CHAPTER 5

GENERAL DISCUSSION

Karen farmers at Huai Tee Cha village, Sob Muai district, Mae Hong Son province in northern Thailand have a good practice to maintain their shifting cultivation system. They have been successful in managing a fallow enriching tree, pada that is beneficial to maintained upland rice yield. The reduction of fallow cycle from 10-15 years to 7 years did not affect to rice yield. Hidden resources of this success were found to be the arbuscular mycorrhizal (AM) fungi. Previous studies of Youpensuk (2004) and also this study found high dependency of this tree to AM fungi. The fallow enriching tree, pada sometimes grew hardly at all without helpful from the AM fungi. It has previously not been known how some 17 varieties of upland rice and 56 species of other swidden crops that were grown during the cropping phase (Yimyam, 2006) benefit from the symbiosis with AM fungi.

In this thesis, I have described the association between AM fungi and swidden crops in farmer's field in term of root infection and spore density in rhizsosphere of the plants (Chapter 2). The effects of association between indigenous AM fungi and swidden crops were determined in pot trail (Chapter 3) and the role of AM fungi with upland and lowland rice also investigated in pot trial (Chapter 4). From these studies I have found differences in dependence to AM fungi in among and within plant species, and also differential effects of the plant on the AM fungi.

5.1 Different dependency to AM fungi among plant species

This thesis confirmed previously reported studies (Youpensuk, 2004) that AM fungi can strongly increased growth and nutrient contents of the fallow enriching tree, pada, especially when P was limiting. However, I have also found that AM fungi also enhanced growth and yield of swidden food crops to varying degrees. Mycorrhizal dependency of the swidden crops in low P ranged from 18 to 68% and from 19 to 35% in hig P. AM fungi increased seed yield of upland rice and sorghum in low P only, while seed yield of Job's tears increased in both P levels. Although this results showed benefit AM on enhancing plant growth at low P but only to half of high P. In contrast, for pada the effect of AM was much larger, with AM increasing growth to the same extent as increasing P from low to high. Without the AM infection, pada grew very little. Seedlings of tropical rainforest tree species have been reported incapable of absorbing phosphorus when not mycorrhizal (Grandcourt *et al*., 2004). Pada was a highly mycorrhizal dependent, derive more benefits from AM fungi in comparison with a lower mycorrhizal dependency like corn, Job's tears and sorghum. Differential responses to AM fungi among plant species have been frequently reported in the literature e.g. Huante *et al*. (1993), they observed effect of AM on seedling growth of four tree species were grown inside the greenhouse and they found that *Caesalpinia eriostachys* and *Pithecellobium mangense*, showed a larger mycorrhizal dependency than *Cordia alliodora* and *Ipomoea wolcottiana*. In addition, the studies of Plenchette. (1983); Plenchette and Morel. (1996); Giovannetti *et al*. (1988); Bagayoko *et al*. (2000); van der Heijden *et al*. (2003); Klironomos *et al*. (2000) and Klironomos. (2003); Turjaman *et al*. (2006), have all illustrated that mycorrhizal dependency depends on host plant species.

The reason for differential AM dependency among plant species remains to be fully explained. Apart from the level of soil P, mycorrhizal dependency also depended on the specific combination of plant species and AM fungi taxa (van der Heijden *et al.*, 2003; Diop *et al.*, 2003). Root morphology has been suggested as one of the reasons why some plants are more mycorrhizal dependent than others (Hetrict *et al.*, 1992). These authors found that the roots of plant species with high mycorrhizal dependency often have thick, unbranched roots, and few root hairs. This suggestion agrees well with the finding in this study that rice was least responsive to AM infection, as rice roots are fine, highly branched and have numerous root hairs. Plant with a low dependency for example, rice, is hardly enhanced by AM fungi.

5.2 Different responses to arbuscular mycorrhizal fungi between different varieties of the same plant species

From the symbiosis of AM fungi in Bue Bang (upland rice) and KDML 105 (lowland rice) in freely drained soil studies (Chapter 4), I found AM inoculation to have different effects on different rice varieties. Although the AM fungi had no effect vegetative growth of KDML105 and Bue Bang, AM had different effects on some aspects of the nutrition of the two rice varieties. AM fungi enhanced P and Cu concentrations in brown rice of both varieties. In addition, AM inoculation also increased S in the husk of Bue Bang but not in KDML 105. KDML 105 had higher seed number, seed weight and hundred seed weight than Bue Bang, this suggested that the nutrient use efficiency of KDML 105 was better than Bue Bang. These findings are in contrast with a previous report that the effect of AM fungi inoculation dry weight of rice varied among varieties (Dhillion, 1992). Differences among the

Medicago species in their reaction to *Glomus* species ranged from negative to highly positives have been reported by Monzon and Azcón. (1996). This study evaluated only 2 rice cultivars, there is a possibility that genotypic variation in response to AM may be found with a wider range of rice varieties. The anomalies in rice responses to AM, between experiments in this study and also with published reports, remains to be explained.

5.3 Variation in root colonization and spore density

From these studies, AM fungi responses differed according to the host plant species, sampling time, location and P application. In 2003, soils rhizosphere of pada were taken from the farmer's field was 19 spore g^{-1} fresh soil whereas the largest number of spores was found in the wet season (Youpensuk *et al*., 2004). In this study, spore density of soil rhizosphere of pada in a different field in the same village in 2005, but also in the wet season, was 16 spore g^{-1} soil, while in the swidden crops they ranged from 6-15 spore g^{-1} soil. This difference may be attributed to sampling time and variation between mountain slopes.

Perhaps because of soil P was directly in contact with spore therefore, sensitivity to adding P in soil grown medium was found in sporedensity more than root colonization (Chapter 3; Figure 3.3, Table 3.7 and Chapter 4; Figure 4.5). However, degree of root colonization showed no correlation with mycorrhizal dependency of host plant species. For example, at low P colonization of corn, Job's tears and sorghum (80 – 100%) was as high or even higher than pada (88%), but they showed lower mycorrhizal dependency than pada. Highly colonized root of AM at low P soil may due to the root exudation. Tawaraya *et al*. (1998) found that in root exudates from P-deficient onion increase appressorium formation and therefore, enhance mycorrhiza development. Moreover, branching of the primary germ tube and the number of branches and the total hyphal length were significantly inhibited by adding of P (Nagahashi *et al*., 1996).

From these studies (Chapter 3, 4), although, *Acaulospora* was the dominant genus however, we do not know which genus/ species was most effective for each swidden crop. *Acaulospora* was a among the most effective spore type for the fallow enriching tree, pada (Youpensuk, 2005). Notwithstanding, not all plants promoted to the same extent from AM fungi, and the extent of benefit depended upon the AM species, specific AM fungi had effects on growth but these were not the same for each plant (Hart and Reader, 2002). Twelve tropical legumes inoculated with *Glomus aggregatum* showed varied dependency from 26.2 to 92.7% (Duponnois *et al*., 2001). Furthermore, there was variation among VA mycorrhizal fungi in their ability to enhance phosphorus uptake could be due to differences in the length, distribution and phosphorus uptake of external hyphae (Jakobsen *et al*., 1992).

These studies found no correlation between root colonization and plant growth or nutrient uptake. It was demonstrated that percentage of root colonization only is a poor parameter of AM effectiveness. Because of the external hyphea can absorb and translocation phosphorus to the host directly from soil outside the root depletion zone of roots, therefore, determination host plant in responsiveness to mixed AM spores with colonized root did not know which AM species were effective. The effect of AM fungi providing phosphorus to the host plants depends very much on the AM species. For instances, *Glomus intraradice* and *Acaulospora* sp. were considered efficient and suitable for inoculation into rice nurseries (Secilia and Bagyaraj, 1992), *Glomus mosseae* in maize (Bi *et al*., 2003), *Glomus fasciculatum* in cashew (Ananthakrishnan *et al*., 2004), *Acaulospora* sp. in enriching tree, pada (Youpensuk, 2005), *Glomus monosporum* in grapevine (Giovannetti *et al*., 1988).

These studies also found spore types varied with different plant species and varieties. Pada had equal spore densities of *Acaulospora* and *Glomus* whereas the rhizosphere of swidden crops was dominated by *Acaulospora*. In addition spore density was higher for upland rice, Bue Bang than lowland rice, KDML 105.

5.4 General conclusion

These studies have demonstrated that AM fungi in the root zone of fallow enriching tree, pada directly enhanced plant growth, yields and nutrient uptake of swidden food crops especially at low P. Variation in dependence to AM fungi was found among the different swidden crops and also between two rice varieties. Moreover, the most abundant AM fungi in rhizosphere of all swidden crops was *Acaulospora*. Mycorrhizal dependency of swidden crops illustrated that AM fungi, a hidden resource for shifting cultivation system are very useful for crops. So, agricultural practices which undisturbed AM community, can be contributed opportunity of effective AM fungi to be matched with the host plant.

5.5 Implications for further research

The present study used indigenous soil from Huai Tee Cha village's fields as inoculum and it was contained with mixed AM spores. After AM spores determination we found that AM type were identified by morphotype was high diversity especially they are many species within the same genus. For instance, spores of *Acaulospora* genus consisted of many species such as: *levies*, *morrowwea*, *eligans*, *scrobiculata*, *luciana*. Although, we can classified in many genus or species but we did not know which spores were effective for each host plant. So, a single spore culture should be further examined by study effect of each AM fungi on each plant. High variation of P was found in the farmers' fields, how its affect to the distribution of AM fungi in different host should be observed. Although *Acaulospora* is a dominant genus in many host plant rhizosphere, however, should be confirmed by single culture. In addition, AM hyphea in each host plant should be demonstrated by molecular technique results reinforce observation colonized in root. Moreover, the responses to AM fungi in different upland rice varieties and other swidden crops that were grown during cropping phase at Huai Tee Cha village should be further investigated.