CHAPTER 2

LITERATURE REVIEW

2.1 Nutrient deficiency in northern soil

In the northern Laos, on the large valleys that are not covered by recent deposits, soils are most likely Acrisols. In the smaller valleys and on the steep slop, particularly in the areas where shifting cultivation is practiced (causing erosion), the parent material of the low land soils is alluvium and these soil are useful in identifying major soil differences between regions (Linquist and Sengxua 2001). 80% of the soil in north contain less than 2% organic matter, 68 % are coarse - textured (sands, loamy sands, and sand loams), and 87% have a pH (H_20) of less than 5.5 (Saphangthong 1998). The prevalence of less fertile soil in the north may be due to less fertile and low temperature than those typically found in the mountain. Almost the soil in the north have been limited by nutrients especially Ca, Mg and Na beside N, P and K. (SSLCC 2001). Phosphorus was the first most limiting nutrient, with 71% of the area responding to P and approximately 37 % in the north, the soil were so P-deficient that they are no response to other nutrients unless P was applied first (Linquist and Sengxua 2001).

2.2 Rubber (*Heavea brasislensis)*

2.2.1 Characteristic of rubber

Heavea brasislensis is a fast-growing tree that reaches 40 m in height and 35 cm d.b.h. The tree has straight trunk that is column - shaped and thick at the base. The species grows well in soil at least 1 m deep with a pH of 4.0 - 6.5. The tree grows on slopes ranging from zero to 70 percent at elevation from sea level to 1200 m. The optimum temperature range for the species is 22 to 30^{o}C with an ideal average of 25^{o}C and a minimum temperature higher than 15^{o}C. Relative humidity should not exceed 70 to 80 percent (Bustamante, 1991). Annual precipitation much be between 1500 and 3000 mm. Root system with a well-developed taproot and far-spreading laterals. Rubber seed as a high content of oil, the seed quickly loses germinative power; therefore, planting much occur which in 98 days after collection. Fifteen days after collection, the seeds' germination percentage decreases considerably. As a recalcitrant seed, it does not tolerate drying and dies when its moisture content is lower than 25 percent of its fresh weight. Because a great amount of water is contained in the seed, temperature less than 5 ^{o}C will kill it. If they do not dry out, rubber seed can survive from a few weeks to few months. Ventilation should not be limited because the seeds have a high respiration. Pre germination of seeds can be done in sawdust beds. Seeds germinate shortly after release from the mother plant and 8 day after being planted. The germinator should be 1 m wide by 10 cm high with variable lengths. The average germination percentage is 60 percent. The germinator is prepared with muddy soil, with their ventral surfaces on the sawdust, 1 cm apart. One thousand seeds will fit into 1 m 2 of germinator. A threshing floor of 1.7 m^{2} will produce 1,700 seeds, which provide the 500 plants needed to plant 1 ha. Germinator occurs 8 to 10 days after planting, and the seedlings are transplanted when they reach an appropriate developmental state at six - ten months in the northern Laos. (Ketphan 2005).

2.2.2 Status and situation of rubber plantation in Laos

The long journey of rubber began during the 20 century with its introduction into Laos as an exotic from China (Ketphan *et al .n.d.*). It has become a much more familiar and important crop. From an ordinary commodity it became a strategic commodity. Farmer living on the Chinese border in north provinces began interest in rubber in the early 1990s, during the year 2003 and an economic export crop since then. The importance and expansion of this crop had great effect government organisations after 2003 (NAFRI 2006). While Laos is facing a shortage of trees at the moment rubber is a foreign exchange earner for producing and exporting countries and it is a golden crop for various industrial countries as importers who have an assured source of raw material at a cheap price. And the losers from the introduction of rubber as an economic crop in the promotion of modern agriculture are local crops which perhaps at the moment have no value but which have a value in the long-term self-reliance of local communities. Organization (Burger and Smit 1992).

Rubber tree is one of many cash crops growing in environment and also can be grown around in Northern provinces of Laos such as Luangprabang, Oudomxay, Luangnumtha and Borkeo provinces.

Rubber planting has experienced a significant boom during the last decade in northern Laos as Chinese demand for natural rubber has increased, coupled with rising world price of natural rubber. Local authorities in northern Laos are frequently approached by Chinese investors with investment plant for rubber planning. In the meantime, rural farmer are also showing interest to plant rubber with the hope of securing a source of long-term income for their family. Unlike other crop (i.e. job's tear, maize), there are yet no sign that the surging interest in rubber is about to diminish (Ketphanh *et al* n.d.).

According to Table 1, northern Laos accounts for 58 percent of the total rubber in Laos today. The plan of the Ministry of Agriculture and Forestry is to expand this by more than seven times up to 121,000 ha by 2010.

Table 1.1 Target and potential for planting rubber (Unit: ha)

Regions	2007	2010(Plan)
Northern	16,547	121,000
Central	2,946	10,000
Southern	8,738	52,840
Total area of rubber	28,231	183,840
Share of total land	0.12%	0.78%

Source : base on Forestry Research Centre (2007)

As interest in rubber increased, a number of issues have also been identified. One major concern is the widespread conversion of forest lands its implication on natural resource management and local livelihoods. For example, Schipani (2007) points out the detrimental impact the expansion of rubber has had in Luang Namtha on forest conservation and ecotourism activities.

The global demand for natural and synthetic rubber has increased since the early 1990s, largely driven by the booming economies in Asia. While the total consumption for both natural and synthetic rubber in Northern America and Europe accounted more than 60 percent of the global consumption in 1965, the share declined down to approximately 30 percent in 2005. According to the international Rubber Study Group (IRSG), Asia’s consumption is now more than 50.This change is primarily due to the rapid industrial development and economic growth of China and India. It is expected that China will consume 30 percent of global rubber production (both natural and synthetic rubber) by 2020 (Ketphan *et al .n.d.*). Almost all natural rubber imported by China originates from Southeast Asia, with Thailand accounting for approximately 70% of the total imports. China’s other main sources of rubber are Vietnam, Malaysia and Indonesia (IRSG *et al* nd). Although there is a steady demand for rubber, this does not necessarily mean that prices will continue to rise. The world market price of natural rubber is volatile despite efforts to regulate the market price of rubber by organizations such as the International Natural Rubber

Rubber is a fast-growing, multi-purpose tree species are widely plated on farms in Northern Laos as they perform a key role in stabilizing and improving farm soils while providing many additional and varied products such as timber, fodder and fruit and increasing total farm productivity through exploitation of different niches, above and below ground. Many of tree species employed are leguminous and from symbiotic associations with N2 - fixing bacteria and arbuscular mycorrhizal fungi, with enable them to sustain growth in the phosphorus and nitrogen deficient soils typical of the region. These soil are often degraded through over- cultivation and erosion, and such intensification of land - us may lead to insufficient or ineffective populations of microsymbionts(NAFRI, 2006). In these cases inoculation with effective rhizobia and AM fungi may be needed for the re- establishment of trees while long - term improvement in soil fertility and growth of the crops will require land management regimes which sustain and promote mycorrhizal fungi populations.

2.3 Arbuscular mycorrhizal fungi (AM)

2.3.1 Functions of AM fungi

Many results of experiments suggest that AM fungi absorb N, P, K and other nutrients from the soil and translocate them to associated plants (Thompson *et al*., 1983). However, the most prominent and consistent nutritional effect of AM fungi is in the improved uptake of immobile nutrients such as P and Zn by increasing the absorptive surfaces of the root. The supply of immobile nutrients to roots is largely determined by the rate of diffusion. In soils not adequately supplied with nutrients, uptake of nutrients by plants far exceeds the rate at which the nutrients diffuse into the root zone, resulting in a zone around the roots depleted of the nutrients. Mycorrhizal fungi help overcome this problem by extending their external hyphae to areas of soil beyond the depletion zone, thereby exploring a greater volume of the soil than is accessible to unaided root. Enhanced nutrient uptake by AM fungi is often associated with dramatic increase in dry matter yield, typically amounting to several - fold increases for plant species having high dependency on mycorrhiza. AM fungi may have biochemical capabilities for increasing the supply of available P and other immobile nutrients. These capabilities may involve increases in root phosphates activity, excretion of chelating agents, and rhizophere acidification.

When a nutrient is deficient in the soil solution, the critical root parameter controlling its uptake is surface area. Hyphae of mycorrhizal fungi have the potential to greatly increase the absorbing surface areas of the root. For example, Robson found that while extrametrical mycelia (aggregate of hyphae) accounted for less than 20% of the total nutrient absorbing surface area of the pine seedlings. It is also important to consider the distribution and function of the extrametrical hyphae. If the mycorrhiza is to be effective in nutrient uptake, the hyphae must be distributed beyond the nutrient depletion zone that develops around the root. A nutrient depletion zone develops when nutrient are moved from the soil solution more rapidly than they can be replaced by diffusion. For a poorly - mobile ion such as phosphate, a sharp and narrow depletion zone develops close to the root. Hyphae can readily bridge this depletion zone and grow into soil with an adequate supply of phosphorus. Uptake of micronutrients such as zinc and copper is also improved by mycorrhizae because these elements are also diffusion - limited in several soils. For more mobile nutrients such as nitrate, the depletion zone wide is less like those hyphae grows extensively into the zone that is not influenced by the root alone (Rajan *et al* 2000).

Another factor contributing to the effective absorption of nutrients by mycorrhizae is their narrow diameters relative to roots. The steepness of the diffusion gradient for a nutrient is inversely related to the radius of the absorbing unit; therefore, the soil solution should be less depleted at the surface of a narrow absorbing unit such as hyphae. Furthermore, narrow hyphae can grow into small soil spores inaccessible to root or even root hairs. Another advantage attributed to mycorrhizal fungi is access to pools of phosphorus not readily available to the plant. One mechanism for this access is the physiochemical release of inorganic and organic phosphorus by organic acids through the action of low - molecular - weight organic anions such as oxalate which can be (Fox, et al., 1990): (i) replace phosphorus sorbet at metal-hydroxide surfaces through ligand-exchange reactions, (ii) dissolve metal - oxide surfaces that absorbs phosphorus, and (iii) complex in a solution and thus prevent precipitation of the metal phosphates. AM fungi associations from when host roots and compatible fungi are both active in close proximity and soil condition are favorable. The infection process consist of three different steps: (1) hyphae growth from a germinating spore, dependent initially upon its own nutritional supply; (2) stimulation of further fungal growth by root exudates and initiation of the infection process; and (3) fungal development of intracellular arbuscules which connect the fungus to the nutrient flux from the plant (Morton, 1997).

2.3.2 Benefits of arbucular mycorrhizal (AM) fungi to plants

The wide dispersal of fungal hypha in soil, and the small diameter of hyphaerelative to roots, gives access to a much larger volume of soil than the root system itself. Hyphae of AM fungi act more or less as a pump, supplying the root with a supplement of water and mineral salts to with it normally would not have full access (Dalpe, 1997). Jakobsen *et al.,* (1992) studied hyphal transport of p by three AM fungi (*A. leavis, Glomus* sp. And S. *calospora*) associated with Trifolum subterraneum. Ahyphy compament was separated from root compartment by a fine mesh preventing root penetration, which contained layers of p - labeled soil at different distances from root compartment. A time - course over 37 days showed that *A. laevis* transported most p to shoot over soil - root distances longer than *Glomus* sp. While S. calospora transported much less p to plants, but accumulated more P in its hyphae than the two other fungi. In experimental chambers, the external hyphae of

AM fungi can deliver up to 80% of plant P, 25% of plant N, 10% of plant K, 25% of plant Zn and 60% of plant Cu (Marschner and Dell, 1994). Experimental data showed that AM plants benefit from the uptake of P, N , K Mg, Ca, S, Cu, Mn, and Zn. For example, Dodd *et al*. (1990) reported that the combination treatment of AM fungi and rock phosphate have the potential to increase plant growth where phosphorous is limiting plant production. Rutto *et al.* (2002) evaluated the effect of *Gigaspora margarita* on mineral status of peach seedling. Mycorrhizal seedlings showed significantly higher concentrations of shoot P, K and Zn. Ahmad & Maziah (1998) stated that mineral nutrition of micro propagated of pine when colonized by nine species of AM fungi. Shoot Ca and Mg were higher in plants inoculated with all AM fungi species. The majority of isolates of AM fungi significantly increased shoot Mn concentration. (Marschner. *et al.,* 1994). Nye *et al* (1997) reported that the uptake of nitrogen phosphorus and potassium from soil and transport it to the host plant. Inoculating senna spectabilis with *Glomus intraradices* increased significantly the shoot biomass yield. The shoot biomass production increased by 213% and was highly significant. (Marschner *et al*). In addition the supply of immobile nutrients to roots is largely determined by the rate of diffusion. Inorganic nutrients, AM fungi may have access to some organic mineral forms, particularly of nitrogen. Different AM fungi have been to shown to differ in the extent to which they increase nutrient uptake and plant growth. Rajan *et al* (2000) studied the efficacy of nine AM fungi generally showed an increase in growth and nutritional status (P, Zn and Cu) over those growths in the absence of the AM fungi and concluded that *G. leptotrichum* was the best AM symbiont.

2.3.3 Arbuscular mycorrhizal fungi in ecosystem and agriculture and forestry

Arbuscular mycorrhizal fungi are a major component of rhizosphere soils, and they can form mutualistic associations with the fine roots of approximately 80% of all terrestrial plants. In this symbiosis, the host plant provides the fungus with soluble carbon sources, at the same time the fungus enhances the uptake by plants of certain nutrients, particularly phosphate (Jayachandran and Shetty, 2003). At present, AM fungi are considered as an important component in the restoration and reestablishment of the vegetation in fragile or degraded ecosystems, and in the maintenance of plant biodiversity and ecosystem functioning (van der Heijden *et al.*, 1998 and Dhillion and Gardsjord, 2004). AM fungi are commonly associated with plants in arid and small precipitation regions, and various studies have characterized the distribution and abundance of AM fungi in these environments (Dell, 2001**)**. Arbuscular mycorrhizal fungi are present in most natural and agriculture. They contribute to plant health, nutrient cycling, survival rate, and conservation of soil structure (Morton, 1997). Moorland and Revees (1979) reported that the diversity of mycorrhizal fungi contributes to the “buffering capacity” of the forest ecosystem; or the ability of the system to withstand and recover from disturbance. It is evident from their effects upon soil health and host plant growth that AM fungi are an important part of sustainable agricultural systems that have low inputs of chemical fertilizers and pesticide (Jeffries and Barea, 1994). Plikomol *et al*. (1982) examined mycorrhiza- Rhizobium interaction on growth of soybean. Total dry weight of soybean inoculated with AM fungus (Gigapora sp). Nopamornbodi (1982) compared the growth of corn inoculated and non-inoculated with AM fungi (unnamed species found in root zone of maize in

Thailand). The best colonization and nutrient absorption were obtained with maize inoculated with spores and infected roots at the same time. Fungicides are extensively used in agricultural systems to control fungal pathogens. However, agriculture fungicides are not only pathogen-specific but also affect a wide rang of non - pathogenic fungi, including those which are beneficial to plant growth, such as AM fungi (Vyas, 1988). Several investigations have shown that AM fungi can be effected fungicides (Aliette, Benlate and Ridomil) on AM symbiosis. All three fungicides markedly reduced and total length of infected root. The greatest effect being observed with Benlate followed by Aliette and Ridomil. Sukarno *et al.* (1996) reported that 31 mg benomyl/kg (A. cepa) and P acquisition. However, Larsen *et al.* (1996) reported that 10 mg benomyl/kg soil reduced formation of mycorrhizas by *G. caledonium* on *Cucumis sativus*. Merryweather and Fitter (1996) found that 63 mg benomyl /kg soil inhibited AM colonization on Hyacinhoides non- seripta (bluebell).Diversity of AM fungi has been studied in a variety of natural and agricultural ecosystems. Generally, forests support maximum mycorrhizal diversity and this reduced by agricultural practices (Verma et al., 2000). Vander Heijder et al. (1998) determined relationship between AM fungal species richness and plant diversity. They manipulated AM fngi diversity by adding 0, 1, 2, 4, 6, 8 or 14 AM fungi species to macrocosms containing sterile field soil and a seed mix comprising 15 plant species. They found that plant diversity and biomass increased with AM fungal diversity because the growth of different plants was stimulated by different fungal species.

2.3.4 Potential of arbuscular mycorrhizal fungi in agroforestry system

Arbuscular mycorrhizal fungi present in most natural and agroforestry system, they are important for plant health, nutrient cycling, survival rate, and conservation of soil structure. AM fungi procure and transport phosphate and other nutrient from the soil to plant roots. On the other hand, the host plant provides fixed carbon to its fungal partner (Harrison, 1999). Furthermore, AM fungi could facilitate th management of metal contamination in soil for a restoration and /or bioremediation program. This information indicated the challenge of the transferring this abilities to non -legumes such as cereals representing a very long term or the possibilities of this fungus opening the sustainable agriculture and forestry. As a consequence, AM fungi were crucial determinants of plant biodiversity, ecosystem variability, and the productivity of plant communities (Onguen *et al.*, 2001).

The wide dispersal of fungal hypha in soil, and the small diameter of hyphae relative to roots, gives access to a much larger volume of soil than the root system itself. Hyphae of AM fungi act more or less as a pump, supplying the root with a supplement of water and mineral salts to with it normally would not have full access (Dalpe, 1997). Jakobsen *et al*. (1992) studied hyphal transport of P by three AM fungi (*A. leavis*, *Glomus* sp. And S. *calospora*) associated with Trifolum subterraneum. Ahyphy compament was separated from root compartment by a fine mesh preventing root penetration, which contained layers of P - labeled soil at different distances from root compartment. A time - course over 37 days showed that *A. laevis* transported most p to shoot over soil - root distances longer than *Glomus* sp. While S. calospora transported much less P to plants, but accumulated more p in its hyphae than the two other fungi. In experimental chambers, the external hyphae of AM fungi can deliver up to 80% of plant P, 25% of plant N, 10% of plant K, 25% of plant Zn and 60% of plant Cu (Marschner and Dell, 1994). Experimental data showed that AM plants benefit from the uptake of P, N , K Mg, Ca, S, Cu, Mn, and Zn. For example, Dodd *et al*., (1990) reported that the combination treatment of AM fungi and rock phosphate have the potential to increase plant growth where phosphorous is limiting plant production. Rutto *et al.,* (2002) evaluated the effect of *Gigaspora margarita* on mineral status of peach seedling. Mycorrhizal seedlings showed significantly higher concentrations of shoot P, K and Zn. Taylor and Harrier (2001) examined mineral nutrition of micro propagated of strawberry when colonized by nine species of AM fungi. Shoot Ca and Mg were higher in plants inoculated with all AM fungi species. The majority of isolates of AM fungi significantly increased shoot Mg concentration. Frey and Schuepp (1993) examined the ability of AM fungi to take up nitrogen from soil and transport it to the host plant. Inoculation of maize with *Glomus intraradices* increased the N content of mycorrhizal plant compare to the non - mycorrhizal plant when N was applied as $(NH4)_2 S0_4$. In addition to supplying inorganic nutrients, AM fungi may have access to some organic mineral forms, particularly of nitrogen. For example, Hawkins *et al.* (2000) reported that some species of *Glomus* could transport the amino acids glycine and glutamine into wheat. Different AM fungi have been to shown to differ in the extent to which they increase nutrient uptake and plant growth. Rajan *et al.,* (2000) studied the efficacy of nine AM fungi generally showed an increase in growth and nutritional status (P, Zn and Cu) over that growth in the absence of the AM fungi and concluded that *G. leptotrichum* was the best AM symbiont.

Therefore, the selected study of AM fungi diversity may be the most important to need as components of forestation programs. In the same way, Morton (1997) reported that the diversity of mycorrhizal fungi contributes to the "buffering capacity "of the forest ecosystem; or the ability of the system to withstand and recover from disturbance. Therefore, th mycorrizal fungi are hoped for reforestation with rapid conversion of tropical forest. It is imperative to collect and assess indigenous mycorrhizal fungi for successful establishment of tree plantations. There are many reports about diversity of AM fungi agroforestry systems. Fourteen species were found in the root zone of plants in a bamboo forest in Taiwan (Wu and Chen, 1986). Eleven AM fungi were found in the root zones of rubber (*Heavea*) in Sri Lanka (Jayaratne and Waidyanatha, 1982). Twenty-eight species were found in Eucalyptus plantation, South China (Chen *et al.*, 1998). Mycorrhizal interactions between plants, fungi and the environment are complex, interdependence, and often inseparable. Although much has yet to be learned about the dynamics of each association, it is clear that mycorrhizas are an essential below - ground component in establishment and sustainability of plant communities as the earth's geography and climate undergoes continual flux and change (Morton, 1997).

It is now widely accepted that AM mycelial networks from links between plant species in ecosystems, and that they are responsible for the transfer of nutrients between different plant species (Read, 1991). (Haselwandter and Bowen, 1996) proposed that AM fungi associated with agroforestry tree species may serve an additional role by maintaining active AM propagules in the soil, which could then rapidly colonize roots of emerging crop seedlings. Subsequent studies have supported this view (Leakey *et al.*, 1999) reported that maize grown in soil taken from close to

S. siamea formed more mycorrhizas than when it was grown in soil collected at 2 m distance, while (Daigne *et al.*, 2001) examined soils from agroforestry systems in Senegal and found beneficial effects of Acacia tortilis trees on mycorrhizal fungi colonization and growth of millet seedlings. The role of perennial trees in maintaining AM fungi inoculum and in sustaining mycelial networks for short-lived crops may therefore be an unintended benefit of agroforestry systems and provide an alternative approach to the use of cover crops to build up soil inoculum.

The term mycorrhizal fungi defines a structural as well as functional association: A mycorrhizae is a mutualistic symbiosis between plant and fungus localized in a root in which energy (carbon compounds) move primarily from plant to fungus and inorganic resources (Principally phosphate) move from fungus to plant.

One type of mycorrizal fungi is termed an endomycorrhizae. In endomycorrhizal fungi, following hyphal penetration into the root, the hyphae penetrate the cell walls of the cortical cells. These types are generally called AM fungi. The intracellular hyphae produce structures that frequently branch many times within the host cells. These structures are known as arbuscules. Arbuscules are the organs where nutrients and carbon are exchanged between host and fungus. Typically, also formed are vesicles, which are fungal storage units. The hyphae within the cells and older roots are subsequently reabsorbed by the host. The association is specifically referred to as a arbuscular mycorrhizal fungi. AM fungi association are found in nearly all families of angiosperms and in some ferns, mosses, and liverworts.

2.4 Agroforestry system in the upland of northern Laos

In recent years various development and research projects have introduced alternative agroforestry systems that focus on improved plant nutrient management and soil erosion control. Such systems include contour hedgerows, alley cropping, and biologically enriched fallows. While northern Laos is facing a shortage of trees at the moment rubber is a foreign exchange earner for producing and exporting countries and it is a golden crop for various industrial countries as importers who have an assured source of raw material at a cheap price. And the losers from the introduction of rubber as an economic crop in the promotion of modern agriculture are local crops which perhaps at the moment have no value but which have a value in the long-term self-reliance of local communities. These crops could be medicinal herbs, forest vegetables, indigenous vegetables, ornamentals, etc. Laos is one of the few countries with rainforests which are generally recognized to enjoy rich biological diversity. 80% of the world's varieties are found in these zones. Also the special qualities of rubber which allow it to adapt to all conditions have led to forest encroachment to plant rubber. At the present the environmental problems are increasing by the day in their extent and their severity. In the case of rubber farmers there have been attempts to extend, to study and to learn and suggest alternatives, to improve their standard of living and environment by company and relevant government agencies such as the Chinese Rubber company. The Rubber Research center will set up a Rubber Intercropping Research Project with local rubber farmers who are interested. The various parties join in studying and seeking new alternatives which do not neglect the knowledge of the previous generations, and suggest strategies to deal with each new condition. There are various processes of studying such as training and study tours, in order to create an ongoing understanding among people, communities and society.

The case study of rubber intercropping by farmers scattered throughout the five provinces of LuangNamtha, Bokeo, Oudomxay, Phonsaly and Luanprabang is a study of the knowledge and experience that stems from local wisdom. The geographical diversity of the other places from the mountaintops to the shore creates an informal knowledge which it is becoming ever more necessary to pass on, to maintain a steady evolution of new knowledge. Alternative agroforestry systems have been introduced on a trails basis, such as biologically improved fallows, alley cropping and contour hedgerows. These systems aim mainly at soil improvement and plant nutrient management, but many also produce firewood, fodder and mulching material. However adoption has been very limited, probably because these systems provide farmers with few or no immediate economic benefits - real or perceived. Their adoption is further hampered by the relatively easy access to land, cash tree and forest products when compared to more densely populated areas. (Hanson and Sodarak, 1996).