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Study on Soil Nitrogen Enrichment in Mixed Species Trial with Teak (*Tectona grandis* Linn.f.)

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ကျွန်းနှင့် နိုက်ထရိုဂျင်ဓါတ်ဖြည့်သစ်မျိုးများ ရောနှောစိုက်ပျိုးခြင်းဖြင့် မြေဆီလွှာတွင် နိုက်ထရိုဂျင်ဓါတ်တိုးတက်မှုကို လေ့လာခြင်း

ဆွေဆွေထွန်း၊ သုတေသနလက်ထောက်-၂၊ သစ်တောသုတေသနဌာန
ဘီလီနေဝင်း၊ သုတေသနလက်ထောက်-၂၊ သစ်တောသုတေသနဌာန
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သစ်တောသုတေသနဌာန

စာတမ်းအကျဉ်း

ကျွန်းစိုက်ခင်းများတွင် မြေဆီလွှာအဆင့်အတန်းကျဆင်းခြင်းနှင့် ရေရှည်ထုတ်လုပ်နိုင်မှု ကျဆင်းလာခြင်းတို့ကြောင့် ကျွန်းစိုက်ခင်းများတည်ထောင်ရာတွင် နိုက်ထရိုဂျင်ဓါတ်ဖြည့်သစ်မျိုးများကို ရောနှောစိုက်ပျိုးရန် စိတ်ဝင်စားလာကြပါသည်။ နိုက်ထရိုဂျင်ဓါတ်ဖမ်းယူနိုင်သော သစ်မျိုးများ သည် လေထဲရှိ နိုက်ထရိုဂျင်ကို မြေဆီလွှာအတွင်းတွင် ဖမ်းယူခြင်းဖြင့် ကျဆင်းနေသောမြေ အဆင့်အတန်းကို ကောင်းမွန်တိုးတက်စေပါသည်။ ထို့ကြောင့် ၂၀၀၀ခုနှစ်တွင် ငလိုက်ကြိုးဝိုင်း၊ အကွက်အမှတ် ၂၄ တွင် ကျွန်းနှင့် နိုက်ထရိုဂျင်ဓါတ် ဖြည့်သစ်မျိုးများဖြစ်သည့် ဘောစကိုင်း (၅၀ း ၅၀)၊ ကုက္ကို (၆၀ း ၄၀)၊ မြန်မာရှား (၇၀ း ၃၀) တို့ကို ရောနှော စမ်းသပ် စိုက်ပျိုးခဲ့ပါသည်။ မြေဆီလွှာတွင် စုစုပေါင်း နိုက်ထရိုဂျင်ပါဝင်မှုအား ခန့်မှန်းရန်အတွက် အပေါ်ယံ မြေဆီလွှာ (၀-၂၀ စင်တီမီတာ) ကို အချိန်အပိုင်းအခြားအလိုက် စမ်းသပ်ဆောင်ရွက်ခဲ့ပါသည်။ နိုက်ထရိုဂျင်ပါဝင်မှုနှုန်းကို Total Nitrogen Difference method (TND) နည်းသုံး၍ တွက်ချက်ခဲ့ပါသည်။ စမ်းသပ်တွေ့ရှိချက်များအရ ကျွန်းနှင့် ကုက္ကိုသည် နိုက်ထရိုဂျင်ဓါတ်ပါဝင်မှုနှင့် နိုက်ထရိုဂျင်ဖြည့်ပေးမှုအကောင်းဆုံးဖြစ်ကြောင်းတွေ့ရှိရပါသည်။ ၎င်းနောက် ကျွန်းနှင့် မြန်မာရှား ရောနှောစိုက်ပျိုးခြင်းသည် ဒုတိယနေရာတွင်ရှိပြီး ဘောစကိုင်းနှင့်ရောနှော စိုက်ပျိုး မှုသည် တတိယ နေရာတွင် ရှိပါသည်။ စိုက်ပျိုးစမ်းသပ်ကွက်သည် နိုက်ထရိုဂျင် လုံလောက်မှုရှိနေခြင်းနှင့် ကျွန်းစိုက်ခင်း သက်တမ်းငယ်နေခြင်းတို့ကြောင့် စိုက်ပျိုးပြီး ခြောက်နှစ်အကြာတွင် ကျွန်းသီးသန့် စိုက်ပျိုးထားသည့် နေရာတွင်လည်း နိုက်ထရိုဂျင်ဓါတ် တဖြည်းဖြည်းတိုးသော်လည်း ၂၀၀၇ ခုနှစ် တွင် တဖြည်းဖြည်း ကျဆင်းလာကြောင်းတွေ့ရှိရပါသည်။ အဆိုပါလေ့လာမှုသည် စိုက်ခင်းသက်တမ်း ကိုးနှစ်အတွင်းတွင် လေ့လာထားခြင်းဖြစ်ပြီး ပိုမိုခိုင်မာသော အဖြေရရှိရန်အတွက် ရေရှည်လေ့လာမှုများ ဆောင်ရွက်ရန် လိုအပ်မည်ဖြစ်ပါသည်။ ၎င်းအပြင် ကျွန်းစိုက်ခင်း များတည်ထောင်ခြင်းကို နိုက်ထရိုဂျင်ဓါတ်လုံလောက်မှုမရှိသောနေရာများတွင် အဓိက ရောနှော စိုက်ပျိုးပေးရန် လိုအပ်မည်ဖြစ်ပါသည်။

Study on Soil Nitrogen Enrichment in Mixed Species Trial with Teak (*Tectona grandis* Linn.f.)

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Abstract

Concerning to promote in soil fertility and long-term productivity of teak plantation, it has been interested by using N_2 fixing tree as mixed species for establishment of Teak Plantations. Nitrogen fixing trees are able to fix atmospheric nitrogen that they may allow them to perform better soil condition on degraded soils. Teak and nitrogen fixing trees species including Bawzagaing (*Luecaena leucocephala)*, Kokko (*Albizzia lebbek)* and Sha (*Acacia catechu)* were planted in different proportions (50:50, 40:60 ,30:70) to compare with pure teak system (100:0) which were tested in 2000, in Ngalaik Reserved Forest, Compartment No.24. Soil nitrogen concentration and nitrogen fixation rate in surface soil layer (0-20 cm) were assessed in different time interval. Nitrogen fixation rate was determined by using Total Nitrogen Difference method (TND). The result of mixing different nitrogen fixing species indicated that mixtures containing Teak and Kokko showed the highest soil nitrogen content and nitrogen fixation in this trial. Teak and Sha is the second and then followed by Teak and Bawzagaing. Although soil N_2 gradually increase in pure teak in six years of planting because of sufficient soil N_2 and young-age of the plantation and slightly decrease from 2007. As the study period is relatively short (within 9 year), long-term observations are required for better understanding of the nutritional status and growth benefits. Especially, teak and N_2-fixing trees should be established at the limited soil N_2 site.

Key Word: Teak, N_2-fixing tree species, Mixture, Soil fertility.

Contents

1. Introduction

Teak (*Tectona grandis*) has recognized as a most valuable premium wood in the world's timber trade. The sustainable supply of teak from natural forests diminishes and the demand continues to increase. Therefore, the general trend in the future of teak growing will be towards increasing production and utilization of plantation-grown teak. The plantation sites select on flat and gentle slopes between 200 - 800 m above the sea level. Teak monoculture is no longer practiced, because pure teak suppresses nearly all undergrowth and causes soil erosion during the rainy season (Chimi, D., 1995). Through surface runoff, many of the available nutrients from soil surface leached out or washed away. As an alternative to monocultures, mixed plantation systems seem to be the most appropriate for production, protection, biodiversity conservation and restoration. The long-term sustainability of high productivity in plantations depends on a continued supply of nutrients.

Nitrogen (N_2) is one of the most important nutrients required by plants but also one of the most deficient nutrients in most ecosystems, particularly on degraded land. In addition, most of the N_2 contained in the top layer of tropical soils that easily washed out in steep, denuded slope. They also cause a loss of fertility and soil degradation. So, adequate Biological Nitrogen Fixation (BNF) or fertilizer (N_2) inputs will be required to replace the N_2 lost or removed. Chemical fertilizer is expensive and supplies are often limited. In addition, these sources may also have a polluting effect.

Therefore, concerns about decline in soil fertility and long-term productivity of teak plantations have promoted interest in using N_2-fixing trees in mixed species plantation. Leguminous spp. have been widely decorated for their soil-improving characteristics, often rapidly decomposing leaf litter and fixation of root nodules. N_2–fixing plants such as *Acacia*, *Albizzia*, *Luecaena*, *Casuarina* have been enriched nitrogen and improved tree form and wood quality in a few years after plantation establishment (Khanna, P.K.,1998).

2. Objectives

Despite teak plantation mixed with N_2-fixing species was widespread used, and accepted by foresters, there is hardly any study or account of fixation of N_2 in teak plantation. Therefore, the present study was undertaken with the following objectives;

1. To assess the influence of N_2-fixing trees on soil fertility (especially for soil nitrogen) in teak plantations
2. To evaluate N_2 fixation rate (in soil) between mixed and pure teak plantations
3. To find out the effect of N_2-fixing tree species in unlimited soil N_2

3. Literature Review

Most of the investigators suggested that there may be a productivity advantage in planting forest stands containing more than one species. Based on these considerations, facilitation by using N_2 –fixing trees in association with non N_2–fixing species may be a good ecological mixture on N_2–limiting sites (Kelty, 1992). N_2-fixation in the grass-soil systems occurred when the initial soil nitrogen levels were low (0.05 %) but not when they were somewhat higher (0.07-0.09 %) (Moore A.W., 1963).

Often the primary objective of using N_2-fixing species in mixed systems is to increase the N_2 available to the main crop or companion species. Total N_2 in the plant-soil system can increase by atmospheric N_2-fixation (Kelty and Cameron, 1995). Either way N_2 can be transferred between N_2- fixing species to the non-N_2 fixing species via the decomposition of litter (such as foliage and fine-roots) and the subsequent mineralization of organic N_2 (including root exudates) (Khanna P.K., 1998).

N_2 fixation rate calculated from the following equation;

N_2-fixation rate = (dry matter) x (% N in species) x (percentage of clover Nitrogen derived from the atmosphere - pNfa)

N_2 fixation can only perform by certain strain of prokaryotic microbes (Fisher and Binkley, 2000). These microbes use the N_2 fixing enzyme, nitrogenase, to reduce atmospheric N_2 to ammonia (NH_3) that plants can utilize (Walker et al., 1983; Sprent, 1987). Many plants form symbiotic, mutuality relationships with these prokaryotes, which receive carbohydrates and micro aerobic environments and supply reduced N_2 for use in amino acids, proteins and other biochemical. Plant capable of forming such symbioses; such as legumes or actinorhizal plants, are sometimes used in agroforestry and forestry systems. Legumes such as *Acacia, Albizzia, Falcataria, Luecaena, Lupinus* and *Robinia* have symbiotic, mutualistic relationships with the bacteria genera *Rhizobium* and *Bradyrhizobium* (Fisher and Binkley, 2000). Actinorhizal species from genera such as *Alnus*, *Casuarina* and *Ceanothus* are associated with the Frankia genus of actinomycetes. (Forrester D.I., 2004). Rates of N_2 – fixation depend on the density, age and growth of the host, mycorrhizae ,the degree of nodulation, the genetics of the host, mycorrhizae and N_2 –fixing bacteria, and environmental factors that affect plant growth (Fisher and Binkely, 2000).

4. Materials and Methods

4.1. Study site

The study site is located in compartment No. 24 of Ngalaik Reserved Forest, Pyinmana Township (see Fig-1). The site is on latitude of 19° 56' N and longitude of ၉၆° 56' E, and it is 600 m above sea level. The topography consists of generally flat.

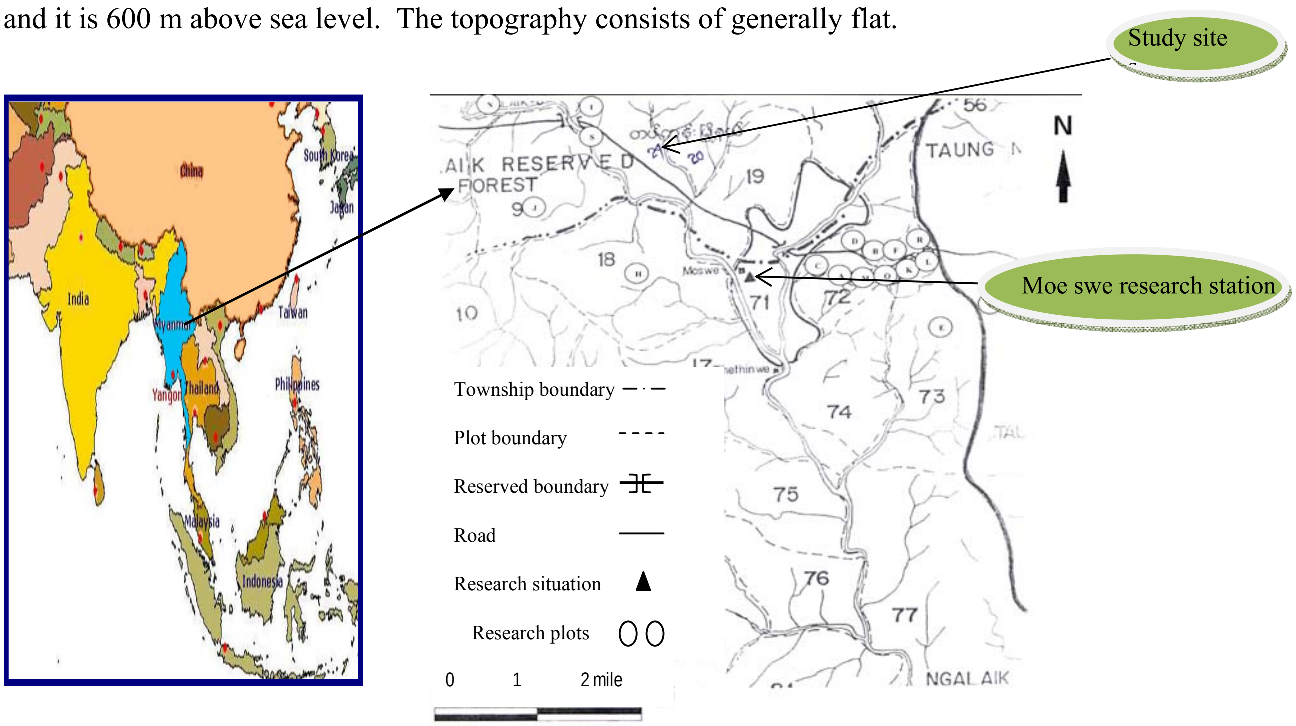


Fig-1. Location map of trial site

Soil is laid by buff to yellowish color, medium to thick bedded, coarse to gritty, poorly consolidated sand stone. The soil i drained, and has a sandy loam texture with pH 6.3 (Kyi, 1991).

The area lies tropical savannah climate with a pronounced dry period between the monsoon rains. According to the climatic data of study area 1999-2008, raining season begins at the end of April or the first week of May and ends in October. The study area gets 6 months of more than 20 aridity index by DEMARTONNE's method. Some critical climatic data (1999-2008) and climatogram are shown in Table- 1 and Fig- 2.

Table-1. Climatic data (monthly means) and aridity index (1999 – 2008)

Month	**Temperature (˚C)**	**Rainfall (mm)**	**DeMartonne's Aridity Index**
Jan	22.0	1.5	1.75
Feb	23.2	0	0
Mar	26.4	8.7	2.89
Apr	29.7	17.9	5.41
May	27.8	201.9	64.14*
Jun	26.3	275.8	91.06*
Jul	25.9	205.4	68.64*
Aug	25.7	250.3	84.04*
Sep	26.1	203.0	67.39*
Oct	26.4	158.5	52.17*
Nov	24.3	25.3	8.90
Dec	21.8	4.9	1.85

Source: Moswe Research Weather Station (* indicates the month with the aridity index larger than 20 and these months on the year is not arid)

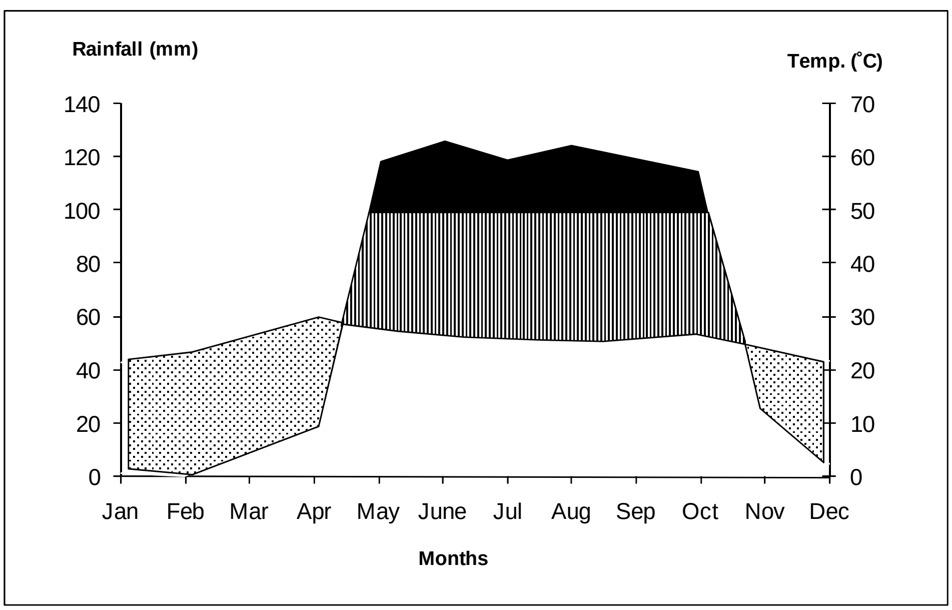


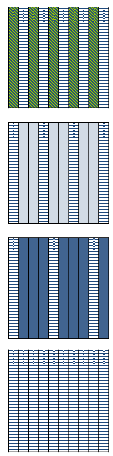
Fig-2. Climatogram (1999-2008) of study area

4.2 Experimental Design

The stand originally planted with teak and N_2- fixing tree species in 2000. The experimental design is a complete randomized block with four replications in 0.57 ha. A unit plot has a gross area of 0.035 ha and there were total 16 plots as shown in Fig-3. The plot size is 20 m x 20 m. The treatment were mixtures of Teak with Bawzagaing (*Luecaena leucocephala)* (T_1), Teak with Kokko (*Albizzia lebbek)* (T_2), Teak with Sha (*Acacia catechu)* (T_3) and Pure Teak for control plot (T_4). Tree spacing was (2 x 2) m^2. There are 1600 trees in total or 100 trees in each plot.

Block 1	Block2	Block3	Block 4
T_2	T_4	T_3	T_1
T_3	T_1	T_2	T_4
T_4	T_3	T_1	T_2
T_1	T_2	T_4	T_3

Plot treatment codes:



(i) Teak: Bawzaging (50:50) - T_1

(ii) Teak: Kokko (40:60) - T_2

(iii) Teak: Sha (30:70) - T_3

(iv) Pure Teak (100:0) - T_4

Fig-3. Experimental plot layout

4.3 Soil Sampling

Of the available techniques for assessing N_2-fixing in soil, the Total Nitrogen Difference method (TND) is the simplest to estimates the amount of N_2 fixation by species. In TND, the proportion of total nitrogen in a N_2 –fixing species that has accumulated from the soil (Ns) estimated and the remaining N_2 attributed to nitrogen fixation. Ns is assessed by considering it to be equal to the total Nitrogen (N_2) in the control non- N_2 –fixing species (reference plant). Non-N_2 –fixing species, Teak, was used as a reference plant for calculation of N_2 fixation rate. The first soil sample collected in 2000. The second soil sample collected in 2004 and then collected in 2005, 2006, 2007 and 2009. Forty-eight soil samples taken in 0-20 cm depth in each time. In each plot, three points as a triangle form are set to the north, southeast and southwest direction and 5 m apart from the centre of plot and layout of sample plot was as shown in Fig- 4.

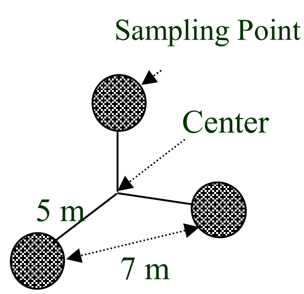


Fig-4. Design of soil sample collecting under trial site

4.4 Laboratory analysis

Soil samples dried air and sieved. Total soil nitrogen (N_2) and organic carbon (OC) were determined on the 2 mm portion of the soil. Total N_2 analyzed by using Micro Kjedahal digestion and Pro nitro distillation unit and OC was tested by weight loss on ignition.

4.5 Statistical Analysis

One-way analysis of variance (ANOVA) in SPSS used to calculate the OC and soil N_2. Least significant difference in post hoc test used to separate the means of dependent variables, which significantly affected by treatment.

5. Results

5.1 Soil Organic Carbon under Mixed Species Trial with Teak

Soil organic carbon has many beneficial for plant growth indirectly. Factors that affect soil OC are climate (temperature and rainfall; greatest accumulation where cool and wet), natural vegetation and texture and drainage system of the soil. The rate of degradation of different fractions of soil OC varies from a half-life of only a few months for non-humic substances to centuries for the most resistant humic substances (http//www.foodshedproject . com).

At the first stage of study site, there was no difference in OC between mixed and pure teak trial site. Within four years these soil OC are decreasing. Then OC turns to increase among the N_2-fixing tree spp., except in pure teak trial site. In these states mixed with Kokko was significant higher than other N_2-fixing spp. as shown in Fig-5 .

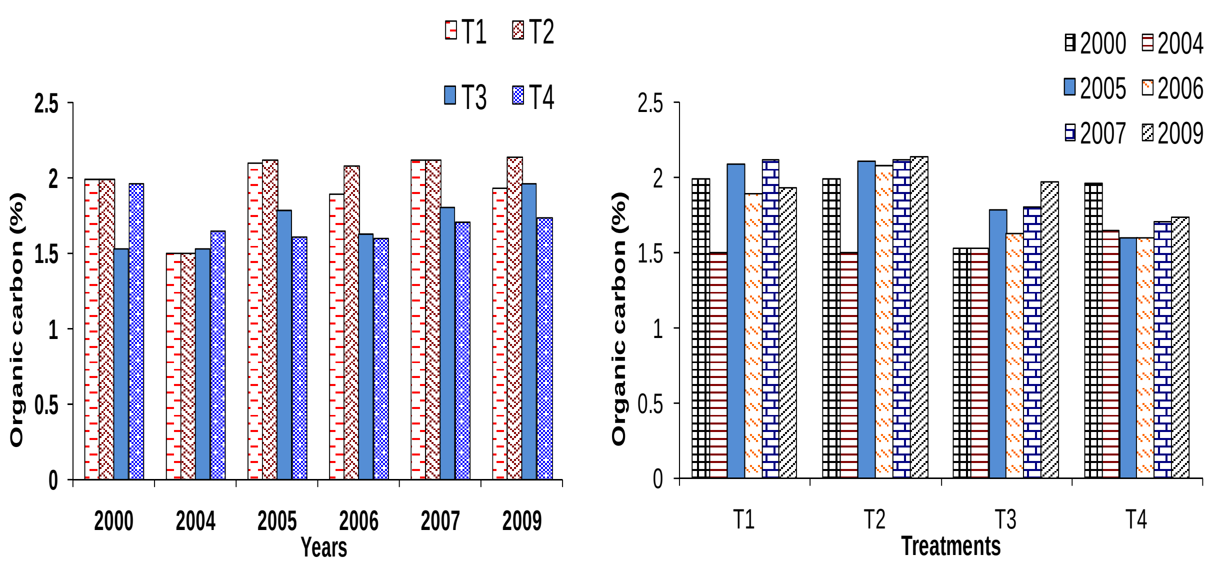


Fig-5. Comparison of soil OC among mixed species trial with teak

5.2 C:N ratio among mixed species trial with teak

Another aspect of residue composition that affects the rate of decomposition is C:N ratio. The organisms that decompose residues need N_2 (and other essential elements) as well as C. If there is little N_2 in the residue, decomposition is slow. In other way C:N ratio is high available of soil N_2 is limit for plant. In the study site, C: N ratio within four years planting is not good to get available N_2 for the plant (see in Table-2). After five year C:N ratio among all treatments is optimal condition for the decomposition. At this stage, the soil nitrogen was enough to take up by organism and plants.

Table-2. Relation of C: N ratio in all treatments

	T_1	T_2	T_3	T_4
2000	26	26	21	25
2004	23	23	27	36
2005	20	17	14	23
2006	17	14	13	15
2007	20	18	17	16
2009	17	16	16	17

5.3 Soil nitrogen dynamic under mixed species trial with teak

Soil N_2 is a significant interaction between age and vegetation type with older plantations containing a higher soil N_2 concentration than the younger ones as shown in Fig-6.

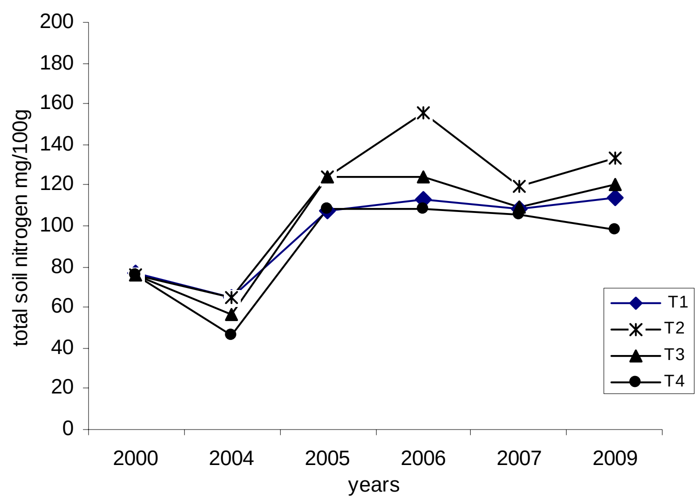


Fig-6. Soil nitrogen concentration under mixed species trial with teak

There was no significant difference of soil N_2 under all trial in 2000 as shown in Fig-7 and table- (a) in appendix.

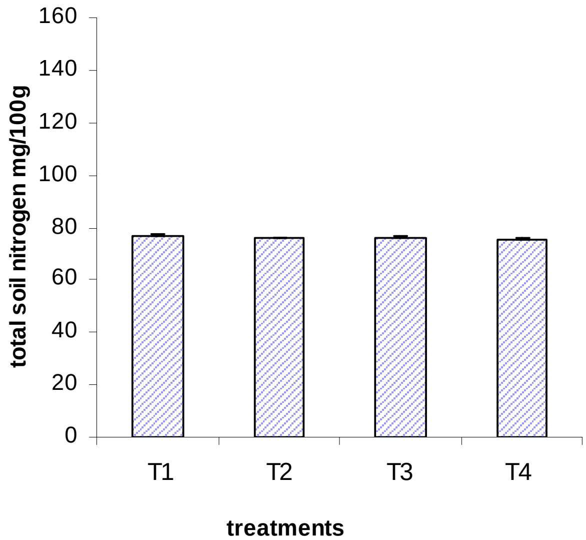


Fig-7. Comparison of soil nitrogen between pure teak and N_2 fixing tree species in 2000

There was no significant difference of soil nitrogen in all mixed systems in 2004. However, soil N_2 in both T_1 and T_2 shows more than T_4. In all treatments, soil N_2 content is lower than original soil N_2 in this year in Fig- 8 and table-(b) in appendix.

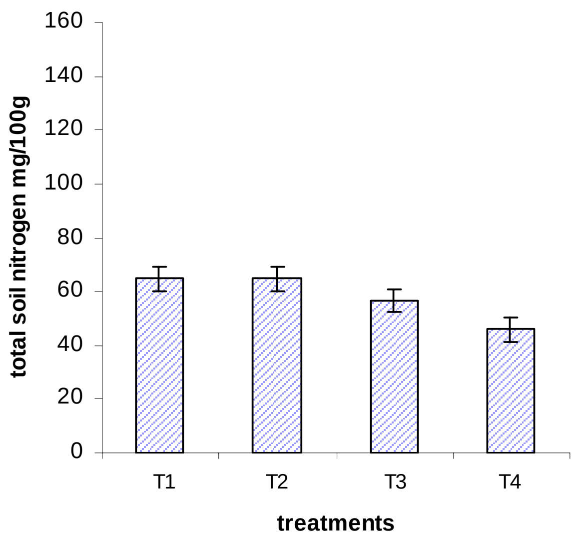


Fig-8. Comparison of soil nitrogen between pure teak and N_2 fixing tree species in 2004

All mixed stands were significantly different in soil N_2 as compared with pure stand, but not significantly different within mixed stands as in Fig- 9 and table- (c) in appendix.

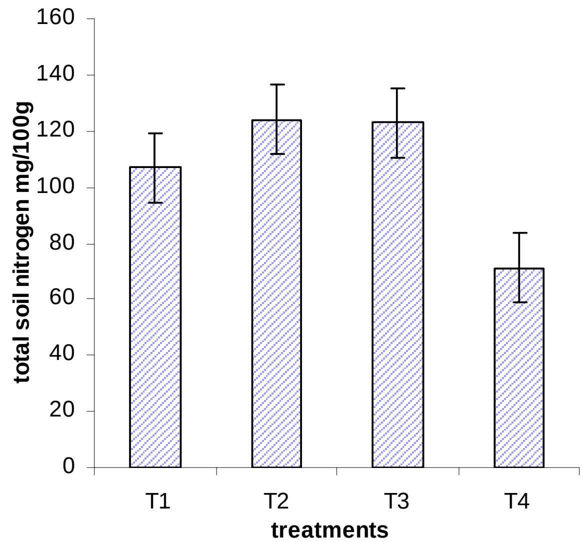


Fig-9. Comparison of soil nitrogen between pure teak and N_2 fixing tree species in 2005

Under a mixture of teak and Kokko spp., soil N_2 was significantly higher than pure teak. The two others were not significantly difference compare with pure teak as in Fig-10 and table- (d) in appendix.

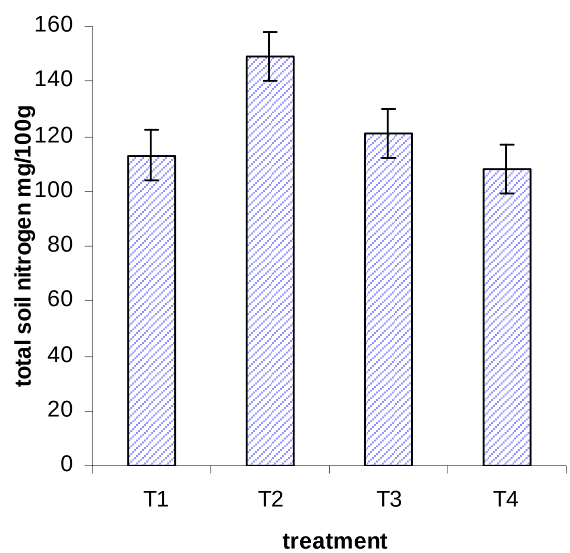


Fig-10. Comparison of soil nitrogen between pure teak and N_2 fixing tree species in 2006

There was no significant difference among all planting types. But soil N_2 content under mixed stands tends to be higher than pure stand as in Fig-11 and table- (e) in appendix.

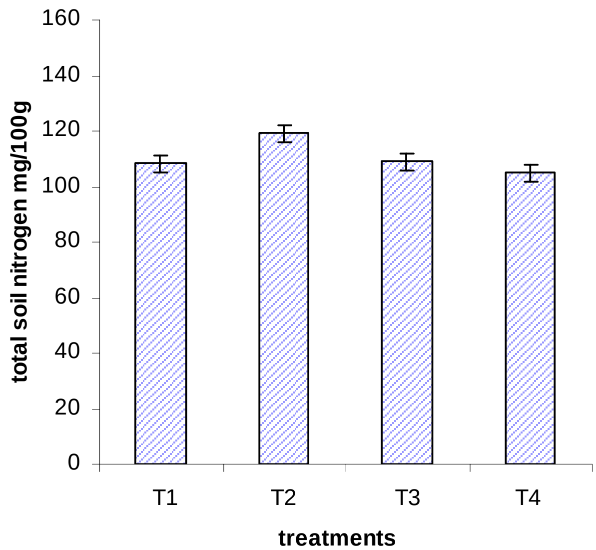


Fig-11. Comparison of soil nitrogen between pure teak and N_2 fixing species in 2007

Among all mixed systems, mixtures of teak and Kokko alone were significant as in Fig-12 and table- (f) in appendix. Soil nitrogen in the mixtures of teak and Bawzaging but also mixtures of teak and Sha show significantly difference when compared with pure system.

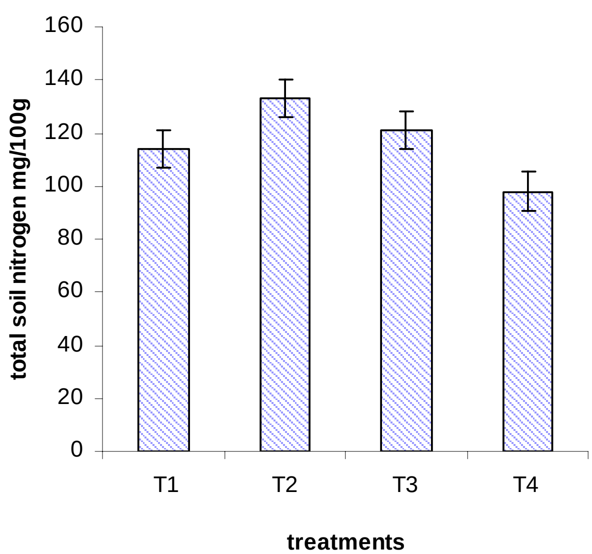


Fig-12. Comparison of soil nitrogen between pure teak and N_2 fixing species in 2009

Soil N_2 dynamic was not the same in the study period (table-3). It may be due to different annual accumulation of nitrogen residue from the different N_2 fixing tree.

Table. 3- **Annual nitrogen fixation rate in mixed system**

Species \ year	**2000**	**2004**	**2005**	**2006**	**2007**	**2009**
Teak+*Bawzagaing*	0.077*	(-) 0.012#	(+) 0.03#	(+) 0.036# 1.51∞	(+) 0.036# 1.21∞	(+) 0.037# 1.67∞
Teak+*Kokko*	0.076*	(-) 0.011#	(+) 0.048#	(+) 0.069# 12.67∞	(+) 0.043# 5.30∞	(+) 0.057# 4.30∞
Teak+*Sha*	0.073*	(-) 0.016#	(+) 0.05#	(+) 0.051# 6.67∞	(+) 0.036# 3.00∞	(+) 0.048# 3.67∞
Pure Teak	0.078*	(-) 0.032#	(-) 0.007#	(+) 0.031#	(+) 0.027#	(+) 0.026#

* indicates percentage of soil N_2 in original site
# indicates yearly increment of soil N from the yearly 2000
∞ indicates annual fixation rate (kg N ha^{-1}) than pure teak species

6. Discussion

Soil OC under pure teak system was lower than other systems because decomposition of biomass from teak is a few forming of soil organic matter (OM). Within four years planting, not all planted spp. provide soil OM. The main reason might be the result of increasing biological activities, in other way utilizing of soil OC for their growth. After four years, N_2-fixing species mixed with teak provide more soil OC than pure. This time is the good condition for decomposition of biomass and forming soil OM and provide available nutrient to plant by activities of organism.

Mixed plantations had a positive effect on the DBH of teak when compared with the monoculture but the relative proportion of N_2-fixing spp. did further unaffected (see fig-13). It appears that N_2-fixing tree spp. fixes substantial amounts of N_2 after the five years of establishment and a significant amount of that N_2 transferred to adjacent teak, thereby improving the growth and nutrition for teak. Because of some symbiotic fungi cannot only exist in association with one species in a mixture, but can also benefit other components of a stand. Undergrowth and debris from N_2-fixing species may assist teak growth in this area. Particularly exacerbate erosion and leaching problems in teak plantations protected.

.

Teak Growth in mixture and pure teak trial (2007)

Treatment	**DBH (cm)**	**Height (m)**
T_1- teak	35.81	14.90
- Bawzaging	7.88	12.44
T_2- teak	35.81	14.89
- Kokko	5.907	5.39
T_3- teak	35.81	14.82
- Sha	14.33	12.00
T_4- teak	32.47	14.80

Source: Silviculture Section in Forest Research Institute

Fig-(13) Mixed species trial with teak in Ngalaik Reserved Forest, compartment No.24 in Pyinmana

For N_2 fixing plants to make a positive contribution to stand growth, the site conditions must be suitable, that is there must not only be a deficiency of nitrogen but other nutrients, especially phosphate, and moisture (Sprent, 1987) must also not be limiting. If nitrogen is not deficient an admixture of nitrogen fixing trees does not enhance growth of the main species and may even inhibit it through competition for light, moisture or other nutrients (Binkley.D., 1983). In the present study, the original site condition is not the limited soil N_2. So, after four years, increment of soil N_2 and growth of teak found in all types of treatments. Although biological nitrogen fixation (BNF) associated with trees and shrubs play a major role in the functioning of many ecosystems but it is surprisingly difficult to quantify the amounts of N_2 fixed. Therefore, BNF was not included for the calculation of soil N_2 concentration.

N_2 fixing trees are only effective when they are dominants or co-dominants (Binkley, 1992). Within the study period, the height growth of teak was not different by the presence of N_2- fixation species. It is possible that light competition effect by N_2-fixing tree spp. in all mixed systems with pure teak stand.

A number of nutrient interaction in mixed stand could result from decomposition of above ground litter, changed microbial populations and their activities in the soil, changed soil fauna (earthworms) and micro-environmental condition(Brown,1992). During successive sampling period, soil N_2 concentration changes under mixed and pure system. Within the four years planting soil N_2 decrease than the original state in 2000. The maximum conditions under all planting trees were in 2005, 2006, and return to decrease in 2007 but not to original state. Then slightly increase again was in 2009, except teak.

Rates of N_2 fixation depend on the density, age and growth of the host plants, the degree of nodulation, the genetics of the host, mycrorhizar and N_2 fixing bacteria and environmental factors that affect plant growth. Khanna, P.K., 1998, stated that N_2 input rates from symbiotic N_2 fixation in plant symbiosis have been estimated to be less than 1 to more 200 Kg N ha^{-1} $year^{-1}$. Within the framework of the experiment, soil N_2 maximized when these grow together in the relative proportions of 60 % of Kokko and 40 % of teak, except 2007. This may be suitable proportion and match species in the study area via the decomposition of litter such as (foliage and fine root) and subsequent mineralization of organic nitrogen including root exudates. In addition, this species is the least by human destructions.

Sha clearly stimulated soil N_2 after a substantial amount of Sha leaves had shed. Therefore, mixtures of teak and Sha were significantly higher in soil nitrogen than pure stand in both in 2005 and 2009. And among N_2-fixing tree spp. this spp. was the second one of N_2 – fixing species. Bernhard- Reversat, 1988, stated that in situ N_2 mineralization under the native *Acacaia* forest was about 7-11 % of soil total N per year. In Ivory Coast rain forest, 8-12% of total N_2 mineralized by this species (depending on the site). As the mixed with *Sha* encouraged to the improvement of mineralization N_2, soil N_2 under acacias is greater than pure teak.

Soil N_2 under mixtures of teak and Bawzagaing was significantly different in 2005 from pure stand. The presumed transfer of N_2 after four years of plantation development probably results from belowground turnover of roots and nodules because aboveground litter decomposition and contribution of little to the overall N dynamics. Among these N_2 fixations spp. Bawzagaing is more interested and used for firewood by local people than others two spp. Therefore, this species is the lowest among the tested N_2 fixing tree species.

The decreased rate of N_2 under pure teak system than mixed system related to the low level of nitrogen in the plant-soil system but also a low mineralization rate than N_2-fixing species. In pure teak plantation, soil–N_2 production was maximum in 2006 and decrease in 2007 and 2009, which not reach to the original state. It may be enough soil total N content in the original state and improvement of mineralization N_2. In addition, a protective understory tends to avoid the deterioration of the soil, particularly when the undergrowth contributes to the fixation of nitrogen.

In 2007, all treatments were lower soil N_2. In this year aboveground biomass of some N_2-fixing tree spp. were disturbed by human but not underground biomass. Moore A.W., 1963, found that some nutrients are accumulated in the topsoil from the atmosphere and most of the nutrients in the topsoil are derived from minerals in the subsoil or from litter. N_2 fixation in the roots of some plants is an example of this process. Although difficult to measure the concentration and turnover of N_2 in fine roots is the most important flux requiring attention. So the rate of soil N_2 in the study site provided from the underground portion of stump.

As the different annual accumulation of nitrogen rich residue soil nitrogen content varies in these systems. High rate of N_2 fixation by Kokko than other two spp. in the study may be the favorable of soil type, climate condition, width of the spacing and less human disturb for Kokko. Annual nitrogen fixation rate in Kokko species with Eucalyptus has been reported 94 Kg N ha^{-1} (Liya *et.al*, 1990). In the present study, increased fixation starts in 2005 and peak value is 12 Kg N ha^{-1} in 2006 and 5 Kg N ha^{-1} in 2007 compare with pure teak plantation. Langkamp, *et.al*. 1979 stated that fixing rate by Sha species was 0.1 - 34 Kg N ha^{-1} in Eucalyptus plantation. In the trial site, the fixation rate is 6 Kg N ha^{-1} under Sha than pure teak after four years plantation. This mixed spp. is the second of N_2 fixing power among the tested species. Sanginga, *et. al.* (1985) reported that annual nitrogen fixation in Bawzagaing ranged from 110-192 Kg N ha^{-1}. In the study area, annual nitrogen fixation rate in Bawzagaing was quite substantial in 2005 years. Soil N_2 fixation rate was 1.5, 1.2 and 1.6 Kg N ha^{-1} in 2006, 2007 and 2009 respectively.

7. Conclusion

1. The increase in soil nitrogen was lowest in the control plot. This is a good reason for the influence of mixed plantations as N-fixing tree on nutrition.
2. The results of nutrient return and growth indicated that mixed plantations of these species were more productive than monoculture plantation. In the present study, the different proportion of N_2-fixing species affected the varying capacity of soil N_2 but not to teak growth.
3. In this study site, mixtures of teak and Kokko species get the highest in soil N_2, Sha is the second and then followed by Bawzagaing.
4. Within four year, the study site will need to provide soil nutrient for teak and N_2-fixation tree species as the downward trend of soil N_2.
5. Soil N_2 gradually increase in pure teak after five years as the study site is not the limited soil N_2 and young-age of the plantation and slightly decrease from 2007. As the study period is relatively short (within 9 years), long-term observations are required for better understanding of the nutritional status and growth benefits. The N_2-fixing trees as soil improvers and to prevent further site degradation should be used in the study area.

8. Recommendation

1. Nitrogen fixing trees species should be planted and tested in same proportions (50:50) with the buffer zone in a large area for the assessment of total soil N_2.
2. The increased soil nitrogen as well as the rate of nitrogen fixation by N_2-fixing tree spp. within four year should be maintained by adding phosphorous fertilizer.
3. Further study for BNF will need to confirm the increment of nitrogen fixation rate from the N_2-fixing spp. in the study area.
4. N_2-Fixation rate that depend on the type of organism should be more studied.
5. Teak and N_2-fixing tree species should be mixed and tested in limited soil N_2.

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Appendix

Table –(a) Analysis of variance for total soil nitrogen in 2000

	Sum of squares	df	Mean Square	F	Sig.
Treatments	2.73	3	0.909	0.003	1.000
Residual error	3260.12	12	271.68		
Total	3262.89	15			

Table – (b) Analysis of variance for total soil nitrogen in 2004

	Sum of squares	df	Mean Square	F	Sig.
Treatments	965.10	3	321.70	5.591	0.012
Residual error	690.47	12	57.54		
Total	1655.56	5			

Table –(c) Analysis of variance for total soil nitrogen in 2005

	Sum of squares	df	Mean Square	F	Sig.
Treatments	7228.40	3	2409.47	5.07	0.017
Residual error	15702.565	12	475.21		
Total	12930.96	5			

Table-(d) Analysis of variance for total soil nitrogen in 2006

	Sum of squares	df	Mean Square	F	Sig.
Treatments	3139.87	3	1046.62	16.58	0.000
Residual error	757.63	12	63.14		
Total	3897.49	5			

Table –(e) Analysis of variance for total soil nitrogen in 2007

	Sum of squares	df	Mean Square	F	Sig.
Treatments	445.81	3	148.60	0.326	0.807
Residual error	5475.13	12	456.26		
Total	5920.94	15			

Table –(f) Analysis of variance for total soil nitrogen in 2009

	Sum of squares	df	Mean Square	F	Sig.
Treatments	2625.57	3	875.19	6.978	0.006
Residual error	15.4.97	12	125.41		
Total	4130.54	15			