1-year fallow were added in this study (Fig. 3 and Table 2). The following categories of land were chosen:

1 Agricultural fields

Due to the common practice, the land would be burned and ploughed before cultivation.

1.1 The groundnut field (Fig. 4)

The groundnut field was 545 m above sea level. It had been abandoned for 5 years preceding cultivation. Chemical fertilizer (13-13-13) was applied one time after one month of cultivation. The growing period started in September and ended in December.

1.2 The kra chai dam field (Fig. 5)

The kra chai dam field was 552 m above sea level and in a slope from east to west. It had been abandoned for 2 years. Chemical fertilizer (15-15-15) was applied at planting and top-dressed with 13-13-21 for improving rhizome growth. The growing period started in May and ended in January.

1.3 The glutinous rice field (Fig. 6)

The glutinous rice field was 540 m above sea level and a quite steep slope from north to south. Rice had been cultivated there every year. Chemical fertilizer (16-20-0) was applied at sowing and top-dressed with 46-0-0 when seedling height reached 50 cm. The growing period started in May and ended in December.

1.4 The mulberry field (Fig. 7)

The mulberry field was 532 m above sea level and located near Nam Phrae (*nam*, river). The field had been used to cultivate groundnuts earlier, but the yield was low. So, the mulberry replaced it, and had been cultivated there for 2 years. Chemical fertilizer was used during growing period.

2 Fallows

2.1 The 1-year-fallow (Fig. 8)

The 1-year-old fallow was 563 m above sea level and the area sloped from west to east. It was dominated by *Imperata cylindrica* (L.) P. Beauv. It had been cultivated corn here last year, but it did not give good yield. The field was now grazed by cattle.

2.2 The 4-year-fallow (Fig. 9)

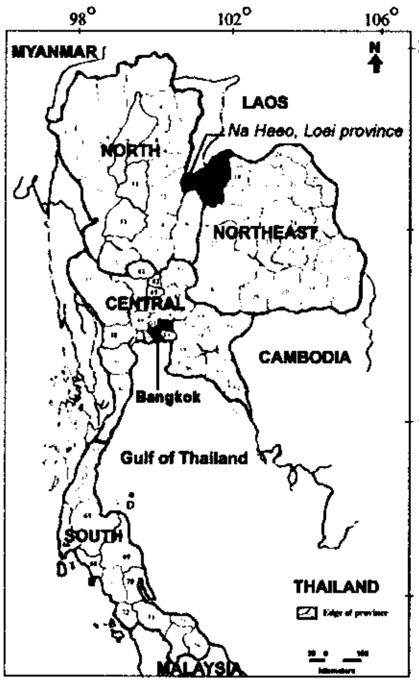
The 4-year-old fallow was 540 m above sea level and sloped from west to east. It was dominated by *Chromolaena ordorata* (L.) R. M. King & H. Rob. This species was found both as small single-stemmed herbs, and as more "shrublike" plants with many stems and more than one meter tall. The field had been used for cultivation of corn before abandonment, but it did not give a good yield. The owner had planned to utilize the land for cultivation next year.

2.3 The 27-year-fallow (Fig. 10)

The 27-year-old fallow was 550 m above sea level. It was covered with trees and difficult to distinguish from surrounding forest. Corn had been grown there, and chemical fertilizer had been used at that time. The area was by now a dense forest with a higher numbers of trees and climbers than in general. However, the average diameter of trees was small (3.46 cm.). The canopy was more or less continuous, and ground vegetation was sparse.

3 Forest (Fig. 11 a, b)

The forest was a mixed deciduous forest and situated on a plateau at about 550 m above sea level. The most common trees were *Aporosa serrata* Gagnep., *Croton poilanei* Gagnep., *Lagerstroemia calyculata* Kurz, *Memecylon edule* Roxb., *Cananga latifolia* (Hook. F. & Thomson) Finet & Gagnep. and Phan see (unidentified), while *Chromolaena odorata* (L.) R. M. King & H. Rob. was a dominate herb. The most common climbers were *Celastrus paniculata* Willd., *Fissistigma* spp. and *Jasminum* spp. In addition, sub-communities of bamboo, mature trees and planted teak were found in the forest (Austreng. 2001, Punyawichai and Choosang. 2000).



a.

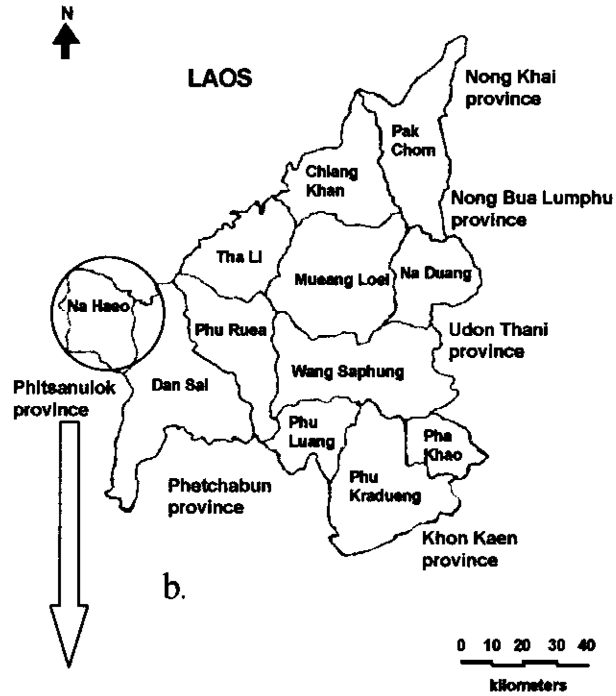


Figure 2 The study site in Na Haeo, Loei province from Ampornpan and Dhillion (2003)

a. Loei province in Northeast Thailand
b. Twelve districts in Loei porvince focusing on Na Haeo
c. Na Haeo district comprising of 5 tambons (*italic*) focusing on the 3 research sites, FIRS

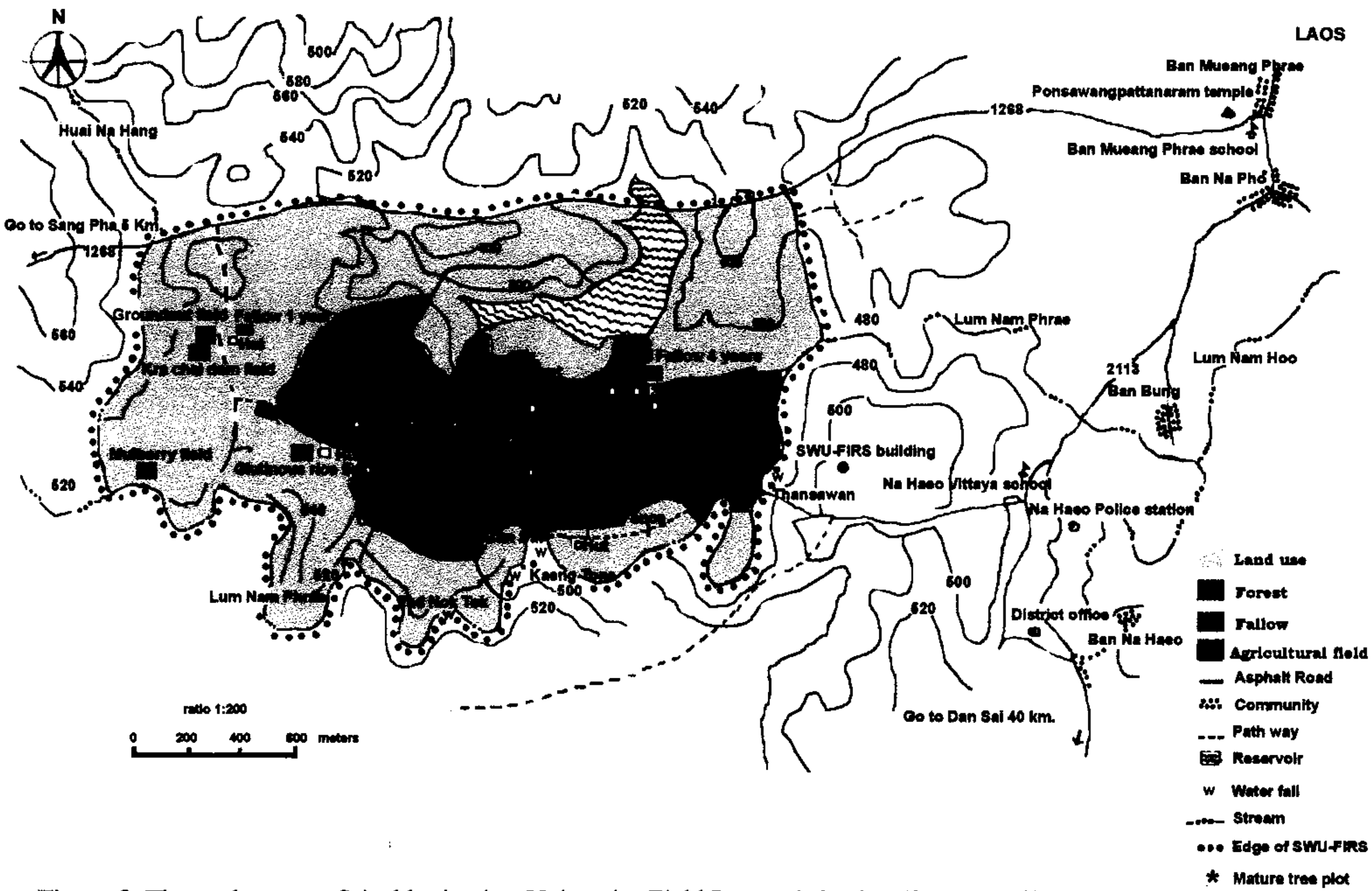


Figure 3 The study area at Srinakharinwirot University-Field Research Station (SWU-FIRS)

Figure 4 The groundnut (*Arachis hypogaea* L.) field with plants 2 months old

Figure 5 The kra chai dam (*Kaempferia parviflora* Wall. ex Baker) field with plants 5 months old

Figure 6 The glutinous rice (*Oryza sativa* L. var. *glutinosa* L.) field with plants 3 months old

Figure 7 The mulberry (*Morus alba* L.) field with plants 2 years old

Figure 8 The 1-year-fallow dominated by *Imperata cylindrica* L.

Figure 9 The 4-year-fallow dominated by *Chromolaena ordorata* (L.) R. M. King & H. Rob.

Figure 10 The 27-year-fallow dominated by young trees and climbers

a

b

Figure 11 The mixed deciduous forest
a) The transect plot
b) The mature tree plot

Table 2 Land use and management based on interviews with owners and users.

Land uses	Dominating species	Period for fertilizer application	Crop previously grown	Management before cultivation
Agricultural fields				
Groundnut	*Arachis hypogaea*	1 month after cultivation	Groundnut and ginger	Burn and plough
Kra chai dam	*Kaempferia parviflora*	1st cultivating started, 2nd growing period	Ginger, corn and glutinous rice	Burn and plough
Glutinous rice	*Oryza sativa*	1st at sowing, 2nd at 50 cm height	Glutinous rice	Burn and plough
Mulberry	*Morus alba*	Growing period	Groundnut	Slash and plough
Fallow stages				
1-year-fallow	*Imperata cylindrica*	None	Corn	Fire
4-year-fallow	*Chromolaena odorata*	None	Corn and groundnut	Fire
27-year-fallow	Young trees and climbers	None	Corn	Fire
Forest	Mixed deciduous forest	None	Never cultivated	Fire every year

Assessment of the richness of herbaceous plant species

To assess plant richness, general sample sites of the previous study of Austreng (2001), Punyawichai and Choosang (2000) were used. All plant species collected were pressed and dried. Scientific names and family level were identified.

Agricultural fields and Fallows

For assessments of species abundance in agricultural fields and fallows, transect lines were also used. Quadrats 1x1 meter were placed along the transect lines for measuring the species number in each study site (Fig. 13-19). Plant species collected were taken from outside the plots.

Forest

A 280 meter long transect line in east-west direction was set up to represent a randomly chosen spot for the forest in the study area. The transect line was at all points at least 20 meters away from the main path of the area, in an attempt to minimize edge effects. Thirteen circular plots with 1 meter radius were placed along the transect line with 20 meter distance between each plot. However, the second plot was in the middle of a big path so there were 40 meters between the first and the second plot on the transect line (Fig. 12). In order to cover the maximum number of species, stratified sampling was used for the other 5 plots with 1 meter radius among the mature trees.

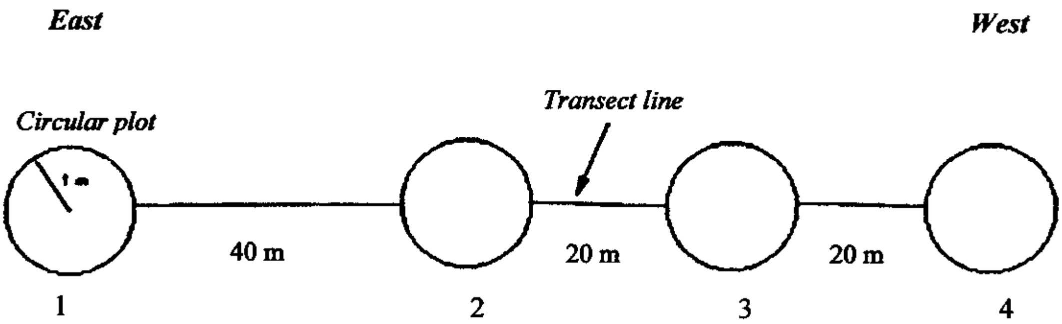


Figure 12 The transect line in the forest

Root preparation

Roots were collected from 3 individual plants of each species. Roots collected were at least 0.5-1 g. The roots were washed and preserved in 40% ethanol in glass vials until further processing.

In the fields where roots were collected, measurement of light, humidity and temperature (above-ground and below-ground in 5 cm depth) were noted (Table. 3).

Table 3 Details of physical data in each sites

Site	**Date**	**Light (x 100 lux)**	**Humidity (%)**	**Temperature (°C)**	
				Above-ground	Below-ground
Agriculture fields					
Peanut	27/12/01	932	53	29	25
Kra chai dam	28/12/01	628	98	28	16
Glutinous rice	27/11/01	1080	53	29	24
Mulberry	2/01/02	1046	55	27	25
Fallow stages					
1-year-fallow	14/02/02	728	88	33	34
4-year-fallow	4/02/02	760	58	26	24
27-year-fallow	16/02/02	40	67	22	20
Forest*	26-29/11/01	15	70	20	17

* = the detail presented by average

Soil collection for nutrient analysis

Since this work had used the same sample sites as the previous studies by Austreng (2001) and Punyawichai and Choosang (2000), the information of soil nutrients was also obtained from them. In order to assess possible relationships between AM colonization and soil properties, soil samples in the new sites were collected. In addition, soil samples from the previous sites, which had had changes in land use, were also collected, such as the groundnut field and the kra chai dam field. These had been changed from fallow to agricultural field. In each land use type, the samples were taken at 25 cm depth along transect lines at least 9 points (Fig. 13-18), using a soil core. In each site, the soil samples were combined and then air-dried.

The soil analyzes were done by The Soil and Water Analysis working group, Agrochemistry Section, Division of Agricultural Research, Ministry of Agriculture. The soil samples were analysed for pH, organic matter content (% OM), available phosphorus (P), magnesium (Mg), potassium (K), calcium (Ca) and soil texture.

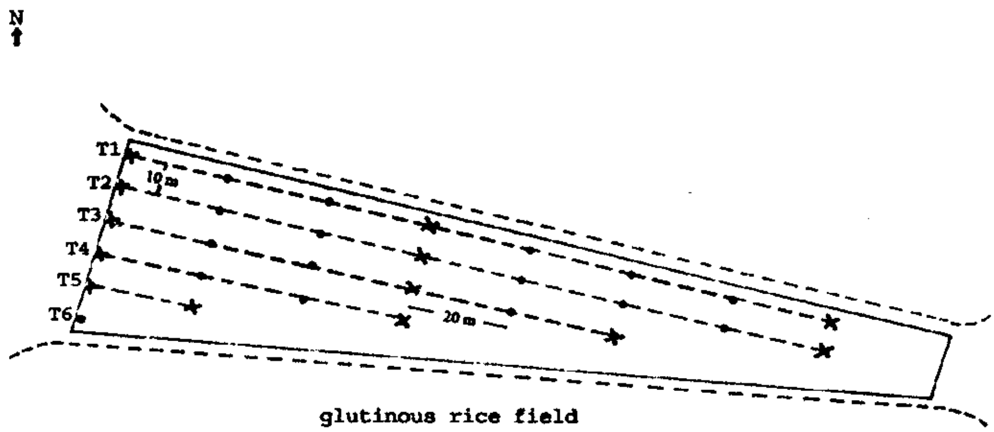


Figure 13 The transect lines in the groundnut field: T = transect lines, • = quadrats, x = quadrats and soil samples

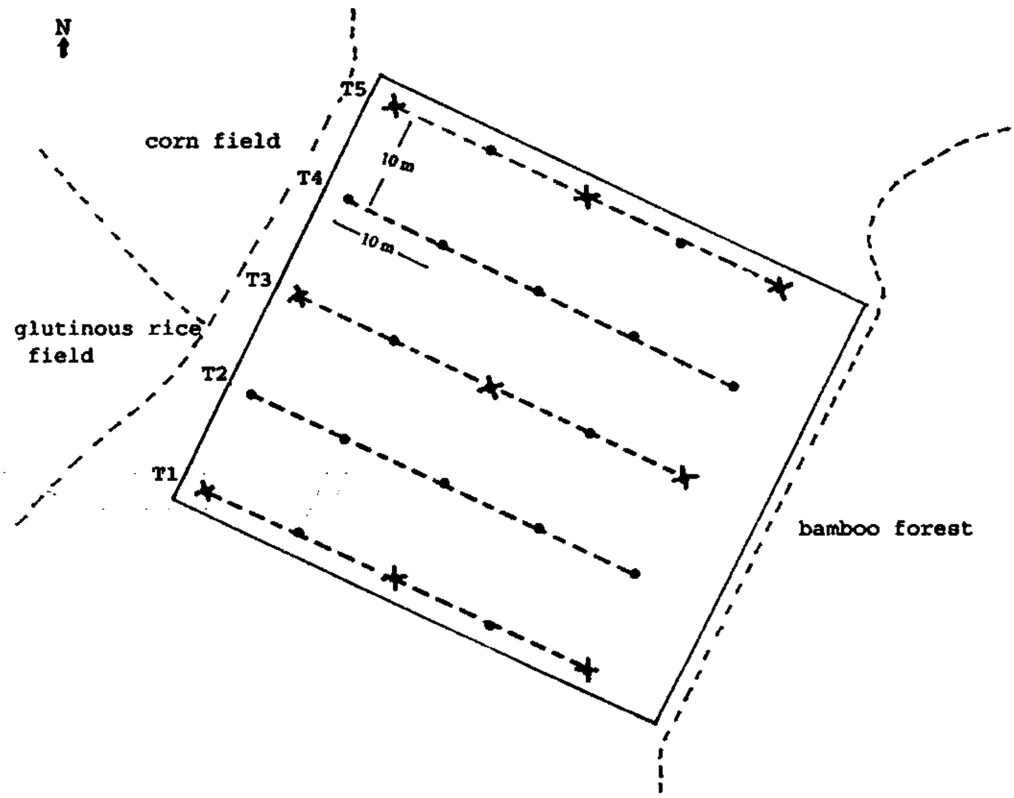


Figure 14 The transect lines in the kra chai dam field: T = transect lines, • = quadrats, x = quadrats and soil samples

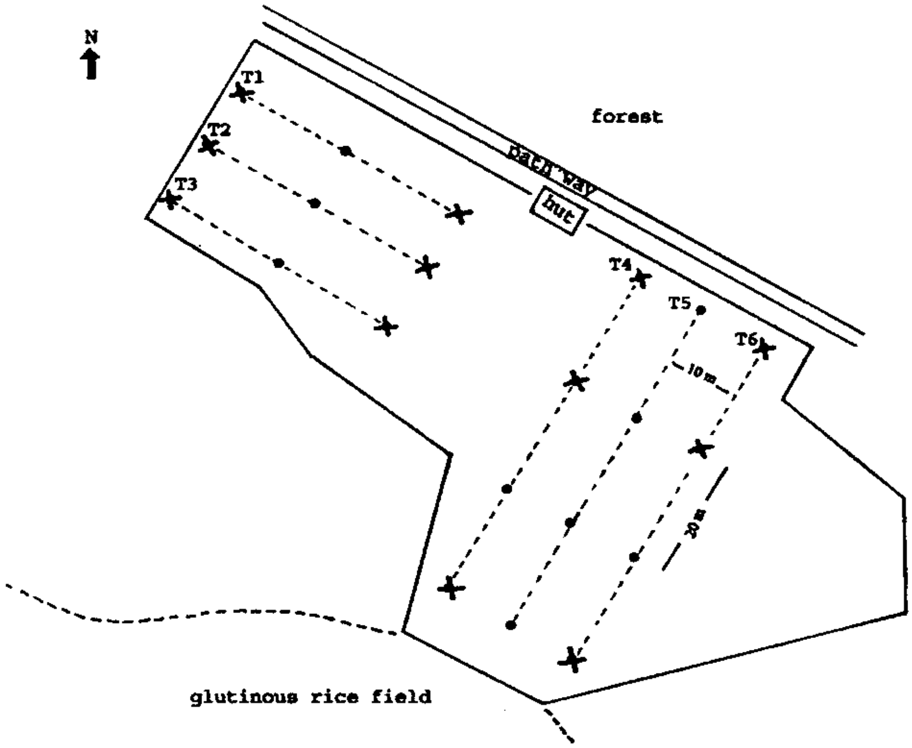


Figure 15 The transect lines in the glutinous rice field: T = transect lines, • = quadrats, x = quadrats and soil samples

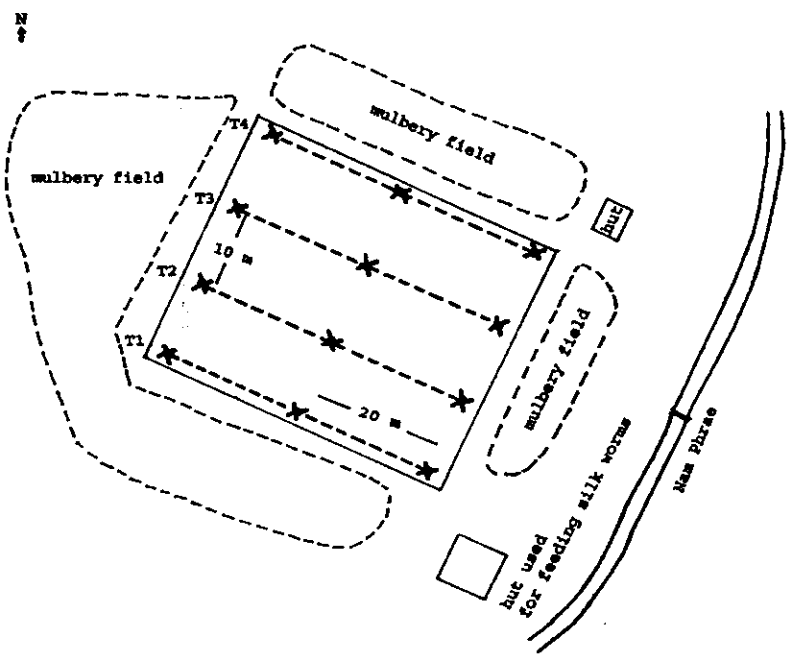


Figure 16 The transect lines in the mulberry field: T = transect lines, • = quadrats, x = quadrats and soil samples

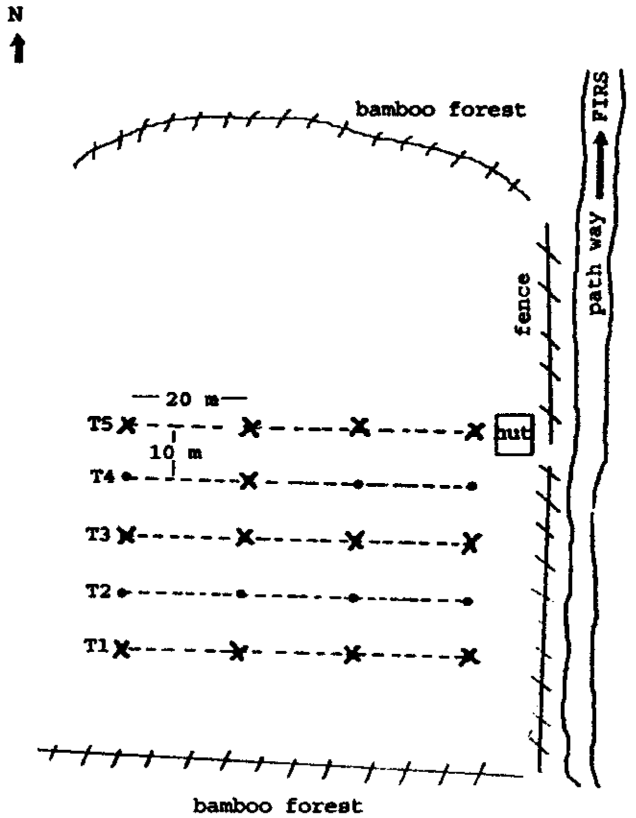


Figure 17 The transect lines in the 1-year-fallow: T = transect lines, • = quadrats, x = quadrats and soil samples

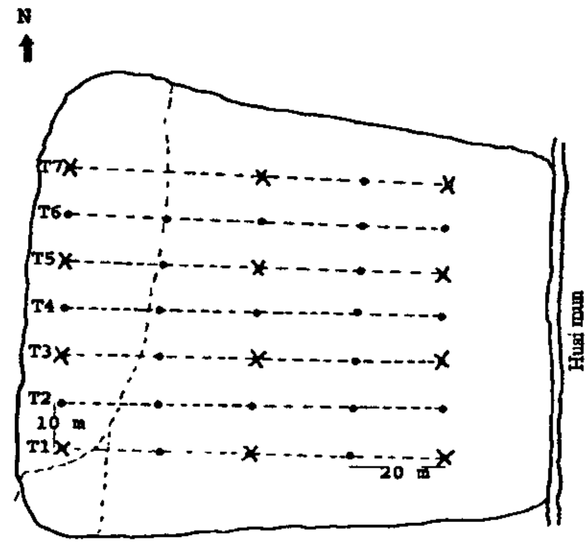


Figure 18 The transect lines in the 4-year-fallow: T = transect lines, • = quadrats, x = quadrats and soil samples

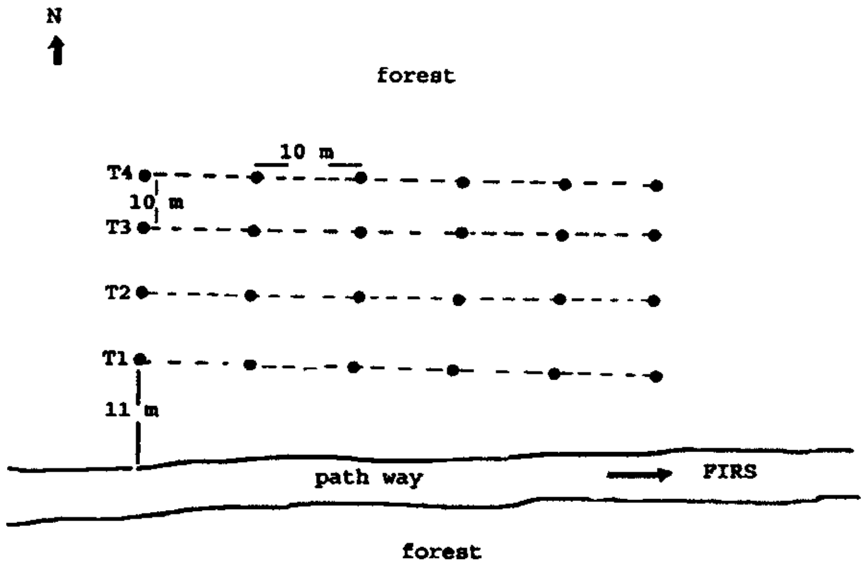


Figure 19 The transect lines in the 27-year-fallow: T = transect lines, • = quadrats

Assessment of arbuscular mycorrhizal colonization

Processing roots for mycorrhizal assessments

Mycorrhizal structures within roots are normally invisible, unless roots have been cleared in hot alkali to make them transparent and stained with a dye (Trypan blue) that binds to fungal hyphae. Observations at this level are normally used to quantify mycorrhizal associations (Phillips and Hayman. 1970, Koske and Gemma. 1989).

Root samples were rinsed and remained in water for 15-20 minutes. Then, the roots were transferred to 10% KOH and put in 80-90 °C waterbath for 30-60 minutes (which hasten the process). This process will remove the pigments and soften the tissue. The roots were again rinsed and remained in water for 15-20 minutes. If the roots were heavily pigmented, they were bleached with an alkaline solution of H_2O_2 for 10-30 minutes, and rinsed 3 times, then left in water for at least 1 hour. The roots were kept in 0.1 N HCl for neutralization of KOH and acidification in about 24 hours. The roots were stained with 0.06% trypan blue (0.06 g trypan blue in 100 ml in lactoglycerol) in waterbath at 90° C for 30-60 minutes, then stored in lactoglycerol (200 ml lactic acid, 400 ml glycerol, 400 ml distilled water).

Mycorrhizal assessments

All the roots were examined for mycorrhizal colonization using a modified version of the magnified intersection method (McGonigle *et al.* 1990b).

The slides were marked with 8 vertical lines with 7 mm distance between each line.

Roots were mounted horizontally on a slide with a coverslip. Four among the thinnest pieces of a root were placed across vertical lines on each slide. Therefore, 32 intersections were investigated on each slide. Infection was quantified from 2 to 4 slides for each individual. Sometimes only one slide was made if the roots were very few. Therefore, the intersects ranged from 30 to 348 per species.

The roots were investigated using a compound microscope at 100 times magnification. Intersections were counted in the following categories; arbuscules, vesicles, hyphae only and negative (no fungal material). To examine the intersections, the slides were moved along the vertical lines. If one or more arbuscles/ vesicles were found at an intersection, the number would be noted only once and similarly for intersections where hyphae were found. When both vesicles and arbuscles were scored at an intersect, the total number of intersects were only increased by one. The arbuscular, vesicular and hyphal colonization were calculated by dividing the count for vesicles, arbuscles and hyphae only categories respectively by the total number of intersections examined. The total root colonized by mycorrhizal fungi was calculated as the proportion of non-negative intersections. Counts were expressed as percentage.

$$\%AC = 100 \times \frac{\text{No. of intersections with arbuscules}}{\text{Total No. of intersections}}$$

$$\%VC = 100 \times \frac{\text{No. of intersections with vesicles}}{\text{Total No. of intersections}}$$

$$\%HC = 100 \times \frac{\text{No. of intersections with hyphae only}}{\text{Total No. of intersections}}$$

$$\%RC = 100 \times \frac{\text{Total No. of intersections - No. of negative intersections}}{\text{Total No. of intersections}}$$

AC = arbuscular colonization; VC = vesicular colonization; HC = hyphal colonization; RC = total root colonization

Permanent slides were made if clear structures of arbuscules vesicles and hyphae were seen in a root. Photographs of AM structures were taken when possible.

Chapter 4
Results

Soil characteristics in different land use types

The soil in the area was found to be a combination of sandy loam and sandy clay loam, and acidic with a pH ranging from 4.9-6. The organic matter content (OM) was relatively low (1-3%). The soil from the agricultural fields was found to have higher phosphorus (P) content than that in the fallow and the forest. The content of potassium (K) and magnesium (Mg) were found to be highest in the mulberry field and lowest in the kra chai dam field. The contents of calcium (Ca) showed a high variation (45-922 ppm).

Table 4 Soil characteristics in different land use types

Land use	pH	OM (%)	P (ppm)	K (ppm)	Ca (ppm)	Mg (ppm)	Texture
Agricultures							
Groundnut	5	1.01	5	90	155	41	Sandy loam
Kra chai dam	4.9	1.34	5	84	95	34	Sandy loam
Glutinous rice*	5	2	6	125	70	47	Sandy clay loam
Mulberry	5.8	2.25	5	127	707	149	Sandy loam
Fallows							
1 year fallow	5.8	1.11	3	86	922	198	Sandy clay loam
4-year-fallow*	6	1	2	100	116	73	Sandy loam
27-year-fallow*	5	2	3	87	45	61	Sandy loam
Forest*	5	3	3	122	140	103	Sandy loam

* = data from previous study

The richness of herbaceous plant species in the study area (Appendix 1-8)

Among 144 plant species totally found in the study area, there were 86 herbaceous (3 crop species), 37 tree species, 17 shrubs (1 crop), 3 bamboo species and 1 woody climber species. Regarding herbaceous plants in each land use type, there were 50, 42 and 46 species in agricultural field, fallows and forest, respectively. The sixteen most common herbaceous species [*Ageratum conyzoides, Carex condensta, Chromolaena odorata, Crassocephalum crepidioides, Cynodon dactylon, Cyperus rotundus, Desmos chinensis, Lygodium flexuosum, Paracalyx scariosa, Sida rhombifolia, Tadehagi triquetrum, Urena lobata, Vigna adenantha, Zoysia matrella,* Chi cho (unidentified) and Phak yod dieo (unidentified)] appeared in all land use types, and *Chromolaena odorata* was found in every plot of each land use type.

Arbuscular mycorrhizal (AM) colonization

Altogether, 58 plant species were examined for AM, including 55 herbaceous and 3 shrubs (Appendix 9). Three out of fifty-five herbaceous plants were crop species. Although the AM study focused on herbaceous plants, the 3 shrubby seedlings were included due to their availableness in the study area. Mulberry, one of the crop species and *Lepisanthes rubiginosa* and *Muntingia calabura* were those shrubby seedlings. Fifty-seven out of 58 species had AM structures. One species, *Cyperus rotundus,* had no root colonization. Three others, (*Amaranthus viridis, Cyperus* sp. and *Lygodium flexuosum*) had less than 10% colonization. Phak yod dieo (unidentified) and *Phyllodium longipes* were not colonized at some sites.

AM in the crop species

The most common crops grown in the area are glutinous rice (*Oryza sativa* L. var. *glutinosa* L.), groundnut (*Arachis hypogaea* L.), kra chai dam (*Kaempferia parviflora* Wall. ex Baker) and mulberry (*Morus alba* L.) (Table 5). Vesicles were observed in all crop species examined. Arbuscules were seen in groundnut and kra chai dam, while in glutinous rice and mulberry no arbuscules were found. Groundnut and kra chai dam had a relatively high percentage of AM colonization (76% and 75%), while glutinous rice and mulberry did not seem to have much (24% and 43%). In one individual of glutinous rice, AM spores were found inside the root cortex (Fig. 20). Kra chai dam was found to be infected by non-AM fungi (Fig. 21).

Table 5 Mean (± SD) of arbuscular mycorrhizal (AM) colonization in crops from agricultural fields

Species (Family)	Thai name	%AC	%VC	%HC	%RC
Arachis hypogaea L. (Fabaceae)	Thua li song	0.3±1	53±30	23±23	76±13
Kaempferia parviflora Wall. ex Baker (Zingiberaceae)	Kra chai dam	6±5	36±24	33±23	75±46
Morus alba L. (Moraceae)	Mon	0	15±0.3	28±16	43±17
Oryza sativa L. var. *glutinosa* L. (Poaceae)	Khao niao	0	7±1	17±1	24±5

AC = arbuscular colonization, VC = vesicular colonization, HC = hyphal colonization, RC = total root colonization

AM in the groundnut field

Of 22 herbaceous species found in the groundnut field (Appendix 1), 11 species were examined for AM. AM were found in all species examined (Table 6). Vesicles were found in all species, while arbuscules were seen in four species; *Chromolaena odorata, Conyza sumatrensis, Corchorus aestuans* and *Scoparia dulcis.* Most of the species examined had a relatively high percentage of AM colonization (55%-84%), the exception was *Sida rhombifolia* with only 46%.

Table 6 Mean (± SD) of arbuscular mycorrhizal (AM) colonization of herbaceous plants in the groundnut field

Species (Family)	Thai name	%AC	%VC	%HC	%RC
Ageratum conyzoides L. (Asteraceae)	Sap raeng sap ka	0	39±16	27±14	66±10
Chromolaena odorata (L.) R.M.King & H. Rob. (Asteraceae)	Sap suea	2±3	30±12	41±1	73±13
Conyza sumatrensis (Retz.) Walker (Asteraceae)	Ya dok khao	4±6	16±0.4	39±14	59±17
Corchorus aestuans L. (Tiliaceae)	Khat mon tua phu	3±4	26±4	34±5	63±6
Crassocephalum crepidioides (Benth.) S. Moore (Asteraceae)	Ya dok kham	0	21±28	34±5	55±28
Euphorbia heterophylla L. (Euphorbiaceae)	Yang ueng	0	47±30	18±2	65±29
Mimosa pudica L. (Fabaceae)	Maiyarap	0	57±22	27±23	84±11
Mitracarpus villosus (Cham.& Schltr.) A. DC. (Rubiaceae)	Ya chuk khao	0	11±14	68±9	79±6
Scoparia dulcis L. (Scrophulariaceae)	Krot nam	1±2	11±13	49±26	61±25
Sida rhombifolia L. (Malvaceae)	Ya khat	0	31±3	15±7	46±10
Urena lobata L. (Malvaceae)	Khi khrok	0	32±16	25±6	55±19

AC = arbuscular colonization, VC = vesicular colonization, HC = hyphal colonization, RC = total root colonization

AM in the kra chai dam field

Of 20 herbaceous species found in the kra chai dam field (Appendix 2), 8 species were examined for AM. In addition, seedlings of two species of shrubby trees were also examined. AM were found in all species examined (Table 7). Vesicles were formed in all species, while arbuscules were observed in 4 species; *Ageratum conyzoides, Conyza sumatrensis, Crassocephalum crepidioides* and Phak yod dieo (unidentified). A lot of vesicles were found in Chi cho (unidentified) (64%). *Crassocephalum crepidioides* had a relatively high percentage of arbuscules (16%) (Fig. 22). *Amaranthus viridis* had little colonization (6%), while *Ageratum conyzoides* had high colonization (81%).

Table 7 Mean (± SD) of arbuscular mycorrhizal (AM) colonization of herbaceous plants in the kra chai dam (*Kaempferia parviflora* Wall. ex Baker) field

Species (Family)	Thai name	%AC	%VC	%HC	%RC
Ageratum conyzoides L. (Asteraceae)	Sap raeng sap ka	4±2	36±4	42±9	81±14
Amaranthus viridis L. (Amaranthaceae)	Phak khom	0	1±1	5±8	6±10
Chromolaena odorata (L.) R. M. King & H. Rob. (Asteraceae)	Sap suea	0	8±9	19±26	27±35
Conyza sumatrensis (Retz.) Walker (Asteraceae)	Ya dok khao	4±1	29±15	34±15	69±10
Crassocephalum crepidioides (Benth.) S. Moore (Asteraceae)	Ya dok kham	16±25	34±21	21±13	61±25
Lepisanthes rubiginosa (Roxb) Leenh. (Sapindaceae)*	Ma huat	0	33±12	15±2	47±13
Mitracarpus villosus (Cham.& Schltr.) A. DC (Rubiaceae)	Ya chuk khao	0	18±3	39±30	57±27
Muntingia calabura L (Tiliaceae)*	Ta kob	0	34±4	15±6	49±3
Unidentified	Chi cho	0	64±56	0	64±56
Unidentified	Phak yod dieo	1±1	29±26	17±13	45±17

AC = arbuscular colonization, VC = vesicular colonization, HC = hyphal colonization, RC = total root colonization, *= shrubby tree

AM in the glutinous rice field

Of 33 herbaceous species found in the glutinous rice field (Appendix 3), 15 species were examined for AM. In addition one seedling of a shrubby tree were also examined. AM were found in all species (Table 8). Vesicles were formed in all species, while arbuscules were observed in 9 species; *Ageratum conyzoides, Centella asiatica, Chromolaena odorata, Conyza sumatrensis, Crassocephalum crepidioides, Desmodium triforum, Pseuderanthemum* sp., *Scoparia dulcis* and *Urena lobata. Centella asiatica* had very high percentage of arbuscules (40%), and *Crassocephalum crepidioides, Chromolaena odorata and Scoparia dulcis* had also high percentages of arbuscules (17%, 11% and 11%).

Table 8 Mean (± SD) of arbuscular mycorrhizal (AM) colonization of herbaceous plants in the glutinous rice

Species (Family)	Thai name	%AC	%VC	%HC	%RC
Ageratum conyzoides L. (Asteraceae)	Sap raeng sap ka	6±5	12±2	54±6	71±9
Centella asiatica (L.) Urb. (Apiaceae)	Bua bok	40±8	3±0.02	9±2	51±4
Chromolaena odorata (L.) R.M.King & H. Rob. (Asteraceae)	Sap suea	11±19	14±17	77±4	82±8
Conyza sumatrensis (Retz.) Walker (Asteraceae)	Ya dok khao	1±1	5±4	42±35	47±36
Corchorus aestuans L. (Tiliaceae)	Khat mon tua phu	0	10±10	27±4	37±13
Crassocephalum crepidioides (Benth.) S. Moore (Asteraceae)	Ya dok kham	17±11	11±8	38±9	65±6
Crotalaria quinquefolia L. (Fabaceae)	Hing hoi	0	2±3	45±4	47±7
Desmodium triforum L. DC. (Fabaceae)	Klet hoi	0	13±19	8±2	21±17
Mitracarpus villosus (Cham.& Schltr.) A. DC (Rubiaceae)	Ya chuk khao	0	4±6	58±20	60±18
Muntingia calabura L (Tilaceae)*	Ta kob	0	7±6	18±16	25±22
Pseuderanthemum sp. (Acanthaceae)	Hom pa	1±1	3±4	78±19	82±18
Scoparia dulcis L. (Scrophulariaceae)	Krot nam	11±6	5±2	42±2	55±9
Sida rhombifolia L. (Malvaceae)	Ya khat	0	2±2	47±15	49±16
Tadehagi triquetrum (L.) Ohashi (Fabaceae)	Khao mao nok	3±5	27±29	62±22	91±14
Urena lobata L. (Malvaceae)	Khi khrok	1±1	2±2	39±13	42±16
Vigna adenantha (G. Mey.) Marechal (Fabaceae)	Thua hae phi	0	15±21	36±43	51±22

AC = arbuscular colonization, VC = vesicular colonization, HC = hyphal colonization, RC = total root colonization, *= shrubby tree

AM in the mulberry field

Of 23 herbaceous species found in the mulberry field (Appendix 4), 18 species were examined for AM. AM were found in all species examined (Table 9). Vesicles were formed in all species, except in *Chromolaena odorata*. Arbuscules were seen in 6 species; *Ageratum conyzoides, Conyza sumatrensis, Crassocephalum crepidioides, Euphorbia heterophylla, Euphorbia hirta* and *Mitracarpus villosus*. *Chromolaena odorata* had neither vesicles nor arbuscules. In this site, AM colonization levels varied highly, *Ageratum conyzoides, Oxalis corniculata, Euphorbia hirta* (Fig. 23) and *Conyza sumatrensis* (96%, 94%, 93% and 91%) had very high percentage of colonization while *Cyperus* sp. had low colonization (6%).

Table 9 Mean (± SD) of arbuscular mycorrhizal (AM) colonization of herbaceous plants in the mulberry field

Species (Family)	Thai name	%AC	%VC	%HC	%RC
Ageratum conyzoides L. (Asteraceae)	Sap raeng sap ka	2±4	16±14	78±15	96±3
Chromolaena odorata (L.) R.M.King & H. Rob. (Asteraceae)	Sap suea	0	0	48±49	48±49
Commelina diffusa Burm.f (Commelinaceae)	Ya kab	0	8±14	20±35	28±49
Conyza sumatrensis (Retz.) Walker (Asteraceae)	Ya dok khao	1±1	2±2	88±10	91±8
Crassocephalum crepidioides (Benth.) S. Moore (Asteraceae)	Ya dok kham	3±6	11±7	34±4	49±12
Cyperus sp. (Cyperaceae)	Ya sam liam	0	2±3	3±4	6±7
Dactyloctenium aegyptium (L.) P.Beauv. (Poaceae)	Ya pak khwai	0	1±1	18±13	19±14
Euphorbia heterophylla L. (Euphorbiaceae)	Yang ueng	4±6	24±18	22±20	47±40
Euphorbia hirta L. (Euphorbiaceae)	Nam nom ratchasi	1±2	42±8	50±11	93±6
Imperata cylindrica (L.) P. Beauv. (Poaceae)	Ya kha	0	4±3	76±10	80±10
Ludwigia hyssopifolia (G. Don) Exell (Onagraceae)	Thian na	0	19±10	30±26	48±36
Mitracarpus villosus (Cham.& Schltr.) A. DC (Rubiaceae)	Ya chuk khao	0.3±1	0.3±1	18±29	19±30
Oxalis corniculata L. (Oxalidaceae)	Som kob	0	36±4	58±4	94±6
Pennisetum polystachyon (L.) Schult. (Poaceae)	Ya kha chon chop	0	10±6	28±31	38±29
Scoparia dulcis L. (Scrophulariaceae)	Krot nam	0	4±4	11±5	15±1
Tadehagi triquetrum (L.) Ohashi (Fabaceae)	Khao mao nok	0	29±4	32±25	64±33
Zoysia matrella (L.) Merr. var. *matrella* (Poaceae)	Ya phaet khuea	0	33±23	17±19	51±39
Unidentified	Phak yod dieo	0	10±11	6±1	16±10

AC = arbuscular colonization, VC = vesicular colonization, HC = hyphal colonization, RC = total root colonization

AM in the 1-year-fallow

Of 19 herbaceous species found in the 1-year-fallow (Appendix 5), 11 species were examined for AM. AM were found in all species examined (Table 10). Vesicles were formed in all species, while arbuscules were seen in two species; *Chromolaena odorata* and *Imperata cylindrica*. *Zoysia matrella*, a grass species, had low colonization (8%).

Table 10 Mean (± SD) of arbuscular mycorrhizal (AM) colonization of herbaceous plants in the 1-year-fallow

Species (Family)	Thai name	%AC	%VC	%HC	%RC
Chromolaena odorata (L.) R.M.King & H. Rob. (Asteraceae)	Sap suea	1±2	14±9	54±22	69±28
Cynodon dactylon (L.) Pers. (Poaceae)	Ya phraek	0	14±5	20±3	34±8
Imperata cylindrica (L.) P. Beauv. (Poaceae)	Ya kha	1±2	5±3	49±6	47±19
Mesona palustris Bl. (Lamiaceae)	Tu pa	0	17±2	37±19	52±18
Mimosa pudica L. (Fabaceae)	Maiyarap	0	32±40	19±9	52±34
Pennisetum polystachyon (L.) Schult. (Poaceae)	Ya kha chon chop	0	42±4	15±10	57±7
Sida rhombifolia L. (Malvaceae)	Ya khat	0	10±3	5±2	14±5
Tadehagi triquetrum (L.) Ohashi (Fabaceae)	Khao mao nok	0	11±5	2±2	13±6
Urena lobata L. (Malvaceae)	Khi khrok	0	16±20	29±21	45±40
Zoysia matrella (L.) Merr. var. *matrella* (Poaceae)	Ya phaet khruea	0	6±4	1±1	8±5
Unidentified	Phak yod dieo	0	18±5	24±16	42±11

AC = arbuscular colonization, VC = vesicular colonization, HC = hyphal colonization, RC = total root colonization

AM in the 4-year-fallow

Of 32 herbaceous species found in the 4-year-fallow (Appendix 6), 15 species were examined for AM. AM were found in 14 species examined, and *Phyllodium longipes* was not colonized (Table 11). Vesicles were formed in all mycorrhizal species. Arbuscules were found in 10 species; *Centella asiatica, Chromolaena odorata, Conyza sumatrensis, Desmodium triquetrum, Elephantopus scaber, Hedyotis diffusa, Mimosa pudica, Phyllanthus reticulatus, Sida rhombifolia* and *Urena lobata.* The highest percentage of arbuscules (30%) was found in *Conyza sumatrensis* (Fig 24), while the highest percentage of vesicles (82%) was found in *Phyllanthus reticulatus. Conyza sumatrensis* (Fig. 24), *Phyllanthus reticulatus* and *Commelina diffusa* had very high percentages of colonization (95%, 95% and 90%).

Table 11 Mean (± SD) of arbuscular mycorrhizal (AM) colonization of herbaceous plants in the 4-year-fallow

Species (Family)	Thai name	%AC	%VC	%HC	%RC
Centella asiatica (L.) Urb. (Apiaceae)	Bua bok	4±6	19±10	62±7	85±9
Chromolaena odorata (L.) R.M.King & H. Rob. (Asteraceae)	Sap suea	9±6	28±5	48±18	81±19
Commelina diffusa Burm. f. (Commelinaceae)	Ya kab	0	26±9	64±7	90±2
Conyza sumatrensis (Retz.) Walker (Asteraceae)	Ya dok khao	30±25	56±7	28±21	95±5
Elephantopus scaber L. (Asteraceae)	Do mai ruu lom	16±7	37±9	22±10	67±18
Hedyotis diffusa Willd. (Rubiaceae)	Hom chaeo na	4±6	17±7	34±2	50±9
Mimosa pudica L. (Fabaceae)	Maiyarap	2±4	58±9	11±9	69±7
Oxalis corniculata L. (Oxalidaceae)	Som kop	0	21±15	40±17	61±30
Phyllanthus reticulatus Poir. (Euphorbiaceae)	Kang pla khruea	1±2	82±16	12±18	95±2
Phyllodium longipes (Craib) Schindl. (Fabaceae)	Khet lin	0	0	0	0
Sida rhombifolia L. (Malvaceae)	Ya khat	5±9	16±15	50±13	68±23
Tadehagi triquetrum (L.) Ohashi (Fabaceae)	Khao mao nok	7±12	37±25	24±12	62±17
Urena lobata L. (Malvaceae)	Khi khrok	9±13	18±4	61±16	83±7
Zoysia matrella (L.) Merr. var. *matrella* (Poaceae)	Ya phaet khruea	0	24±11	25±17	48±28
Unidentified	Phak yod dieo	0	38±11	47±11	84±12

AC = arbuscular colonization, VC = vesicular colonization, HC = hyphal colonization, RC = total root colonization

AM in the 27-year-fallow

Of 12 herbaceous species found in the 27-year-fallow (Appendix 7), 11 species were examined for AM. AM were found in 9 species, *Cyperus rotundus* and Phak yod dieo (unidentified) were not colonized (Table 12). Vesicles were formed in all mycorrhizal species. Arbuscules were found in 5 species; *Alpinia* sp., *Christia vespertilionis, Chromolaena odorata, Kaempferia galanga* and *Phlogacanthus paniculatus*. *Cyperus* sp. had very low colonization (2%).

Table 12 Mean (± SD) of arbuscular mycorrhizal (AM) colonization of herbaceous plants in the 27-year-fallow

Species (Family)	Thai name	%AC	%VC	%HC	%RC
Alpinia sp. (Zingiberaceae)	Kha	3±4	4±3	13±19	20±26
Bauhinia sp. (Fabaceae)	Salaeng phan	0	10±9	16±26	29±36
Christia vespertilionis Bakh.f (Fabaceae)	Pik kai dam	0.4±1	30±17	21±13	52±3
Chromolaena odorata (L.) R.M.King & H. Rob. (Asteraceae)	Sap suea	1±1	19±8	65±17	86±8
Cyperus rotundus L. (Cyperaceae)	Ya haeo mu	0	0	0	0
Cyperus sp. (Cyperaceae)	Ya sam liam	0	2±3	0.3±1	2±3
Kaempferia galanga L. (Zingiberaceae)	Wan naeng	1±2	29±28	22±19	54±45
Paracalyx scariosa (Roxb.) Ali (Fabaceae)	Khruea kon	0	15±6	9±5	23±14
Phlogacanthus paniculatus (T.And) T.And (Acanthaceae)	Bu ha pa	1±1	4±6	59±16	67±20
Zoysia matrella (L.) Merr. var. *matrella* (Poaceae)	Ya phaet khruea	0	3±3	9±10	12±8
Unidentified	Phak yod dieo	0	0	0	0

AC = arbuscular colonization, VC = vesicular colonization, HC = hyphal colonization, RC = total root colonization

AM in the forest

Of 44 herbaceous species found in the forest (Appendix 8), 21 species were examined for AM. Vesicles were formed in all species, excepted in *Cyperus rotundus* and *Lygodium flexuosum* (Table 13). Arbuscules were seen in 5 species; *Conyza sumatrensis, Crassocephalum crepidioides, Lygodium flexuosum, Sterculia lanceolata* and Hing hai (unidentified). *Chromolaena odorata* had very high colonization (96%), and *Urena lobata* showed a similar trend (83%). *Cyperus rotundus* were not colonized and *Lygodium flexuosum* had nearly not colonized (1%).

Table 13 Mean (± SD) of arbuscular mycorrhizal (AM) colonization of herbaceous plants in the forest

Species (Family)	Thai name	%AC	%VC	%HC	%RC
Alpinia sp. (Zingiberaceae)	Kha	0	2±3	10±2	12±5
Chromolaena odorata (L.) R.M.King & H. Rob. (Asteraceae)	Sap suea	0	26±16	70±15	96±7
Conyza sumatrensis (Retz.) Walker (Asteraceae)	Ya dok khao	1±1	33±9	15±8	49±0.4
Crassocephalum crepidioides (Benth.) S. Moore (Asteraceae)	Ya dok kham	8±11	30±35	33±8	69±31
Cyperus rotundus L. (Cyperaceae)	Ya haeo mu	0	0	0	0
Desmodium triforum L. DC. (Fabaceae)	Klet hoi	0	25±8	30±30	55±37
*Elephantopus scaber*L. (Asteraceae)	Do mai ruu lom	0	20±4	51±14	71±17
Gigantochloa albociliata (Munro) Munro (Poaceae)	Phai rai	0	3±2	18±10	18±10
Inula cappa (Ham.) DC. (Asteraceae)	Nad kham	0	4±6	68±18	71±13
Jasminum sp. (Oleaceae)	Sai kai	0	23±23	37±3	60±26
Kaempferia galanga L. (Zingiberaceae)	Wan naeng	0	29±5	13±13	51±24
Lygodium flexuosum (L.) Sw. (Schizaeaceae)	Li phao	1±2	0	0	1±2
Phlogacanthus paniculatus (T. And). T. And (Acanthaceae)	Bu ha pa	0	0.3±1	71±24	71±24
Phyllodium longipes (Craib) Schindl. (Fabaceae)	Khet lin	0	24±14	19±19	53±26
Sida rhombifolia L. (Malvaceae)	Ya khat	0	4±4	54±15	60±35
Sterculia lanceolata Cav. (Sterculiaceae)	Po pha sam	4±8	13±5	23±5	36±3
Urena lobata L. (Malvaceae)	Khi khrok	0	47±29	36±23	83±6
Vigna dalzelliana (Kuntze.) Verdc. (Fabaceae)	Thua hae phi	0	24±1	46±9	70±11
Unidentified	Chi cho	0	18±12	18±26	37±14
Unidentified	Hing hai	5±4	40±20	32±17	75±19
Unidentified	Phak yod dieo	0	25±23	8±7	33±20

AC = arbuscular colonization, VC = vesicular colonization, HC = hyphal colonization, RC = total root colonization

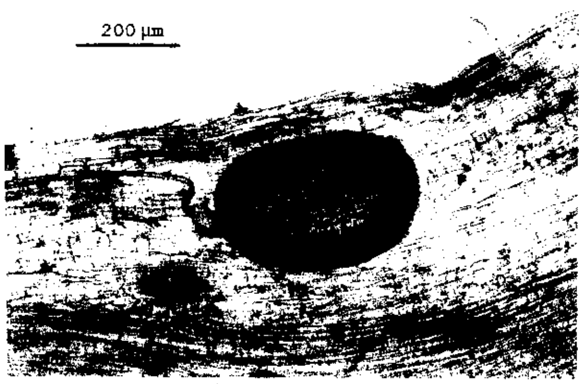


Figure 20 Spore inside the root of *Oryza sativa* L. var. *glutinosa* L. (Poaceae)

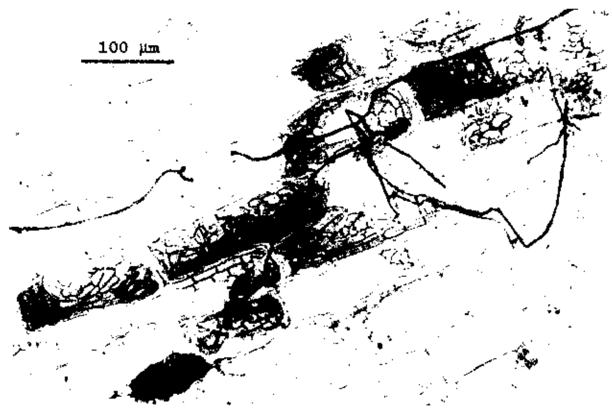


Figure 21 Root infected by non-arbuscular mycorrhizal fungi in *Kaempferia parviflora* Wall. ex Baker (Zingiberaceae)

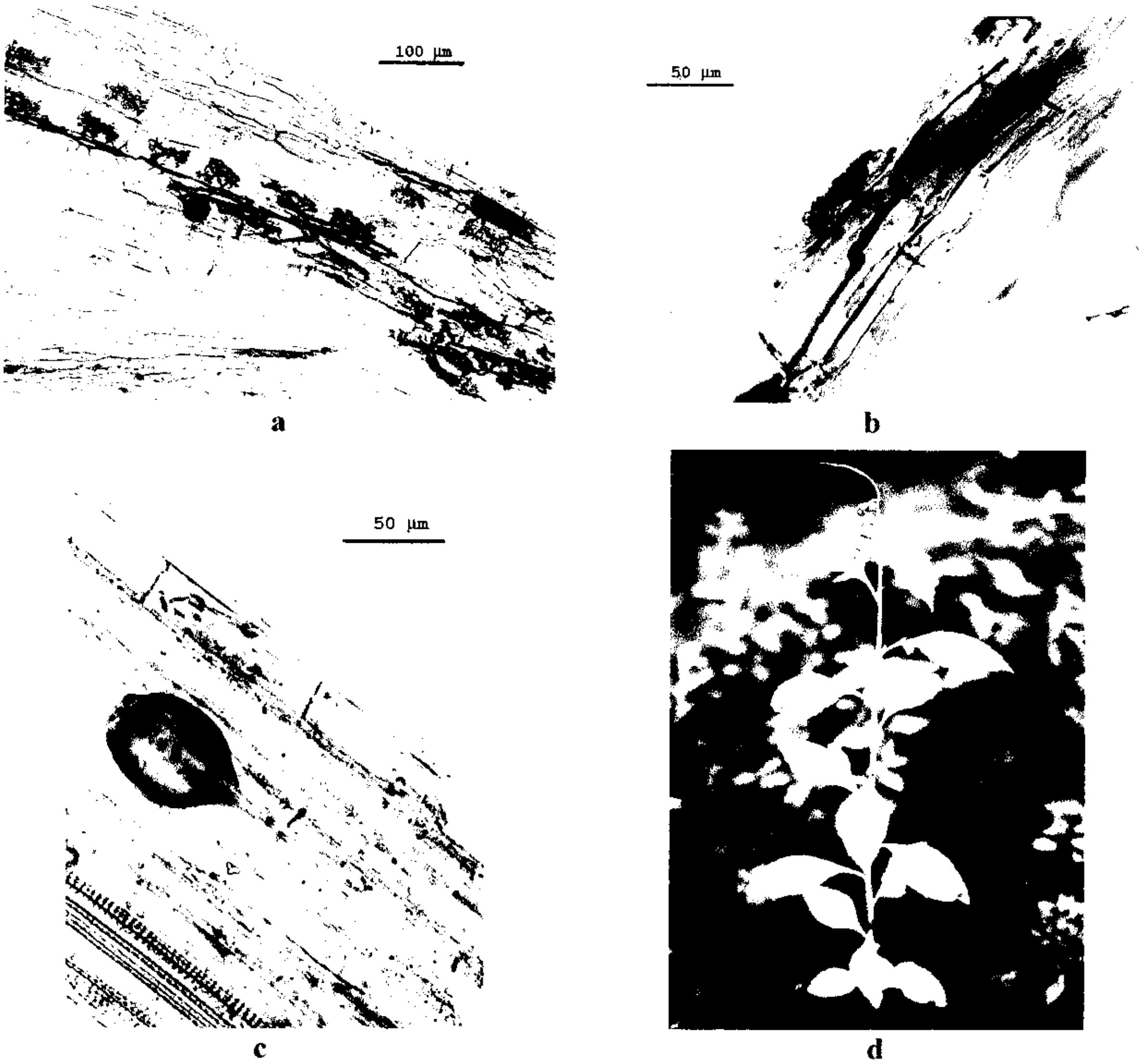
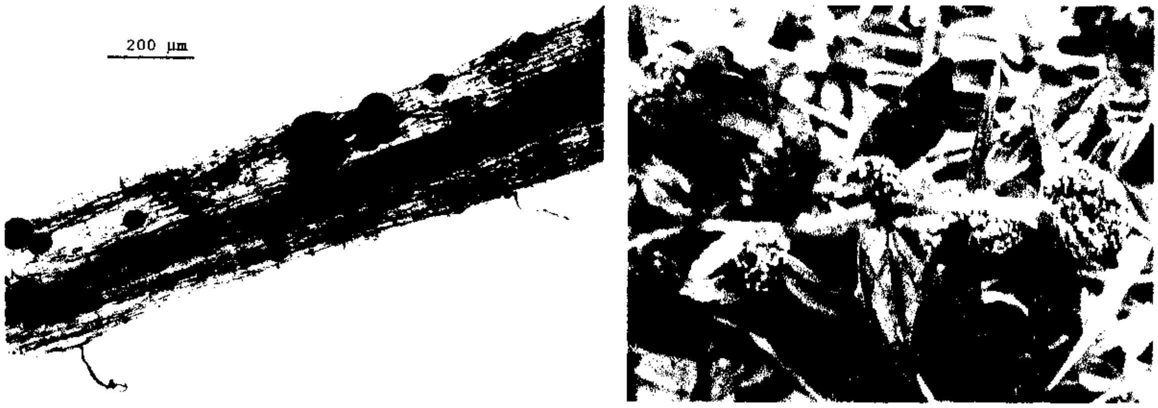
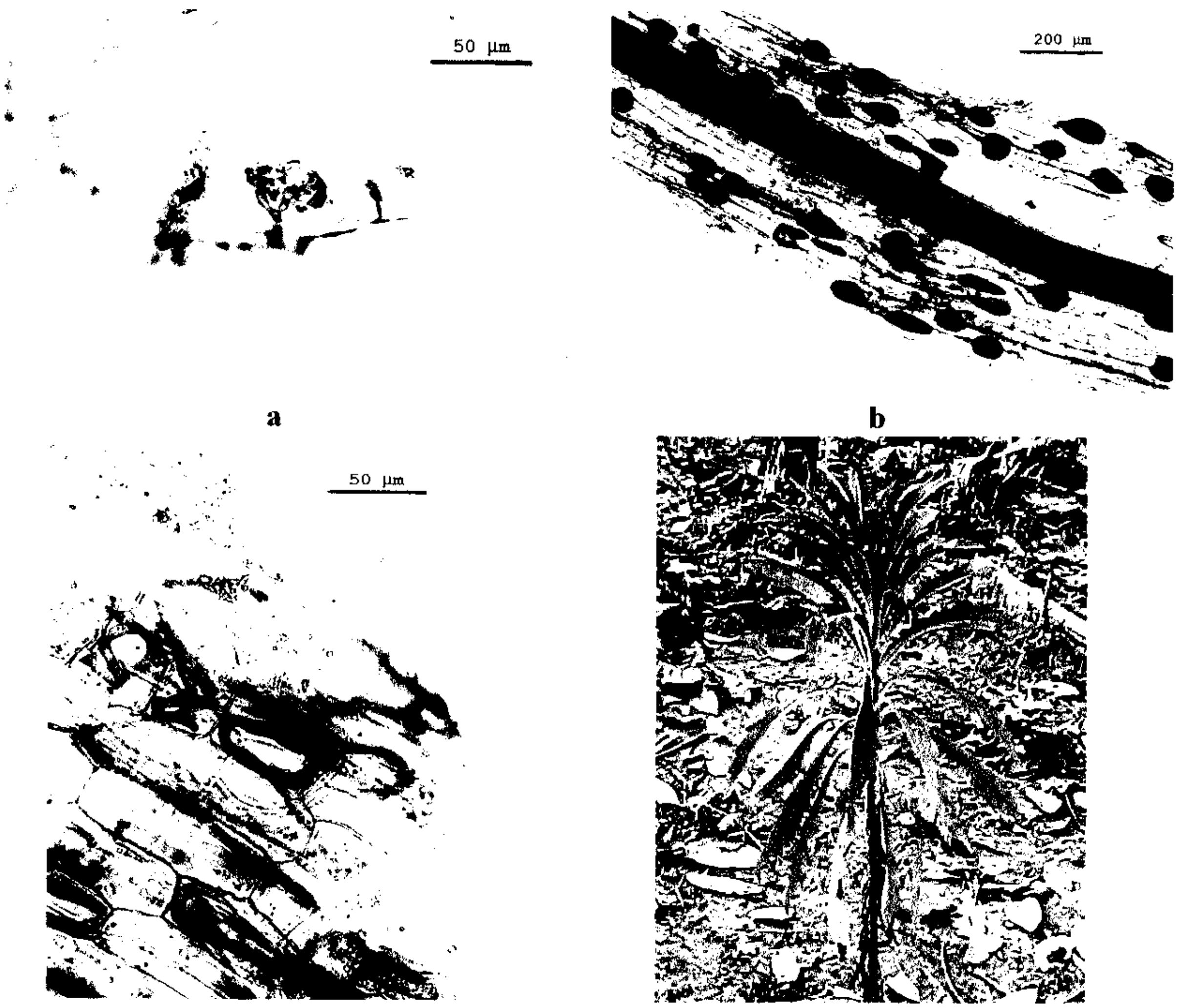


Figure 22 Arbuscular mycorrhizal (AM) colonization in *Crassocephalum crepidioides* (Benth.) S. Moore (Asteraceae) from Kra chai dam field: **a** . vesicle and arbuscules, **b**. arbuscules, **c**. vesicle, **d**. adult plant of *C. crepidioides*



a b

Figure 23 Arbuscular mycorrhizal (AM) colonization in *Euphorbia hirta* L. (Euphorbiaceae) from the mulberry field: **a**. vesicles, **b.** adult plant of *E. hirta*



a b c d

Figure 24 Arbuscular mycorrhizal (AM) colonization in *Conyza sumatrensis* (Retz.) Walker (Asteraceae) from the 4-year-fallow: **a.**. arbuscules, **b.** vesicles, **c.** internal hyhae, **d.** adult plant of *C. crepidioides*

Chapter 5
Discussion and Conclusion

Discussion

In this work mycorrhizal colonization has been assessed. Fifty-eight species were assessed for mycorrrhiza, and 57 (98%) had AM structures. No species were found to have ectomycorrhiza or some of the other non-AM types. Trees were not investigated. The assessment of colonization does not give information about the different species' dependency on mycorrrhiza, but the occurrence of arbuscules and vesicles could indicate something about the actual or potential mycorrhizal activity in the plant and in the field the plant is growing. Finding AM in 98% of the species investigated is a high percentage, since many of them are weeds (Harada *et al.* 1996). Weeds are thought to be less mycorrhizal, but this view is changing (Ishii *et al.* 1998), and this investigation supports the new view.

Cyperus rotundus was not colonized by AM fungi. This supports the view that Cyperaceae is thought to be non-mycorrhizal (Smith and Read. 1997). Anyhow, species of the Cyperaceae should be given more attention since Miller *et al.* (1999) examined 23 species of *Carex* (Cyperaceae) and found that 16 species possessed AM. The four investigated species of *Carex* from boreal grasslands were all found to have AM (Eriksen *et al.* 2002).

Phyllodium longipes and Phak yod dieo (unidentified) were not colonized at some sites, and they might be facultatively mycorrhizal in this agro-ecosystem.

Ageratum conyzoides, Commelina diffusa, Oxalis corniculata and *Tadehagi triquetrum* had very high root colonization in some locations, less in others. This can be explained by heterogeneity in soil contents and availability of fungal inoculum in soil in the different fields (Read. 1991).

AM fungi colonized the most common crops in the area. Groundnut had a high root colonization and many vesicles present corresponding with the results in most reports, e.g. Ahiabor and Hirata. (1994). In kra chai dam (*Kaempferia parviflora*) both arbuscules and vesicles were found, and the total root colonization was high (75%). To our knowledge no earlier reports on AM are published for this species. Further knowledge about AM dependency can be useful, concerning cultivation of this economically very interesting crop, but more fieldwork and experiments are requirs. The root colonization in glutinous rice was relatively low (24%) compared to other species in the area, but in accordance with the colonization percentages. Dhillion and Ampornpan (1992) found in pretransplant rice 25-40% colonization. Reports on mycorrhiza in the glutinous rice are not known. Even if the glutinous rice itself was poorly colonized, the rice field had a lot of mycorrhizal weeds (Table. 7). Mulberry was found to be mycorrhizal, in accordance with earlier findings (Nopamornbodi. 1999, Seuta *et al.* 1999).

To make comparisons between different species are difficult since the variation in AM infection and presence of arbuscules and vesicles between species may be explained by differential species dependency on mycorrhiza. Plants were collected from areas with different land use, but it is not possible to draw any conclusions from the colonization assessments concerning the impact different land use has on colonization. *Chromolaena odorata, Conyza sumatrensis, Sida rhombifolia, Urena lobata* and Phak yod dieo (unidentified) were found in agricultural field, fallow and forest. They vary highly in colonization, and at the time the plants were collected, they did not have many arbuscules, except for *Conyza sumatrensis* in the forest (30%AC). They are weedy species (Harada *et al.* 1996), but they are all mycorrhizal and support the change in view that weedy plants very well can be mycorrhizal, and often are.

All the fields, fallows and the forest have soils that are low in available phosphorus (P), ranging from the fallow 4 years having 2 ppm to the rice field having 6 ppm. Mycorrhizal colonization and activity are supposed to be highest where available P to the plants is lowest (Smith and Read. 1997). Arbuscules are seen in 10 out of 15 species (Table 10) and the total colonization is very high in many species in fallow 4, in accordance with high mycorrhizal activity and low phosphorus content.

The soil pH ranges from 4.9 in the kra chai dam field to 6.0 in fallow 4 years. pH affects the availability of phosphorus, and the optimal pH is 6.5 (Smith and Read. 1997). Anyhow, total phosphorus values must be at a certain level to make P available to the plants. In the fallow 4 years the total phosphorus value is probably very low, since the available P at pH=6 is as low as 2 ppm.

The soil in fallow 1 year has a very high value of calcium, 922 ppm. Calcium can contribute to keeping P inavailable (Smith and Read. 1997). This can explain the low available phosphorus content in the soil from fallow 1 year (3 ppm), but the explanation can also be that the total phosphorus content is low.

Weeds are opportunistic in their life form and they might have a facultative mycorrhizal relationship. The variation in colonization within one species, e.g. *Chromolaena odorata* ranging from 27% to >90% supports this. Their role in the agricultural field (Boyetchko. 1996) and in the regeneration of forest should be looked in to. It is possible that some of them can contribute in building up hyphae and spore numbers in degraded soils during fallow periods and to make the seedling establishment in a reforestation process easier.

AM has an impact on plant species diversity (Van der Heijden *et al.* 1998), and the AM fungi in soil are also affected by plant diversity (Burrows and Pfleger. 2002). The highest plant species richness (n=93) is found in forest. Here the disturbance factor is low, with no tillage or use of fertilizer, and as expected, many species are highly colonized. The lower species richness in the fallow 27 years (n=35 species) compared to fallow 4 years (n=40) and forest (n=93) may be caused by a "long-fallow disorder" (Thompson 1995), with loss of propagules in the soil and loss of plant diversity. Three non-mycorrhizal species are found indicating that this might be the case. More research is needed to confirm this. The agricultural fields vary in richness between n=23 and n=40, and since the environmental factors and disturbance regimes varies between and within the different fields, it is difficult to say much about these factors and colonization levels and species richness.

Conclusion

The high colonization level in plants in all fields, fallows and the forest makes it probable to believe that this traditional slash and burn cultivation conserve the ability of the soil to deliver inoculum to regeneration and growth in the plants presently growing here. Investigations should be done to find the optimal length of fallow periods. Since so many plants are infected, AM must play an important role in this agro-forestry system, in food production, in restoring fields through fallow periods and in forest succession. The most mycorrhizal active phase seems to be the fallow 4 years, maybe a good time for planting trees in attempts to reforest an area with indigenous tree species or to break the fallow period to cultivate the field.

The colonization level and appearance of arbuscules must be seen in the light of the seasonal variation in mycorrhizal activity. In the dry season, the availability of nutrients is low, and the fungus can probably gain from allocating energy to producing vesicles storing material, instead of forming short living arbuscules that will be of little use at that time. To gain knowledge about this one must assess roots collected at different times during the year. The AM can play different roles in the plant life, e.g. the seedling stage. Small colonization levels may also make a difference, and we should keep in mind the many functions of AM and also consider the importance of resistance to drought, protection against pathogenic fungi and herbivory in our research trying to understand the processes in ecosystems like this.

Other aspects that should be considered in future work are how disturbance factors like grazing and fires impact mycorrhizal relationships, and what role AM play in the regeneration of tree species and maintenance of plant species diversity.

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APPENDIX

Appendix 1 Species found in the groundnut field

Scientific name	Local name	Thai name	Family	Life form
Ageratum conyzoides L.	Khee lo	Sap raeng sap ka	Asteraceae	Herbaceous
Arachis hypogaea L.	Thua li song	Thu li song	Fabaceae	Herbaceous
Carex condensta Nees	Ya khom bang	Ya khom bang khao	Cyperaceae	Herbaceous
Chromolaena odorata (L.) R. M. King & H. Rob.	Ya hueng	Sap suea	Asteraceae	Herbaceous
Commelina diffusa Burm. f	Ya kab	Phak plap	Commelinaceae	Grass/ Herbaceous
Conyza sumatrensis (Retz.) Walker	Ya dok khao	Cho lo	Asteraceae	Herbaceous
Corchorus aestuans L.	Ya kad dang	Krachao na	Tiliaceae	Herbaceous
Crassocephalum crepidioides (Benth.) S. Moore	Ya dok kam	Phakkat chang	Asteraceae	Herbaceous
Cyperus rotundus L.	Ya haeo mu	Ya haeo mu	Cyperaceae	Herbaceous
Dactyloctenium aegyptium (L.) P.Beauv.	Ya pak khwaai	Ya pak khwaai	Poaceae	Grass/ Herbaceous
Euphorbia heterophylla L.	Ya yang	Yang ueng	Euphorbiaceae	Herbaceous
Euphorbia hirta L.	Namnom ratchasi	Namnom ratchasi	Euphorbiaceae	Herbaceous
Mimosa pudica L.	Yup yop	Maiyarap	Fabaceae	Herbaceous
Mitracarpus villosus (Cham.& Schltr.) A. DC	Ya chuk khao	Ya chuk khao	Rubiaceae	Herbaceous
Pachyrrhizus erosus Urb.	Man kaeo	Man kaeo	Fabaceae	Climber/ Herbaceous

Appendix 1 (continued)

Scientific name	Local name	Thai name	Family	Life form
Paracalyx scariosa (Roxb.) Ali	Khruea kon	Khruea khao kon	Fabaceae	Climber/ Herbaceous
Scoparia dulcis L.	Luk tai bai	Krot nam	Scrophulariaceae	Herbaceous
Senna tora L.	Lap mue noi	Chumhet thai	Fabaceae	Herbaceous
Sida rhombifolia L.	Ya Khat	Khat Mon	Malvaceae	Herbaceous
Tadehagi triquetrum (L.) Ohashi	Ya ka non	Khao mao nok	Fabaceae	Herbaceous
Urena lobata L.	Khee on	Khee khrok	Malvaceae	Herbaceous
Zoysia matrella (L.) Merr. var. *matrella*	Ya phaet khruea	Ya nuan noi	Poaceae	Grass/ Herbaceous
Unidentified	Phak yod dieo		Euphorbiaceae	Herbaceous

Appendix 2 Species found in the kra chai dam field

Scientific name	Local name	Thai name	Family	Life form
Ageratum conyzoides L.	Khee lo	Sap raeng sap ka	Asteraceae	Herbaceous
Ailanthus triphysa (Dennst.) Alston	Mayom pa	Mayom pa	Simaroubaceae	Tree
Albizia sp.	Mai len		Fabaceae	Tree
Amaranthus viridis L.	Phak kom	Phak kom	Amaranthaceae	Herbaceous
Antidesma acidum Retz.	Mao soi	Mao soi	Euphorbiaceae	Shrub
Aporosa serrata Gagnep.	Mueat	Mueat ton	Euphorbiaceae	Tree
Centella asiatica (L) Urb.	Phak nok	Bua bok	Apiaceae	Herbaceous
Chromolaena odorata (L.) R. M. King & H. Rob.	Ya hueng	Sap suea	Asteraceae	Herbaceous
Clerodendrum petasites (Lour.) S. Moore	Phin phi	Thao yai mom	Labiaceae	Shrub
Commelina diffusa Burm. f.	Ya kab	Phak plap	Commelinaceae	Grass/ Herbaceous
Conyza sumatrensis (Retz.) Walker	Ya dok khao	Cholo	Asteraceae	Herbaceous
Crassocephalum crepidioides (Benth.) S.Moore	Yaa dok kam	Phakkat chang	Asteraceae	Herbaceous
Croton poilanei Gagnep.	Plao	Plao	Euphorbiaceae	Tree
Cyperus rotundus L.	Ya haeo mu	Ya haeo mu	Cyperaceae	Herbaceous

Appendix 2 (continued)

Scientific name	Local name	Thai name	Family	Life form
Dactyloctenium aegyptium (L.) P.Beauv.	Ya pak khwaai	Ya pak khwaai	Poaceae	Grass/ Herbaceous
Eragrostis ciliata (Roxb.) Nees	Ya khai hao	Ya khai hao	Poaceae	Grass/ Herbaceous
Euphorbia hirta L.	Namnom ratchasi	Namnom ratchasi	Euphorbiaceae	Herbaceous
Imperata cylindrica (L.) P. Beauv.	Ya kha	Ya kha	Poaceae	Grass/ Herbaceous
Kaempferia parviflora Wall. ex Baker	Kra chai dam	Kra chai dam	Zingiberaceae	Herbaceous
Lepisanthes rubiginosa (Roxb) Leenh.	Ma huat	Ma huat	Spindaceae	Tree
Lygodium flexuosum (L.) Sw.	Khut ngong	Yan li phao	Schizaeaceae	Fern/ Herbaceous
Mitracarpus villosus (Sw.) DC.	Ya chuk khao	Ya chuk khao	Rubiaceae	Herbaceous
Muntingia calabura L.	Ta kob	Ta kab	Tiliaceae	Tree
Paracalyx scariosa (Roxb.) Ali	Khruea kon	Khruea khao kon	Fabaceae	Climber/ Herbaceous
Schima wallichii (DC.) Korth.	Khai cheo	Thalo	Theaceae	Tree
Sida rhombifolia L.	Ya khat	Khat mon	Asteraceae	Herbaceous
Siphonodon celastrineus Giff.	Ma duk	Ma duk	Celastraceae	Tree
Sterculia sp.	Por daeng		Sterculiaceae	Shrub
Vigna adenantha (G. Mey.) Marechal	Thua hae phi	Thua hae phi	Fabaceae	Climber/ Herbaceous

Appendix 2. (continued)

Scientific name	**Local name**	**Thai name**	**Family**	**Life form**
Zoysia matrella (L.) Merr. var. *matrella*	Ya phaet khruea	Ya nuan noi	Poaceae	Grass/ Herbaceous
Unidentified	Chi cho			Herbaceous
Unidentified	Kam phee			Tree
Unidentified	Lae ling			Climber/ Herbaceous

Appendix 3 Species found in the glutinous rice field

Scientific name	Local name	Thai name	Family	Life form
Ageratum conyzoides L.	Khee lo	Sap raeng sap ka	Asteraceae	Herbaceous
Aporosa serrata Gagnep.	Mueat	Mueat ton	Euphorbiaceae	Tree
Bauhinia sp.	Khruea han	Salaeng pun	Fabaceae	Climber/ Herbaceous
Carex condensta Nees	Ya khom bang	Ya khom bang khao	Cyperaceae	Herbaceous
Centella asiatica (L.) Urb.	Phak nok	Bua bok	Apiaceae	Herbaceous
Chromolaena odorata (L.) R. M. King & H. Rob.	Yaa hueng	Sap Suea	Asteraceae	Herbaceous
Conyza sumatrensis (Retz.) Walker	Ya dok khao	Cho lo	Asteraceae	Herbaceous
Corchorus aestuans L.	Ya kad dang	Krachao na	Tiliaceae	Herbaceous
Crassocephalum crepidioides (Benth.) S.Moore	Ya dok kam	Phakkat chang	Asteraceae	Herbaceous
Crotalaria quinquefolia L.	Hing hoi	Hing hoi	Fabaceae	Herbaceous
Croton poilanei Gagnep.	Plao	Plao	Euphorbiaceae	Tree
Cynodon dactylon (L.) Pers.	Ya pheat	Ya phraek	Poaceae	Grass/ Herbaceous
Derris elliptica (Roxb.) Benth.	Khruea lai	Hang lai daeng	Fabaceae	Climber/ Herbaceous
Desmodium triforum L. DC.	Klet hoi	Klet hoi	Fabaceae	Herbaceous
Desmos chinensis Lour.	Khruea khao klaep	Sai yut	Annoanaceae	Climber/ Herbaceous

Appendix 3 (continued)

Scientific name	Local name	Thai name	Family	Life form
Imperata cylindrica (L.) P. Beauv.	Ya kha	Ya kha	Poaceae	Grass/ Herbaceous
Lepisanthes rubiginosa (Roxb) Leenh.	Ma huat	Ma huat	Spindaceae	Tree
Lygodium flexuosum (L.) Sw.	Khut ngong	Yan li phao	Schizaeaceae	Fern/ Herbaceous
Mimosa pigra L.	Pi rap yak	Mai ya rap ton	Fabaceae	Herbaceous
Mimosa pudica L.	Yup yop	Maiyarap	Fabaceae	Herbaceous
Mitracarpus villosus (Sw.) DC.	Ya chuk khao	Ya chuk khao	Rubiaceae	Herbaceous
Muntingia calabura L	Ta kob	Ta kob	Tiliaceae	Tree
Oryza sativa L. var. *glutinosa* L	Khao niao	Khao niao	Poaceae	Herbaceous
Paracalyx scariosa (Roxb.) Ali	Khruea kon	Khruea khao kon	Fabaceae	Climber/ Herbaceous
Pseuderanthemum sp.	Hom pa	Hom pa	Acanthaceae	Herbaceous
Scoparia dulcis L.	Luk tai bai	Krot nam	Scrophulariaceae	Herbaceous
Senna tora L.	Lap mue noi	Chumhet thai	Fabaceae	Herbaceous
Sida rhombifolia L.	Ya khat	Khat mon	Malvaceae	Herbaceous
Smilax micro-china T.Koyama	Hua ya khao yen	Hua ya khao yen	Smilacaceae	Herbaceous
Syzygium cumini (L.) Skeels	Wa	Wa	Myrtaceae	Tree

Appendix 3 (continued)

Scientific name	Local name	Thai name	Family	Life form
Tadehagi triquetrum (L.) Ohashi	Ya ka non	Khao mao nok	Fabaceae	Herbaceous
Themeda triandra Forssk.	Ya faek	Ya faek	Poaceae	Grass/ Herbaceous
Urena lobata L.	Khee on	Khee khork	Malvaceae	Herbaceous
Vigna adenantha (G. Mey.) Marechal	Thua hae phi	Thua hae phi	Fabaceae	Climber/ Herbaceous
Zoysia matrella (L.) Merr. var. *matrella*	Ya phaet khruea	Ya nuan noi	Poaceae	Grass/ Herbaceous
Unidentified	Hup khao			Climber/ Herbaceous
Unidentified	Kam phee			Tree
Unidentified	Khruea yang			Climber/ Herbaceous
Unidentified	Phak hat khee mu			Herbaceous
Unidentified	Phak yod dieo			Herbaceous

Appendix 4 Species found in the mulberry field

Scientific name	**Local name**	**Thai name**	**Family**	**Life form**
Ageratum conyzoides L.	Khee lo	Sap raeng sap ka	Asteraceae	Herbaceous
Chromolaena odorata (L.) R. M. King & H. Rob.	Ya hueng	Sap Suea	Asteraceae	Herbaceous
Conyza sumatrensis (Retz.) walker	Ya dok khao	Cho lo	Asteraceae	Herbaceous
Crassocephalum crepidioides (Benth.) S.Moore	Ya dok kam	Phakkat chang	Asteraceae	Herbaceous
Cyperus rotundus L.	Ya haeo muu	Ya haeo mu	Cyperaceae	Grass/ Herbaceous
Dactyloctenium aegyptium (L.) P.Beauv.	Ya pak khwaai	Ya pak khwaai	Poaceae	Grass/ Herbaceous
Desmos chinensis Lour.	Khruea khao klaep	Sai yut	Annoanaceae	Climber/ Herbaceous
Eragrostis ciliata (Roxb.) Nees	Ya khai hao	Ya khai hao	Poaceae	Grass/ Herbaceous
Euphorbia heterophylla L.	Ya yang	Yang ueng	Euphorbiaceae	Herbaceous
Euphorbia hirta L.	Namnom ratchasi	Namnom ratchasi	Euphorbiaceae	Herbaceous
Hedyotis diffusa Willd.	Hom chaeo na	Hom chaeo na	Rubiaceae	Herbaceous
Hedyotis rosmarinifolia (Pit.) Craib	Ya hang nok yung	Ya hang nok yung	Rubiaceae	Herbaceous
Imperata cylindrica (L.) P. Beauv.	Ya kha	Ya kha	Poaceae	Grass/ Herbaceous
Ludwigia hyssiopifolia (G. Don) Exell	Ya kad dang	Thian na	Onagraceae	Herbaceous
Mitracarpus villosus (Sw.) DC.	Ya chuk khao	Ya chuk khao	Rubiaceae	Herbaceous

Appendix 4 (continued)

Scientific name	Local name	Thai name	Family	Life form
Morus alba L.	Mon	Mon	Moraceae	Shrub
Oxalis corniculata L.	Wan khok	Som kop	Oxalidaceae	Herbaceous
Paracalyx scariosa (Roxb.) Ali	Khruea kon	Khruea khao kon	Fabaceae	Climber/ Herbaceous
Pennisetum polystachyon (L.) Schult.	Ya kha chon chop	Ya kha chon chop	Poaceae	Grass/ Herbaceous
Scoparia dulcis L.	Luk tai bai	Krot nam	Scrophulariaceae	Herbaceous
Tadehagi triquetrum (L.) Ohashi	Ya ka non	Khao mao nok	Fabaceae	Herbaceous
Vigna adenantha (G. Mey.) Marechal	Thua hae phi	Thua hae phi	Fabaceae	Climber/ Herbaceous
Zoysia matrella (L.) Merr. var. *matrella*	Ya phaet khruea	Ya nuan noi	Poaceae	Grass/ Herbaceous
Unidentified	Phak yod dieo			Herbaceous

Appendix 5 Species found in the 1-year-fallow

Scientific name	Local name	Thai name	Family	Life form
Ageratum conyzoides L.	Khee lo	Sap raeng sap ka	Asteraceae	Herbaceous
Byttneria pilosa Roxb.	Kamyan	Kamyan khruea	Sterculiaceae	Climber/ Herbaceous
Chromolaena odorata (L.) R. M. King & H. Rob.	Ya hueng	Sap suea	Asteraceae	Herbaceous
Clausena sp.	Song fa	Song fa	Rutaceae	Shrub
Crassocephalum crepidioides (Benth.) S.Moore	Ya dok kam	Phakkat chang	Asteraceae	Herbaceous
Croton poilanei Gagnep.	Plao	Plao	Euphorbiaceae	Tree
Cynodon dactylon (L.) Pers.	Ya pheat	Ya phraek	Poaceae	Grass/ Herbaceous
Desmos chinensis Lour.	Khruea khao klaep	Sai yut	Annoanaceae	Climber/ Herbaceous
Grewia sp.	Leaw sai leaw khwa	Leaw sai leaw khwa	Tiliaceae	Herbaceous
Imperata cylindrica (L.) P. Beauv.	Ya kha	Ya kha	Poaceae	Grass/ Herbaceous
Mesona palustris Bl.	Tu pa	Tu pa	Lamiaceae	Herbaceous
Mimosa pudica L.	Yup yop	Maiyarap	Fabaceae	Herbaceous
Oxalis corniculata L.	Wan khok	Som kop	Oxalidaceae	Herbaceous
Paederia lineris Hook. f.	Ya tot ma	Tot mu tot ma	Rubiaceae	Climber/ Herbaceous
Pennisetum polystachyon (L.) Schult.	Ya kha chon chop	Ya kha chon chop	Poaceae	Grass/ Herbaceous

Appendix 5 (continued)

Scientific name	Local name	Thai name	Family	Life form
Phoebe lanceolata (Wall. Ex Nees) Nees	Pee tong	Lae buk	Lauraceae	Tree
Sida rhombifolia L.	Ya khat	Khat mon	Malvaceae	Herbaceous
Tadehagi triquetrum (L.) Ohashi	Ya ka non	Khao mao nok	Fabaceae	Herbaceous
Urena lobata L.	Khee on	Khee khork	Malvaceae	Herbaceous
Vigna adenantha (G. Mey.) Marechal	Thua hae phi	Thua hae phi	Fabaceae	Climber/ Herbaceous
Zoysia matrella (L.) Merr. var. *matrella*	Ya phaet khruea	Ya nuan noi	Poaceae	Grass/ Herbaceous
Unidentified	Mai chick			Tree
Unidentified	Phak yod dieo			Herbaceous

Appendix 6 Species found in the 4-year-fallow

Scientific name	Local name	Thai name	Family	Life form
Ageratum conyzoides L.	Khee lo	Sap raeng sap ka	Asteraceae	Herbaceous
Aporosa serrata Gagnep.	Mueat	Mueat ton	Euphorbiaceae	Tree
Centella asiatica (L.) Urb.	Phak nok	Bua bok	Apiaceae	Herbaceous
Chromolaena odorata (L.) R. M. King & H. Rob.	Ya hueng	Sap suea	Asteraceae	Herbaceous
Conyza sumatrensis (Retz.) Walker	Ya dok khao	Cho lo	Asteraceae	Herbaceous
Cratoxylum formosum (Jack) Dyer	Tio	Tio Khao	Clusiaceae	Tree
Crotalaria alata L.	Hing hoi	Hing men noi	Fabaceae	Shrub
Croton poilanei Gagnep.	Plao	Plao	Euphorbiaceae	Tree
Cynodon dactylon (L.) Pers.	Ya pheat	Ya phraek	Poaceae	Grass/ Herbaceous
Cyperus rotundus L.	Ya haeo mu	Ya haeo mu	Cyperaceae	Grass/ Herbaceous
Desmos chinensis Lour.	Khruea khao klaep	Sai yut	Annoanaceae	Climber/ Herbaceous
Elephantopus scaber L.	Tao fai nokkhum	Do mai ruu lom	Asteraceae	Herbaceous
Euphorbia hirta L.	Namnom ratchasi	Namnom ratchasi	Euphorbiaceae	Herbaceous
Grewia sp.	Leaw sai leaw khwa	Leaw sai leaw khwa	Tiliaceae	Herbaceous
Hedyotis diffusa Willd.	Hom chaeo na	Hom chaeo na	Rubiaceae	Herbaceous

Appendix 6 (continued)

Scientific name	Local name	Thai name	Family	Life form
Imperata cylindrica (L.) P. Beauv.	Ya kha	Ya kha	Poaceae	Grass/ Herbaceous
Jasminum sp.	Sai kai	Sai kai	Oleaceae	Climber/ Herbaceous
Lygodium flexuosum (L.) Sw.	Khut ngong	Yan li phao	Schizaeaceae	Fern/ Herbaceous
Melastoma sp.	Khao chi	Khlong khleng	Melastomaceae	Herbaceous
Mimosa pudica L.	Yup yop	Maiyarap	Fabaceae	Herbaceous
Mitracarpus villosus (Sw.) DC.	Ya chuk khao	Ya chuk khao	Rubiaceae	Herbaceous
Oxalis corniculata L.	Wan khok	Som kop	Oxalidaceae	Herbaceous
Paederia lineris Hook. f.	Ya tot ma	Tot mu tot ma	Rubiaceae	Climber/ Herbaceous
Paracalyx scariosa (Roxb.) Ali	Khruea kon	Khruea khao kon	Fabaceae	Climber/ Herbaceous
Phyllantus reticulatus Poir.	Ya lep maeo	Kang pla khruea	Euphorbiaceae	Shrub
Phyllodium longipes (Craib) Schindl.	Klet lin	Klet lin yai	Fabaceae	Herbaceous
Polyalthia suberosa (Roxb.)	Nam noi	Klueng klom	Annonaceae	Shrub
Pterocarpus macrocarpus Kurz	Pradu	Pradu	Fabaceae	Tree
Scoparia dulcis L.	Luk tai bai	Krot nam	Scrophulariaceae	Herbaceous
Sida rhombifolia L.	Ya khat	Khat mon	Malvaceae	Herbaceous

Appendix 6 (continued)

Scientific name	Local name	Thai name	Family	Life form
Stemona tuberosa Lour.	Khruea hak mot	Non tai yak	Stemonaceae	Climber/ Herbaceous
Streptocaulon juventas (Lour.) Merr.	Khruea khao sung	Chukka rohini	Periplocaceae	Climber/ Herbaceous
Tadehagi triquetrum (L.) Ohashi	Ya ka non	Khao mao nok	Fabaceae	Herbaceous
Thunbergia grandiflora (Roxb. Ex Rottler) Roxb.	Khruea nom nae	Soi in thannin	Acanthaceae	Climber/ Herbaceous
Urena lobata L.	Khee on	Khee khork	Malvaceae	Herbaceous
Vigna adenantha (G. Mey.) Marechal	Thua hae phi	Thua hae phi	Fabaceae	Climber/ Herbaceous
Unidentified	Phak yod dieo			Herbaceous
Unidentified	Ya bi yao			Grass/ Herbaceous
Unidentified	Khruea yang			Climber/ Herbaceous
Unidentified	Kam pee			Tree

Appendix 7 Species found in the 27-year-fallow

Scientific name	Local name	Thai name	Family	Life form
Ailanthus triphysa (Dennst.) Alston	Ma yom pa	Ma yom pa	Euphorbiaceae	Tree
Antidesma acidum Retz.	Mao soi	Mao soi	Euphorbiaceae	Shrub
Aporosa serrata Gagnep.	Mueat	Mueat ton	Euphorbiaceae	Tree
Bambusa bambos (L.) Voss	Phai khaai	Phai paa	Poaceae	Bamboo
Bauhinia sp.	San pan	Salaeng phan	Fabaceae	Woody climber
Brachiaria mutica (Forssk.) Stapf	Ya khon	Ya khon	Poaceae	Grass/ Herbaceous
Canarium sp.	Ma lium		Burseraceae	Tree
Castanopsis sp.	Ko	Ko	Fabaceae	Tree
Christia vespertilionis Bakh.f	Peek kai dam	Peek kai dam	Fabaceae	Climber/ Herbaceous
Chromolaena odorata (L.) R. M. King & H. Rob.	Ya hueng	Sap suea	Asteraceae	Herbaceous
Clausena sp.	Song fa	Song fa	Rutaceae	Shrub
Crassocephalum crepidioides (Benth.) S. Moore	Ya dok kam	Phakkat chang	Asteraceae	Herbaceous
Cratoxylum formosum (Jack) Dyer	Tio	Tio Khao	Clusiaceae	Tree
Croton poilanei Gagnep.	Plao	Plao	Euphorbiaceae	Tree
Cyperus rotundus L.	Ya haeo mu	Ya haeo mu	Cyperaceae	Grass/ Herbaceous

Appendix 7. (continued)

Scientific name	Local name	Thai name	Family	Life form
Cyperus sp.	Ya sam lium		Cyperaceae	Grass/ Herbaceous
Gardenia sootepensis Hutch	Khai nao	Khammok luang	Rubiaceae	Tree
Goniothalamus laoticus (Finet & Gagnep.)Ban	Khoa lam dong	Po khi haet	Annonaceae	Tree
Grewia sp.	Leaw sai leaw khwa		Tiliaceae	Herbaceous
Grewia sp.	Yap		Tiliaceae	Tree
Helicteres angustifolia L.	Po tao hai	Khi tun	Sterculiaceae	Grass/ Herbaceous
Kaempferia galanga L.	Wan naeng	Pro hom	Zingiberaceae	Herbaceous
Markhamia stipulata Seem. Var.	Khae foi	Khae hua mu	Bianonaceae	Tree
Memcylon edule Roxb.	Mai see	Plong mueat	Memecylaceae	Tree
Paracalyx scariosa (Roxb.) Ali	Khruea kon	Khruea khao kon	Fabaceae	Climber/ Herbaceous
Phallanthus emblica L.	Ma kham pom	Ma kham pom	Euphorbiaceae	Tree
Phyllantus reticulatus Poir.	Ya lep maeo	Kang pla khruea	Euporbiaceae	Shrub
Phyllodium longipes (Craib) Schindl.	Klet lin	Klet lin yai	Fabaceae	Herbaceous
Siphonodon celastrineus Giff.	Ma duk	Ma duk	Celastraceae	Tree
Syzygium cumini (L.) Skeels	Wa	Wa	Myrtaceae	Tree

Appendix 7 (continued)

Scientific name	Local name	Thai name	Family	Life form
Vitex pinnata L.	Tin nok	Tin nok	Verbiaceae	Tree
Zoysia matrella (L.) Merr. var. *matrella*	Ya phaet khruea	Ya nuan noi	Poaceae	Grass/ Herbaceous
Unidentified	Chi cho			Herbaceous
Unidentified	Phak yod dieo			Herbaceous
Unidentified	Som			Tree

Appendix 8 Species found in the forest

Scientific name	Local name	Thai name	Family	Life form
Adenanthera pavonina L.	Ma lam	Ma klam ton	Fabaceae	Tree
Ageratum conyzoides L.	Khee lo	Sap raeng sap ka	Asteraceae	Herbaceous
Ailanthus triphysa (Dennst.) Alston	Ma yom pa	Ma yom pa	Euphorbiaceae	Tree
Albizia sp.	Mai len		Fabaceae	Tree
Alpinia sp.	Kra chai pa		Zingiberaceae	Herbaceous
Antidesma acidum Retz.	Mao soi	Mao soi	Euphorbiaceae	Shrub
Aporosa serrata Gagnep.	Mueat	Mueat ton	Euphorbiaceae	Tree
Asparagus filicinus Buch. Ham	Khud hong	Ma sam ton	Asparaguaceae	Herbaceous
Bambusa sp.	Phai lam		Poaceae	Bamboo
Canarium sp.	Mak lium		Burseraceae	Tree
Canavalia cathatica Thouars.	Ka sam peek	Thua krapao	Fabaceae	Climber/ Herbaceous
Carex condensta Nees	Ya khom bang	Ya khom bang khao	Cyperaceae	Herbaceous
Castanopsis sp.	Ko	Ko	Fabaceae	Tree
Christia vespertilionis Bakh.f	Peek kai dam	Peek kai dam	Fabaceae	Climber/ Herbaceous
Chromolaena odorata (L.) R. M. King & H. Rob.	Ya hueng	Sap suea	Asteraceae	Herbaceous

Appendix 8. (continued)

Scientific name	Local name	Thai name	Family	Life form
Clausena sp.	Song fa	Song fa	Rutaceae	Shrub
Clerodendrum petasites (Lour.) S. Moore	Phin phi	Thao yai mom	Labiaceae	Shrub
Costus speciosus (Koenig.) Smith	Kan tow yai bom	Ueang mai na	Costaceae	Herbaceous
Crassocephalum crepidioides (Benth.) S.Moore	Ya dok kam	Phakkat chang	Asteraceae	Herbaceous
Cratoxylum formosum (Jack) Dyer	Tio	Tio khao	Clusiaceae	Tree
Cratoxylum subsp. Pruniflorum (Kurz) Gogel	Tio daeng	Toi khon	Clusiaceae	Tree
Croton poilanei Gagnep	Plao	Plao	Euphorbiaceae	Tree
Croton tiglium L.	Salot	Salot	Euphorbiaceae	Tree
Cynodon dactylon (L.) Pers.	Ya pheat	Ya phraek	Poaceae	Grass/ Herbaceous
Cyperus rotundus L.	Ya haeo mu	Ya haeo mu	Cyperaceae	Herbaceous
Cyperus sp.	Ya sam lium		Cyperaceae	Herbaceous
Dendrolobium thorelii (Gagnep.) Schindl.	Nat yai	Khao mai	Fabaceae	Shrub
Desmos chinensis Lour.	Khruea khao klaep	Sai yut	Annoanaceae	Herbaceous
Desmodium triforum L. DC.	Klet hoi	Klet hoi	Fabaceae	Herbaceous
Echinochloa spp.	Ya plong		Poaceae	Grass/ Herbaceous

Appendix 8 (continued)

Scientific name	Local name	Thai name	Family	Life form
Elephantopus scaber L.	Tao fai nokkhum	Do mai ruu lom	Asteraceae	Herbaceous
Elettariopsis sp.	Kha pa		Zingiberaceae	Herbaceous
Ficus prostrata Wall.	Mak not	Mak not	Moraceae	Shrub
Gigantochloa albociliata Munro	Phai Hai	Phai ri	Poaceae	Bamboo
Goniothalamus laoticus (Finet & Gagnep.)Ban	Khoa laam dong	Po khi haet	Annonaceae	Tree
Grewia sp.	Yap		Tiliaceae	Tree
Grewia sp.	Leaw sai leaw khwa		Tiliaceae	Tree
Harrisonia perforata (Blanco) Merr.	Nam kai	Khontha	Simaroubaceae	Shrub
Hopea ordorata Roxb.	Cha khian	Ta chian tong	Dipterocapaceae	Tree
Inula cappa (Ham.) DC.	Nat doi	Nat kham	Asteraceae	Shrub
Irvingia malayana Olive ex Bennett.	Krabok	Krabok	Irvingiaceae	Tree
Jasminum sp.	Sai kai	Sai kai	Oleaceae	Climber/ Herbaceous
Kaempferia galanga L.	Wan naeng	Pro hom	Zingiberaceae	Herbaceous
Leea sp.	Ueang gai		Leeaceae	Shrub
Lagerstroemia calyculata Kurz	Puei	Ta baek	Lythraceae	Tree

Appendix 8 (continued)

Scientific name	**Local name**	**Thai name**	**Family**	**Life form**
Lepisanthes rubiginosa (Roxb) Leenh.	Ma huat	Ma huat	Spindaceae	Tree
Litsea glutinosa (Lour.) C. B. Rob.	Mi men	Mi men	Lauraceae	Tree
Lygodium flexuosum (L.) Sw.	Khut ngong	Yan li hao	Schizaeaceae	Fern/ Herbaceous
Memecylon edule Roxb.	Mai see	Plong mueat	Memecylaceae	Tree
Micromelum sp.	Oi soi		Rutaceae	Tree
Paederia lineris Hook. f.	Ya tot ma	Tot mu tot ma	Rubiaceae	Climber/ Herbaceous
Paracalyx scariosa (Roxb.) Ali	Khruea kon	Khruea khao kon	Fabaceae	Climber/ Herbaceous
Phallanthus emblica L.	Ma kham pom	Ma kham pom	Euphorbiaceae	Tree
Phlogacanthus paniculatus (T. And) T. And	Bu ha pa		Acanthaceae	Herbaceous
Phyllantus reticulatus Poir.	Ya lep maeo	Kang pla khruea	Euphorbiaceae	Shrub
Phyllodium longipes (Craib) Schindl.	Klet lin	Klet lin yai	Fabaceae	Herbaceous
Polyalthia suberosa (Roxb.)	Nam noi	Klueng klom	Annonaceae	Shrub
Pterocarpus macrocarpus Kurz	Pradu	Pradu	Fabaceae	Tree
Pterospermum semisagittatum Buch.-Ham.	Thong fan	Kham khua	Sterculiaceae	Tree
Sida rhombifolia L.	Ya khat	Khat mon	Malvaceae	Herbaceous

Appendix 8 (continued)

Scientific name	Local name	Thai name	Family	Life form
Siphonodon celastrineus Giff.	Ma duk	Ma duk	Celastraceae	Tree
Smilax davidiana A. DC.	Khruae khiang	Khueang soi	Schizaeaceae	Climber/ Herbaceous
Stemona tuberosa Lour.	Hak mod	Non tai yak	Stemonaceae	Climber/ Herbaceous
Stephania venosa (blume.) Spreng.	Poa lueat	Kra thom lueat	Menispermaceae	Climber/ Herbaceous
Sterculia lanceolata Cav.	Lin bo uean		Sterculiaceae	Shrub
Streptocaulon juventas (Lour.) Merr.	Khruea khao sung	Chukka rohini	Periplocaceae	Climber/ Herbaceous
Syzygium cimini (L.) Skeels	Wa	Wa	Myrtaceae	Tree
Tadehagi triquetrum (L.) Ohashi	Ya ka non	Khao mao nok	Fabaceae	Herbaceous
Thelypteris sp.	fern		Thelypteridaceae	Fern/ Herbaceous
Thunbergia grandiflora (Roxb. Ex Rottler) Roxb.	Khruea nom nae	Soi in thannin	Acanthaceae	Climber/ Herbaceous
Uraria lagopodioides (L.) Desv. Ex DC.	Hang suea	Ya hang on	Fabaceae	Shrub
Urena lobata L.	Khee on	Khee khork	Malvaceae	Herbaceous
Vigna adenantha (G. Mey.) Marechal	Thua hae phi	Thua hae phi	Fabaceae	Tree
Vitex pinnata L.	Tin nok	Tin nok	Verbiaceae	Tree
Zoysia matrella (L.) Merr. var. *matrella*	Ya phaet khruea	Ya nuan noi	Poaceae	Grass/ Herbaceous

Appendix 8 (continued)

Scientific name	Local name	Thai name	Family	Life form
Unidentified	Bi kon klong			Climber/ Herbaceous
Unidentified	Chi cho			Herbaceous
Unidentified	Ching chun			Climber/ Herbaceous
Unidentified	Jam pe pa			Tree
Unidentified	Khai so			Tree
Unidentified	Khruea mon pa			Climber/ Herbaceous
Unidentified	Lae ling			Climber/ Herbaceous
Unidentified	Mak khruea			Climber/ Herbaceous
Unidentified	Mak ta kai			Herbaceous
Unidentified	Nam tang			Tree
Unidentified	Ngun ngam			Herbaceous
Unidentified	Phak wan pa			Herbaceous
Unidentified	Phak yod dieo			Herbaceous
Unidentified	Pik noi			Shrub
Unidentified	Poa plao			Climber/ Herbaceous

Appendix 8 (continued)

Scientific name	Local name	Thai name	Family	Life form
Unidentified	Som soa			Tree
Unidentified	Tang gua			Tree
Unidentified	Wan sai noi			Herbaceous

Appendix 9 Mean (± SD) of total root colonization (RC) of herbaceous plants in different land use types

Species (Family)	Thai name	%RC								Comment
		Agriculture				Fallow			Forest	
		A1	A2	A3	A4	F1	F2	F3		
Ageratum conyzoides L. (Asteraceae)	Sap raeng sap ka	66±10	81±14	71±9	96±3	-	-	-	-	major weed
Alpinia sp. (Zingiberaceae)	Kha	-	-	-	-	-	-	20±26	12±5	medicinal use and food
Amaranthus viridis L. (Amaranthaceae)	Phak khom	-	6±10	-	-	-	-	-	-	major weed
Arachis hypogaea L. (Fabaceae)	Thua li song	76±13	-	-	-	-	-	-	-	crop species
Bauhinia sp. (Fabaceae)	Salaeng phan	-	-	-	-	-	-	29±36	-	medicinal use
Centella asiatica (L.) Urb. (Apiaceae)	Bua bok	-	-	51±4	-	-	85±9	-	-	medicinal use, food and weed
Christia vespertilionis Bakh. f. (Fabaceae)	Pik kai dam	-	-	-	-	-	-	52±3	-	medicinal use
Chromolaena odorata (L.) R. M. King & H. Rob. (Asteraceae)	Sap suea	73±13	27±35	82±8	48±49	69±28	81±19	86±8	96±7	medicinal use and major weed
Commelina diffusa Burm. f (Commelinaceae)	Ya kab	-	-	-	29±49	-	90±2	-	-	weed

RC = total root colonization, A1 = groundnut field, A2 = kra chai dam field, A3 = glutinous rice field, A4 = mulberry field , F1 = 1-year-fallow, F2 = 4-year-fallow, F3 = 27-year-fallow, - = not sampled

Appendix 9 (continued)

Species (Family)	Thai name	%RC								Comment
		Agriculture				Fallow			Forest	
		A1	A2	A3	A4	F1	F2	F3		
Conyza sumatrensis (Retz.) Walker (Asteraceae)	Ya dok khao	59±17	69±10	47±36	91±8	-	95±6	-	49± 0.4	major weed
Corchorus aestuans L. (Tiliaceae)	Khat mon tua phu	63±6	-	37±13	-	-	-	-	-	major weed
Crassocephalum crepidioides (Benth.) S. Moore (Asteraceae)	Ya dok kham	55±28	61±25	65±6	49±12	-	-	-	69±31	major weed and food
Crotalaria quinquefolia L. (Fabaceae)	Hing hoi	-	-	47±7	-	-	-	-	-	-
Cynodon dactylon (L.) Pers. (Poaceae)	Ya phraek	-	-	-	-	34±8	-	-	-	major weed
Cyperus rotundus L. (Cyperaceae)	Ya haeo mu	-	-	-	-	-	-	0	0	medicinal use and weed
Cyperus sp. (Poaceae)	Ya sam liam	-	-	-	6±7	-	-	2±3	-	weed
Dactyloctenium aegyptium (L.) P.Beauv. (Poaceae)	Ya pak khwai	-	-	-	41±28	-	-	-	-	major weed
Desmodium triforum L. DC. (Fabaceae)	Klet hoi	-	-	21±17	-	-	-	-	55±37	-
Elephantopus scaber L. (Asteraceae)	Do mai ruu lom	-	-	-	-	-	67±19	-	71±18	medicinal use

RC = total root colonization, A1 = groundnut field, A2 = kra chai dam field, A3 = glutinous rice field, A4 = mulberry field , F1 = 1-year-fallow, F2 = 4-year-fallow, F3 = 27-year-fallow, - = not sampled

Appendix 9 (continued)

Species (Family)	Thai name	%RC								Comment
		Agriculture				Fallow			Forest	
		A1	A2	A3	A4	F1	F2	F3		
Euphorbia heterophylla L. (Euphorbiaceae)	Yang ueng	65±29	-	-	47±40	-	-	-	-	major weed
Euphorbia hirta L. (Euphorbiaceae)	Nam nom ratchasi	-	-	-	93±6	-	-	-	-	medicinal use
Gigantochloa albociliata (Munro) Munro (Poaceae)	Phai rai	-	-	-	-	-	-	-	18±10	make fence
Hedyotis diffusa Willd. (Rubiaceae)	Hom chaeo na	-	-	-	-	-	50±9	-	-	weed
Imperata cylindrica (L.) P. Beauv. (Poaceae)	Ya kha		-	-	80±10	47±19	-	-	-	medicinal use
Inula cappa (Ham.) DC. (Asteraceae)	Nat kam	-	-	-	-	-	-	-	71±13	weed
Jasminum sp.(Oleaceae)	Sai kai	-	-	-	-	-	-	-	60±26	medicinal use
Kaempferia galanga L. (Zingiberaceae)	Wan naeng	-	-	-	-	-	-	55±45	51±24	-
Kaempferia parviflora Wall. ex Baker (Zingiberaceae)	Kra chai dam	-	75±46	-	-	-	-	-	-	crop species
Lepisanthes rubiginosa (Roxb) Leenh. (Sapindaceae)*	Ma huat	-	47±13	-	-	-	-	-	-	-

RC = total root colonization, A1 = groundnut field, A2 = kra chai dam field, A3 = glutinous rice field, A4 = mulberry field , F1 = 1-year-fallow, F2 = 4-year-fallow, F3 = 27-year-fallow, - = not sampled

Appendix 9 (continued)

Species (Family)	Thai name	%RC								Comment
		Agriculture				Fallow			Forest	
		A1	A2	A3	A4	F1	F2	F3		
Ludwigia hyssopifolia (G. Don) Exell (Onagraceae)	Thian na	-	-	-	48±36	-	-	-	-	major weed
Lygodium flexuosum (L.) Sw. (Schizaeaceae)	Li phao	-	-	-	-	-	-	-	1±2	make basket and medicinal use
Mesona chinensis Benth. (Lamiaceae)	Tu pa	-		-	-	52±18	-	-	-	-
Mimosa pudica L. (Fabaceae)	Maiyarap	84±11	-	-	-	52±34	69±7	-	-	medicinal use and weed
Mitracarpus villosus (Cham.& Schltr.) A. DC. (Rubiaceae)	Ya chuk khao	79±6	57±27	60±18	19±30	-	-	-	-	major weed
Morus alba L. (Moraceae)	Mon	-	-	-	43±17	-	-	-	-	crop species
Muntingia calabura L (Tiliaceae)*	Ta kob	-	49±3	26±22	-	-	-	-	-	food
Oryza sativa L. var. *glutinosa* L. (Poaceae)	Khao niao	-	-	12±1	-	-	-	-	-	crop species
Oxalis corniculata L. (Oxalidaceae)	Som kop	-	-	-	94±6	-	61±30	-	-	major weed
Paracalyx scariosa (Roxb.) Ali (Fabaceae)	Khruea kon	-	-	-	-	-	-	27±14	-	-

RC = total root colonization, A1 = groundnut field, A2 = kra chai dam field, A3 = glutinous rice field, A4 = mulberry field , F1 = 1-year-fallow, F2 = 4-year-fallow, F3 = 27-year-fallow, - = not sampled

Appendix 9 (continued)

Species (Family)	Thai name	%RC								Comment
		Agriculture				Fallow			Forest	
		A1	A2	A3	A4	F1	F2	F3		
Pennisetum polystachyon (L.) Schult. (Poaceae)	Ya kha chon chop	-	-	-	38±29	57±7	-	-	-	major weed
Phlogacanthus paniculatus (T. And). T. And. (Acanthaceae)	Bu ha pa	-	-	-	-		-	-	71±24	-
Phyllanthus reticulatus Poir. (Euphorbiaceae)	Kang pla khruea	-	-	-	-	-	95±2	-	-	-
Phyllodium longipes (Craib) Schindl. (Fabaceae)	Khet lin	-	-	-	-	-	0	-	53±26	medicinal use
Pseuderanthemum sp. (Acanthaceae)	Hom pa	-		82±18	-	-	-	-	-	-
Scoparia dulcis L. (Scrophulariaceae)	Krot nam	61±25	-	55±9	15±1	-	-	-	-	medicinal use and weed
Sida rhombifolia L. (Malvaceae)	Ya khat	46±10	-	49±16	-	14±5	68±23	-	60±35	medicinal use and weed
Sterculia lanceolata Cav. (Sterculiaceae)	Mak de pa	-	-	-	-	-	-	-	36±3	-
Tadehagi triquetrum (L.) Ohashi (Fabaceae)	Khao mao nok	-	-	91±14	64±33	13±6	62±17	-	-	-

RC = total root colonization, A1 = groundnut field, A2 = kra chai dam field, A3 = glutinous rice field, A4 = mulberry field , F1 = 1-year-fallow, F2 = 4-year-fallow, F3 = 27-year-fallow, - = not sampled

Appendix 9 (continued)

Species (Family)	Thai name	%RC								Comment
		Agriculture				Fallow			Forest	
		A1	A2	A3	A4	F1	F2	F3		
Urena lobata L. (Malvaceae)	Khi khrok	55±19	-	42±16	-	45±40	83±7	-	83±5	major weed
Vigna dalzelliana (Kuntze.) Verdc. (Fabaceae)	Thua hae phi	-	-	51±22	-	-	-	-	70±11	-
Zoysia matrella (L.) Merr. var. *matrella* (Poaceae)	Ya phaet khruea	-	-	-	51±39	8±5	48±28	12±8	-	major weed
Unidentified	Chi cho	-	64±56	-	-	-	-	-	37±14	food
Unidentified	Hing hai	-		-	-	-	-	-	75±19	-
Unidentified	Phak yod dieo	-	45±17	-	16±10	42±11	84±12	0	33±20	-

RC = total root colonization, A1 = groundnut field, A2 = kra chai dam field, A3 = glutinous rice field, A4 = mulberry field , F1 = 1-year-fallow, F2 = 4-year-fallow, F3 = 27-year-fallow, - = not sampled

BIOGRAPHY

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